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Quality (Physico-chemical) attributes of Fuyu persimmon (*Diospyros kaki* L.) fruit

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Abstract
Persimmon (*Diospyros kaki* L.) is of Japanese origin and the most important species from nutritional point of view. It is generally recognized as outstanding source of nutritional and biologically active compounds. The fruit are enriched with different kinds of nutrients. The quality of fruits is defined by its physical and chemical characteristics. Therefore, this study examined the physico-chemical characteristics of persimmon fruit Fuyu. The fruit comprised of 7.20 Kg/cm^2 of firmness and 90.23 percent of flesh content. The various bioactive compounds such as β-carotene (1.54 mg/100 g), ascorbic acid (12.40 mg/100 g) and total phenols (2.70 mg/100 g) are also present. The fruit thus is consumed to reap maximum nutrient benefits.

Keywords: Persimmon, physico-chemical characteristics, phenols

Introduction
The nutritional fruit persimmon of genus *Diospyros* and the family *Ebenaceae* consist of number of species of trees (Yoo and Shin, 2020) [29]. It is traditionally known as *Japaniphal*, kaki or Japanese fruit (Singh *et al.*, 2011) [24]. Persimmon has its origin from China and has been commercialized in China, Korea and Japan (Saha *et al.*, 2015) [23]. Its cultivation is widely distributed in the warm regions of Asia, Africa, Central-South America, China, Korea, Japan, Brazil, Turkey and Italy (Yokozawea *et al.*, 2007) [28]. As per FAO 2019 report, the fruit growth has increased steadily to more than 50 percent in 10 years (2007 to 2017) with an annual production of 5.53 MMT in the year 2017. Annually, the rate at which the production of persimmon is spreading is about 5.76 percent. The rate at which it is spreading is allowing it to become world's 5th rapidly growing fruit crop (Yaqub *et al.*, 2016) [27]. Among different countries in the world, China stood first in persimmon production having an annual production of 2.19 MMT followed by Japan 0.25 MMT (FAOSTAT, 2020) [10] in the year 2019.
In India, persimmon is cultivated in various temperate and subtropical where it is grown on commercial level. The north regions of India include Himachal Pradesh, Jammu and Kashmir and some regions of North East and South India (Nilgiri Hills) where there is scattered plantation of persimmon was found (Mehta *et al.*, 2005) [17]. In Himachal persimmon in the year of 1921 by Captain A.N. Lee persimmon was brought in Kullu Valley (Sugiura, 1983) [26]. In Himachal Pradesh, a range of around 421 ha and annual yield of 943 tonnes is mainly persimmon fruit. The district Kullu, Solan, Mandi and Shimla of Himachal Pradesh are well known for the production of persimmon (Anonymous, 2018) [2]. Depending upon the level of astringency, the fruits of *Diospyros kaki* are classified into astringent and non-astringent cultivars (Hadi *et al.*, 2017) [12]. The astringent variety includes Red, Saijo, Honan, Triumph and Hachiya while non-astringent includes Fuyu, Gosho, Imoto, Izo and Surya (Singh *et al.*, 2011) [24].
Non-astringent fruit cultivar fuyu possesses orange-yellow flesh, firm peel and sweet taste. The colouring compounds *β*-cryptoxanthin and total carotenoids are highly responsible for the dark flesh of persimmon. Persimmon fruit contains energy (70 Kcal), carbohydrate (18.59 g), protein (0.58 g), total lipids (0.19 g) total dietary fiber (3.60 g), vitamin A (1627 IU) and C (7.5 mg) in each 100 g fruit. (Marques *et al.*, 2015) [16]. The various bioactive components, nutrients such as Vitamin A, B, C, E and K as well as minerals present in persimmon are beneficial for healthiness of human (Lee *et al.*, 2015) [15].

Proposed Methodology

Raw materials acquisition

The fruits (fuyu persimmon) were managed to acquire from Seobagh Kullu Training Station namely Regional Horticultural Research and Training Station. The unripe fruits were ripened by keeping under room temperature. The firm and matured persimmon were then stored under cold storage where temperature was maintained at 0±5 °C.

