



Strawberry– More than a Popular Summer Fruit: A Mini-Review

Raghavendra Prasad^{1*}, Jolanta Lisiecka¹, Kavana Raj²

¹Department of Vegetable Crops, Faculty of Agronomy, Horticulture and Bioengineering, Poznan University of Life Sciences, Dabrowskiego 159, 60-594 Poznan, Poland

²Institute of Horticulture Sciences, Department of Vegetable and Medicinal Plants, Warsaw University of Life Sciences, Nowoursynowska 166, 02-787 Warsaw, Poland

Received Date: March 17, 2022; **Accepted Date:** March 30, 2022; **Published Date:** April 07, 2022

***Corresponding author:** Raghavendra Prasad, Department of Vegetable Crops, Faculty of Agronomy, Horticulture and Bioengineering, Poznan University of Life Sciences, Dabrowskiego 159, 60-594 Poznan, Poland. Email: rprasad@up.poznan.pl

Abstract

Strawberries (*Fragaria × ananassa*) are well known for their attractive red fruits, characteristic aroma and distinct taste. They are grown and eaten all over the world and they are considered a popular summer fruit. Apart from the above-mentioned valued characteristics, strawberry fruits are a significant source of vitamins, minerals, flavonoids, phytochemicals, polyphenols, and antioxidants. In recent years, the increase in production and consumption of strawberries around the world can be noticed. Additionally, strawberries are now considered a 'functional food' due to the associated taste, nutritional composition, phytochemicals and multiple health benefits. The review provides a brief overview of strawberries not only as popular summer fruits, but also as health-promoting beneficial fruits. The nutritious, dietary and phytochemical properties as well as biological benefits of strawberries on human health are highlighted. The synergetic role of strawberry as a functional food and some of the key pre-harvest and post-harvest factors which influence strawberry yield and overall fruit quality are discussed. Apart from the numerous benefits associated with strawberries, some allergies are also linked with their consumption which is also mentioned in the article.

Keywords: Antioxidants; Functional food; Health benefits; Nutrition; Phytochemicals; Strawberry

Introduction

Strawberry (*Fragaria × ananassa* Duch.) is a popular, sweet, juicy seasonal berry appreciated around the world. It is a herbaceous perennial plant, a member of the Rosaceae family [1]. The present-day cultivated strawberry is a monoecious octoploid (2n=56) and a hybrid of two dioecious octoploids namely, *Fragaria chiloensis* and *Fragaria virginiana* [2]. Liston et al. (2014) [3] reported that the strawberry is one of the youngest domesticated plants. Botanically strawberry is an aggregate fruit 'etaerio of achenes', having seeds on the surface of a red fleshy receptacle, it is also referred to as a 'false fruit', a pseudocarp. As the fruits mature only on the plant, they are categorized as a non-climacteric crop [4]. Based on bearing seasons strawberries are classified as June-bearing, ever bearing, and day-neutral [5].

Strawberry – More Than A Popular Summer Fruit

Among many fruit crops, strawberries can be cultivated under wide ecological conditions, i.e. from arctic to tropic regions [1, 6]. In the last decade, the global production of strawberries has increased nearly 40%, making it the second-largest berry fruit after grape (*Vitis vinifera* L.) in terms of production. In the global production of strawberries, China occupies the first position followed by the USA. In the European Union, Spain is a leader in strawberry production followed by Poland and both countries are significant global producers [7].

Strawberry is the most economically important soft fruit in the world and a popular summer fruit. Considering their popularity, they are commercially available as fresh, frozen,

and also as processed products like jams, jellies, nectar, and puree [8].

Nutritious and Associated Health Benefits

Strawberries are well known for their attractive red fruits [9], characteristic aroma [10], and distinct taste [11]. Apart from the above-mentioned characteristics, fruits have also numerous dietary and health benefits. They are a significant source of vitamin B, C, E, minerals, and carotenoids, they also contain significant amounts of ellagic acid, tannins, and phytosterols [12, 13]. In comparison to other berry fruits, strawberries contain a higher percentage of vitamin C, phenolics, flavonoids, and phytochemicals [14]. Among nutrients, they are a remarkable source of manganese and also a good source of iodine, magnesium, copper, iron, and phosphorus [15]. Strawberries are also low in calories (100g = 32kcal). Apart from the nutritious and dietary benefits of fruits, the seed oil is reported to be a rich source of polyunsaturated fatty acids, phenolics, dietary fiber and minerals [16].