Physical Analysis

Persimmon fruits were analyzed for the following physical parameters. The fruits were weighed on an electronic weighing scale (Goldface, GFTT-II) and the mean weight in gram was estimated. The size of fruit was determined by a vernier caliper (500-196-20 Digital Vernier Caliper 150 mm/ 6 inch model). The value for length and diameter as measured by vernier caliper was expressed in centimeters (cm). Royal Horticultural Society Colour Chart was used to determine the colour of fruit, flesh and peel of persimmon fruit. A portable penetrometer named "Effigi Penetrometer (FT-327)" for measurement of fruit firmness was used. The data was recorded by inserting knob of plunger having diameter 11 millimetres (mm) towards flesh of the fruit. The average (mean) value of the fruit firmness was determined that was denoted as in "kg/cm^2".

Chemical Analysis

The chemical parameters of ripe persimmon fruit were analyzed using different methodology. The propounded method by Rangana (2009) [22] for moisture estimation was practiced for moisture content analysis. Twenty gram of sample firstly added in a pre-weighed flat bottom metallic flask whereas hot air oven was then set at 60±5 ºC and pre weighed sample (20 g) was placed in it. The samples dried out till stable weight continued. The sample titratable acidity (%) of a known volume was calculated by running against standard solution of NaOH (0.1 N) using phenolphthalein indicator. The sample was titrated till light pink colour persists for at least 15 sec (Ranganna, 2009) [22]. An electronic pH meter named "digital CRISON Instrument, Ltd. Spain" was operated properly and used for samples pH evaluation samples. The representative piece was finely ground and diluted using distilled water to prepare an extract for pH determination. The standard buffers of different pH 4. 7 and 9 were used to calibrate pH meter and then the readings of sample were taken three times (Ranganna, 2009) [22]. Fibre estimation was carried out in instrument Fibro TRON-FRB-2 in which 1g of sample (W) was weighed in the pre-weighed crucibles (W_1). Crucibles were fitted into the instrument fibrotron. Then 100 mL of 1.25 percent H_2SO_4 was added in each sample (AOAC, 2012) [3]. The sample was heat treated at 350 °C for 30 minutes. After completion of running time, acid was drained and crucibles were washed with lukewarm distilled water. Once the sample was acid free, same procedure was repeated with addition of 100 mL of 1.25 percent NaOH followed by washing. After washing, crucibles were placed in an oven at 100 °C for 3 hours. The dried, pre-weighed crucibles as weighed W_1 were placed in muffle furnace and ashing was carried out at 450 °C for 1 hour. At the end samples were allowed to cool and weighed (W_2).

Total phenols

The method Folin-Ciocalteu was suggested by Singleton and Rossi (1965) [25] for total phenols assessment. Weighed (1 g) pieces of slices were ground in pestle and mortar along with 10 mL of 80 percent ethanol. The extract thus obtained was. The unsinkable (supernatant) part thus separated; collected further it was evaporated using oven (hot air oven). The section after drying further added in already measured (5 mL) distilled water. Thereafter, 0.2 mL of an aliquot in separate test tube was taken and volume upto 3 mL of volume was made. After this Folin-Ciocalteu reagent about 0.5 mL added and after 3 minutes 2 mL of Na_2CO_3 (20%) was added to it. The mixture was mixed well and for one minute all the test tubes were left inside hot water bath. After this each test tube were cooled down and at wavelength 765 nm the absorbance was recorded in a spectrophotometer. The standard curve prepared by gallic acid showed concentration in mg/ 100 g of sample.

Antioxidant activity

Brand-Williams *et al.* (1995) [4] recommended the method for the estimation of antioxidant activity. Source of free radical used was DPPH (2, 2-diphenyl-1picrylhydrazyl). Sample extract was made with one gram of sample dissolved in 10 mL methnol. From this, an extract of 0.1 mL was taken in which DPPH (3.9 Ml) was added. The mixed solution for 30 minutes was held over darkness, furthermore at wavelength of 515 nm blank of methanol was used for the measurement of absorbance in UV-VIS spectrophotometer.

The absorbance of DPPH solution was used as absorbance of control.

$$\text{Percent of antioxidant activity (\%)} = \frac{\text{Absorbance of control (Ab}_{(c)}) - \text{Absorbance of sample (Ab}_{(S)})}{\text{Absorbance of control (Ab}_{(c)})} \text{X } 100$$

Result and Discussion

Physical attributes

Table 1 showed the results of fuyu persimmon for different physical characteristics. The result exhibited by the 10 fruits which were randomly chosen came to have a general (average) weight consisting of 193.50±10.93 g. The length and diameter were reported to be 48.46±2.12 and 71.08±3.18 mm, respectively. The results obtained were generally near of Unal *et al.* (2018) [30] and Gautam *et al*. (2020) [11]. Unal *et al.* (2018) [30] noted mean length and diameter 50.25 mm and 71.64 mm, respectively and by Gautam *et al*. (2020) [11] to be 46.15 and 64.17 mm, respectively. Number of fruits/kg and seeds/fruit were 5 to 6 and 2 to 4. The colour of peel and flesh matched orange group (28 A) and Yellow-orange group (22 A), respectively as per Royal Horticulture Society Colour Chart. These findings exist in conformity to such an extent of results obtained by Hadi *et al.* (2017) [12] and Gautam *et al*. (2020) [11]. Hadi *et al.* (2017) [12] recorded L colour value of 36.50 for lightness of bigger sized fruit, 26.20 and 16.00 for yellow and redness of small sized, respectively**.** The colour of fruit analysed by Royal Horticulture Society Colour Chart for fruit peel and flesh belongs to orange group (28 A) and yellow-orange (22 A) for fuyu persimmon as given by Gautam *et al*. (2020) [11], respectively. The fruit firmness was analysed to be 7.20 kg/cm^2. The results obtained for firmness are earlier reported by Gautam *et al*. (2020) [11] to be 7.98 kg/cm^2. The flesh (%), peel (%) and seed (%) was recorded to be 90.23±3.03, 7.85±3.29 and 2.22±0.89, respectively. The ratio of flesh, peel and seed of fruit was 90:8:2. The similar trend of ratio has been revealed by Singh *et al.* (2011) [24], Khademi *et al*. (2013) [3] and Novillo *et al.* (2016) [20].

Table 1: Persimmon fruit fuyu different physical attributes

Physical attributes	Fuyu persimmon (Mean±SD)
Weight (g)	193.50±10.93
Length (mm)	48.46±2.12
Diameter (mm)	71.08±3.18
Per kg number of fruits	5 to 6
Fruit firmness in Kg/cm^2	7.20
Fruit peel colour (Visual)	Orange group (28 A)
Fruit flesh colour (Visual)	Yellow-orange group (22A)
Each fruit containing number of seeds	2-4
Percent of fruit flesh	90.23±3.03
Percent of fruit peel	7.85±3.29
Percent of fruit seed	2.22±0.89
Ratio of flesh, peel and seed (Flesh: Peel: Seed)	90:8:2