Strawberries exhibit antioxidative, antidiabetic, antihypertensive, carcinogenic, antihyperglycemic, and antihypertensive properties due to the presence of phytochemicals like anthocyanins, ellagic acid, catechin, quercetin, ellagitannins, and kaempferol [17]. Among common fruits, strawberries rank fourth for total antioxidant activity [18]. Fruit properties are reported to be beneficial for blood sugar and heart health [17, 19, 20] and also to have an inhibitory effect on liver cancer cells [18]. They help in the prevention of cardiovascular diseases (CVD), metabolic syndromes, and neurological diseases. Clinical studies have demonstrated that the consumption of strawberries increases serum high-density lipoprotein, plasma antioxidant capacity, reduces oxidized (LDL) and lipid peroxidation, lowers serum total, and LDL-cholesterol, and also decreases postprandial glycaemia or lipemia [21]. A variety of studies on health benefits associated with strawberries, in particular attention on human health, was reviewed by Afrin et al. (2016) [15]. Anthocyanins in strawberries are reported to be the best known polyphenolic compounds and quantitatively identified as most important [22, 23]. One of the major anthocyanins in strawberries, which is independent of genetic and environmental factors, is pelargonidin-3-glucoside [20]. Pelargonidin, among others shows the inhibitory activity of proteasome which resulted in neuroprotective effects [24].

Strawberries as Functional Foods

Strawberries are now considered a functional food due to the multiple health benefits associated with their consumption beyond basic nutrition [15, 17]. The substantiated evidence on its antioxidant, anti-inflammatory, antihyperlipidemic, antihypertensive, and proliferative properties further synergies its characterization as a functional food [17]. Strawberries are included as one of the 100 richest sources of dietary polyphenols and they are listed among 89 food and beverages for providing more than 1 mg total polyphenols per 100g [25].

Pre-Harvest Factors Affecting Strawberry Production and Fruit Quality

Consumers select fruits by their color, shape, size, and sweetness, combined with their flavor and aroma. These visible characteristic features, along with synthesis and accumulation of phytochemicals, antioxidants and nutritional elements in strawberries, are related to multiple environmental and genetic factors [26], which are referred to as pre- and post-harvest factors. The pre-harvest factors, such as genotype, environment, and cultivation technique, influences the micronutrients and phenolic compounds concentration in berries, as well as commercial and organoleptic attributes [26, 27, 28].

The quality of the strawberry fruits is influenced by the environmental and growing conditions [29, 30, 31]. Agronomical practices like fertilization [3], irrigation [33, 34], and harvest time [35] play a crucial role in achieving good quality fruits. Types of cultivation also have a great effect on fruit quality [36, 37, 38]. In recent years there is a growing interest in the protected and soilless cultivation of strawberries. It has been substantially reported that major yield and quality affecting factors for strawberries in soilless cultivation may be listed as: type and quality of growing medium, source and type of plants, cultivar, growing season, and efficiency of fertigation system [37-44].

The strawberry's distinct bright red color and delicious sweet taste make them well appreciated among soft fruits. The strawberry fruit color is an important characteristic feature for consumer product acceptance and/or preferences [14]. The color of the fruit depends on genotype and is greatly influenced by environmental conditions, as well as the maturation stage [45]. A case study on consumer preferences and perceptions for strawberries revealed that nearly 95% of consumers preferred red colored and ripened strawberries [46]. According to Nunes et al. (2006), [47] the strawberry fruit color depends on cultivars and the time of harvesting. The total soluble solids (TSS) value characterizes the sweetness of strawberry fruits [48]. Galletta et al. (1995) [49] reported that the TSS in strawberry fruits generally ranges between 7-12%. For strawberry fruits to have an acceptable taste and/or flavor a minimum TSS of 7% is recommended [27]. Many studies showed that substrates and cultivars can influence TSS [39, 40, 50, 51]. It has been also demonstrated that the phytochemical content of strawberries can be influenced by the cultivation techniques [20, 52-54]. Wang and Millner (2009) [55] proved that some of the agronomical practices, like the use of compost as mulch in strawberry cultivation, can increase their antioxidant capacity.