* Royal Horticulture Chart was used to match colour of peel and flesh

Chemical attributes

Different outcomes in the estimation of chemical attributes of persimmon fruit fuyu are highlighted in Table 2. A perusal of data reveals that persimmon fruit had an average moisture content of 80.39±2.00 percent. The data is almost similar to the results represented by Chen *et al.* (2016) [7], Cho *et al.* (2018) [8] and Gautam *et al*. (2020) [11]. Chen *et al.* (2016) [7] recorded a range of 76.34 to 81.10 percent for moisture content with highest value in Rao Tian Hong and a lowest in Yong Ji Qing Shi. Cho *et al.* (2018) [8] found moisture content of 79.31 percent in Sangjudoongsi cultivar of persimmon. Fuyu persimmon with peel and without peel had moisture content of 78.83 and 79.34 percent, respectively was recorded by Gautam *et al*. (2020) [11]. The value for TSS, acidity and pH was reported to be 17.06±1.38 °B, 0.12±0.01 percent and 5.66±0.20, respectively. The result for TSS are supported by Aluntas *et al.* (2011) [1] i.e. 11.50 in fuyu, Cayuela *et al.* (2017) [5] i.e. 15.51 ºB in Rojo Brillante and Gautam *et al.* (2020) [11] in fuyu persimmon with and without persimmon were 16.16 and 15.95 °B, respectively. Similar results for titratable acidity recorded by Hadi *et al.* (2017) [12] and Gautam *et al*. (2020) [11] varied from 0.72 to 0.11 in Gongchengyueshi and Haiyangdabianshi variety of persimmon and 0.13 and 0.12 percent in with peel and without peel Fuyu persimmon fruit, respectively. The data for pH was observed by Khan *et al.* (2019) was 5.31 and average value of pH 3.87 and 3.75 in fuyu persimmon with and without peel. Gautam *et al.* (2020). The data recorded for total sugars (12.60±2.14%) and reducing sugars (5.83±0.96%) are near to the results of Aluntas *et al.* (2011) [1], Chen *et al.* (2016) [7] and Gautam *et al*. (2020) [11]. Altunas *et al*. (2011) [1] reported total sugar content in Fuyu persimmon to be 16.30 g/100 g and by Chen *et al.* (2016) [7] showed a range from 11.55 to 15.67 g/100 g for total sugars and 10.26 to 15.06 g/100 g for reducing sugars in different varieties of persimmon fruit. According to Gautam *et al*. (2020) [11] total sugar content was 9.88 and 9.15 percent, whereas reducing sugar content was 7.85 and 6.85 percent, respectively in with and without peel Fuyu persimmon. Further, the results revealed 12.40±1.70 mg/ 100 g of ascorbic acid in persimmon fruit are also recorded by Naser *et al.* (2015) [18] and Gautam *et al*. (2020) [11]. Naser *et al.* (2018) [18] recorded 20.31 mg/100 g (fresh weight basis) of ascorbic acid in persimmon fruits. The β-carotene content of 1.54±0.07 mg/100 g is supported by the observations of Butt *et al.* (2015) [30], Chen *et al.* (2016) [7] and Gautam *et al*. (2020) [11]. Butt *et al.* (2015) recorded an amount of 253.00 and 156.00 µg/100 g, respectively for *β*-carotene and *β*-cryptoxanthin in Fuyu persimmon. According to results of Chen *et al.* 2016 [7], the carotenoid content in non astringent cultivar Chansiwan was 116.21 µg/100 g while the astringent cultivars *viz.* Tailihong, Raotianhong, Yongjiqingshi and Yueshi recorded a value of 214.05, 163.82, 173.79 and 110.20 µg/100 g, respectively. Gautam *et al*. (2020) [11] found an amount of 15.90 and 14.99 mg/100 g in fuyu persimmon with peel and without peel, respectively for *β*-carotene content. The fibre and ash content in present study was 1.02±0.42 and 0.34±0.03 percent, which are in accordance with the results of Butt *et al.* (2015) [18], Nazir *et al.* (2013) [19], Cho *et al.* (2018) [8] and Gautam *et al.* (2020). The fibre content as recorded by Butt *et al.* (2015) [18] was 3.60 g/100 g in Fuyu persimmon while Gautam *et al.* (2020) [11] noticed with peel and fruits lacking peel as in percent are 0.69 (with peel) and 0.66 (fruits lacking peel), respectively. Gautam *et al*. (2020) [11] recorded the ash content in fuyu fruit with (0.41) and without peel (0.38) in percent, respectively. A higher value for ash content 0.44 percent while slightly lower amount of 0.32 percent has been noted by Nazir *et al.* (2013) [19]. Fuyu persimmon was found to possess 2.70±1.2 mg/100 g of phenols and 70.33±0.35 percent of antioxidant activity. Almost similar level of results was seen by Chen *et al.* (2016) [7], Nazir *et al.* (2013) [19] and Park *et al.* (2006) [21]. According to Chen *et al.* (2016) [7] amount of total phenol in non-astringent cultivar chansiwan was 6.74 mg/100 g while in astringent cultivars *viz.* Tailihong, Raotianhong, Yongjiqingshi and Yueshi the value recorded was 18.44, 8.98, 11.04 and 19.16 mg/100 g, respectively. In Fuyu variety of persimmon total phenolic content has been detected as 250.00 and 190.00 µg/100 g, respectively in fruits when analysed with and without peel by Gautam *et al*. (2020) [11]. A value of 92.00 percent was observed by Naser *et al.* (2018) [18] for antioxidant activity in Karaj cultivar of persimmon. The antioxidant activity of Fuyu persimmon fruits with and without peel was 49.13 and 45.82 percent as per the findings of Gautam *et al*. (2020) [11].

Table 2: Persimmon fruit fuyu different physical attributes

Chemical attributes	Without peel (Mean±SD)
Moisture (%)	80.39±2.00
TSS (ºB)	17.06±1.38
Percentage of titratable acidity	0.12±0.01
Ph value	5.66±0.20
Percentage of total sugars	12.6±2.14
Reducing sugars (%)	5.83±0.96
Ascorbic acid (mg/100 g)	12.40±1.70
β-carotene (mg/100 g)	1.54±0.07
Fiber (%)	1.02±0.42
Ash (%)	0.34±0.03
Total phenols (mg/100 g)	2.70±1.27
Antioxidant activity (%)	70.33±0.35

Conclusion

The results of this demonstrated that non astringent cultivar of persimmon Fuyu (*Diospyros kaki* L.) is highly nutritious, it is under-utilized for processing can be pre-treated and dehydrated for the development of different products. It is also good source of functional component ascorbic acid, β-carotene and total phenols which are responsible for antioxidant activity. Therefore, it can be utilized to cure various diseases.

References

1. Altuntas E, Cangi R, Kaya C. Physical and chemical properties of persimmon fruit. International Agrophysics. 2011;25:89-92.
2. Anonymous. Area and production of fruits and vegetables. Directorate of Horticulture, Navbahar, Shimla; c2018.
3. AOAC. Association of Official Analytical Chemists. Official Methods of Analysis 19th edn. Washington DC; c2012.
4. Brand-Williams W, Cuvelier ME, Berset C. Use of free radical method to evaluate antioxidant activity. Lebensmittel-Wissenschaft and Technology. 1995;28:25-30.
5. Cayuela TG, Escobar BN, Chanesa JW, Canoa MP. *In vitro* bio-accessibility of individual carotenoids from persimmon (*Diospyros kaki* cv. Rojo Brillante) used as an ingredient in a model dairy food. Journal of the Science of Food and Agriculture. 2017;98:3246-3254.
6. Chen J, Du J, Ge ZZ, Zhu W, Nie R, Li CM. Comparison of sensory and compositions of five selected persimmon cultivars (*Diospyros kaki* L.) and correlations between chemical components and processing characteristics. Journal of Food Science and Technology. 2016;53:1597-1607.
7. Chen J, Du J, Ge ZZ, Zhu W, Nie R, Li CM. Comparison of sensory and compositions of five selected persimmon cultivars (*Diospyros Kaki* L.) and correlations between chemical components and processing characteristics. Journal of Food Science and Technology. 2016;53:1597-1607.
8. Cho JH, Kim ID, Dhungana SK, Do HM, Shin DH. Persimmon fruit enhanced quality characteristics and antioxidant potential of beer. Journal of Food Science and Biotechnology. 2018;27:1067-73.
9. FAO. FAO statistical database. Food and Agriculture Organization. http://faostat.fao.org. [11:30 AM, 25th June 2020]; c2019.
10. FAOSTAT. FAO statistical database. Food and Agriculture Organization. http://faostat.fao.org. [10:30 PM, 25th June 2020]; c2020.
11. Gautam A, Dhiman AK, Attri S, Kathuria D. Nutritional and functional characteristics of ripe persimmon (*Diospyros kaki* L.) fruit. Journal of Pharmacoognosy and Phytochemistry. 2020;9:3364-3367.
12. Hadi MAHE, BU Q, Ge BCC, Zhou C. Analysis of main quality characteristics of persimmon (*Diospyros kaki* L.) fruits. International Journal of Advanced Research. 2017;12:970-986.
13. Khademi O, Zamani Z, Poor Ahmadi E, Kalantari S. Effect of UV-C radiation on postharvest physiology of persimmon fruit (*Diospyros kaki* Thunb.) cv. 'Karaj' during storage at cold temperature. Food Research International. 2013;20:247-53.
14. Khan MSN, Durani Y, Hashmi MS, Muhammad A, Uzair M, Ali SA, *et al*. Influences of antioxidant treatments on dried persimmon fruits. Fresenius Environmental Bulletein. 2019;28:8679-688.
15. Lee JH, Lee YB, Seo WD, Kang ST, Lim JW, Cho KM. Comparative studies of antioxidant activities and nutritional constituents of persimmon juice (*Diospyros kaki* L. cv. Gapjubaekmok)", Preventive Nutrition and Food Science. 2015;17:141-151.
16. Marques A, Domingo A, Cervera LM, Guardia M. Mineral profile of kaki fruits (*Diospyros kaki* L.). Food Chemistry. 2015;172:291-297.
17. Mehta K, Thakur BS, Kashyap AS. Present status, problem and prospects of persimmon cultivation in India. Acta Horticulturae. 2005;685:45-48.
18. Naser F, Rabiei V, Razavi F, Khademi O. Effect of calcium lactate in combination with hot water treatment on the nutritional quality of persimmon fruit during cold storage. Scientia Horticulturae. 2018;233:114-23.
19. Nazir A, Wani SM, Gani A, Masoodi FA, Haq E, Mir SA, *et al*. Nutritional, antioxidant and anti-proliferative properties of persimmon (Diospyros kaki). A minor fruit of J&K India. International Journal of Advanced Research. 2013;1:545-54.
20. Novillo P, Salvador A, Crisosto C, Besada C. Influence of persimmon astringency type on physico-chemical changes from the green stage to commercial harvest. Scientia Horticulturae. 2016;206:7-14.
21. Park YS, Jung ST, Kang SG, Delgado-Licon ALM, Ayala MS, Tapia O, *et al.* Drying of persimmons (*Diospyros kaki* L.) and the following changes in the studied bioactive compounds and the total radical scavenging activities. Journal of Food Science and Technology. 2006;39:748-55.

22. Ranganna S. Handbook of Analysis and Quality Control for Fruit and Vegetable Products. Tata McGraw Hill, New Delhi; c2009. p. 112.
23. Saha A, Gupta RK, Sharma RR, Kumar K, Tyagi YK. Edible coating and its effect on shelf life and quality of 'Hachiya', an astringent variety of persimmon fruit. Asian Journal of Biochemical and Pharmaceutical Research. 2015;5:2231-2560.
24. Singh B, Srisvastva JN, Verma VS, Razdan VK. Cultivation of persimmon in India. Rashtriya Krishi. 2011;6:1-2.
25. Singleton VL, Rossi JA. Colorimetry of total phenolics with phosphomolybedic phosphotungstic acid reagents. American Journal of Enology and Viticulture. 1965;16:144-158.
26. Sugiura A, Kataok, Tomana T. Use of refractometer to determine soluble solids of astringent fruit of persimmon (Diospyros kaki). Journal of Horticulture Science. 1983;58(2):241-246
27. Yaqub S, Farooq U, Shafi A, Akram K, Murtaza MA, Kausar T, Siddique F. Chemistry and functionality of bioactive compounds present in persimmon. Journal of Chemistry. 2016;1:2-9.
28. Yokozawea T, Park CH, Noh JS, Roh SS. Role of oligomeric proanthocyanidins derived from an extract of persimmon fruits in the oxidative stress-related ageing process. Molecules. 2007;19:6707-6726.
29. Yoo D, Shin Y. Application of persimmon (*Diospyros kaki* L.) peel extract in indigo dyeing as an eco-friendly alternative reductant. Fashion and Textiles. 2020;7:2-9.
30. Yetisen AK, Martinez-Hurtado JL, Ünal B, Khademhosseini A, Butt H. Wearables in medicine. Advanced Materials. 2018 Aug;30(33):1706910.