Post-Harvest Factors Affecting Strawberry Production and Fruit Quality

The nutritional quality (NQ), micronutrient and phytochemical content are affected by short term storage. The storage temperature plays a key role in the stability of phenolics and antioxidants in fruits. The reduced NQ in processed strawberry products compared to fresh fruits can be

related to the processing time and kind of post-harvest treatment [56]. In strawberries, processing causes loss of ascorbic acid, polyphenols, antioxidant capacity [8], and a reduction of a certain amount of bio-actives [17]. Based on these findings, it can be inferred that the product value addition by processing may lead to deterioration of nutritional quality. Hence, considering its short shelf-life, perishability and nutrient loss due to post-harvest processes it is always best to enjoy the taste and nutritious benefits of strawberries by consuming fresh fruits.

Allergies

Although the strawberries provides so many health benefits, they are also a source of allergens, which results in allergic reactions after its consumption. As reported by Kurze et al. (2018) [27], seven proteins, including different form, have been found in strawberry fruits. They can be responsible for allergic reactions in sensitized individuals, as well as reactions caused due to cross-reactivity of allergens. Along with the other pathogenesis-related proteins, the Fra a 1 protein is present in the fruit [58]. Fra a 1 protein belongs to the PR-10 family, which is reported to be the main allergic compound linked with allergies associated with strawberry consumption [56, 59].

Conclusions

Strawberries exhibit various important nutritional, dietary benefits, including essential vitamins, minerals, alongside serving as a significant source of phytochemicals, benefiting human health. Due to its economical and commercial popularity, the strawberry is considered one of the significant soft fruit worldwide. In this account, strawberries are the most studied berries in agronomical, genomic, and nutritional aspects. The growing empirical and clinical evidences are demonstrating their antioxidative, antidiabetic, antihypertensive, anticarcinogenic, antihyperglycemic properties. This will enable the consumers to gain more health benefits beyond normal nutrition, serving as a ‘functional food’. Considering the popularity and consumers’ preferences, the availability of fruit all around the year is necessary. Even though the development of protected and soilless cultivation systems, allows offseason and year-round production of strawberries, fulfilling consumers’ demands with qualitative, quantitative, and nutritious berries remains a challenge.

1. Hancock JF (1999) Strawberries. CABI Publishing, New York, USA
2. Bowling BL (2000) The Berry Growers Companion. Timber Press Inc., Portland, Oregon, USA. 308p
3. Liston A, Cronn R, Ashman T (2014) *Fragaria*. A genus with deep historical roots and ripe for evolutionary and ecological insights. Am. J. Bot 101: 1686-1699.
4. Cordenunsi BR, Genovese MI, do Nascimento JRO, Hassimotto NMA, dos Santos RJ, et al. (2005) Effects of temperature on the chemical composition and antioxidant activity of three strawberry cultivars. Food Chem 91: 113-121.
5. Durner EF, Barden JA, Himelrick DG, Poling EB (1984) Photoperiod and temperature effects on flower and runner development in day-neutral, Junebearing, and everbearing strawberries. J. Amer. Soc. Hort. Sci 109: 396-400.
6. Guerrero-Chavez G, Scampicchio M, Andreotti C (2015) Influence of the site altitude on strawberry phenolic composition and quality. Sci. Hort 192: 21-28.
7. FAOSTAT (2020) Statistic Database. Available at. <http://www.fao.org/faostat/en/#data/QC>
8. Klopotek Y, Otto K, Bohm V (2005) Processing strawberries to different products alters contents of vitamin c, total phenolics, total anthocyanins, and antioxidant capacity. J. Agric. Food Chem 53: 5640-5646.
9. Hong V, Wrolstad RE (1990) Use of HPLC separation photodiode array detection for characterization of anthocyanins. J. Agric. Food Chem 38: 708-715.
10. Ulrich D, Hoberg E, Rapp A, Kecke S (1997) Analysis of strawberry flavour – discrimination of aroma types by quantification of volatile compounds. Z. Lebensm. Unters. Forsch 205: 218-223.
11. Schieberle P, Hofmann T (1997) Evaluation of the character impact odorants in fresh strawberry juice by quantitative measurements and sensory studies on model mixtures. J. Agric. Food Chem 45: 227-232.
12. Aaby K, Ekeberg D, Skrede G (2007) Characterization of phenolic compounds in strawberry (*Fragaria × ananassa*) fruits by different HPLC detectors and contribution of individual compounds to total antioxidant capacity. J. Agric. Food Chem 55: 4395-4406.
13. Basu A, Fu DX, Wilkinson M, Simmons B, Wu M, Betts NM, et al. (2010) Strawberries decrease atherosclerotic markers in subjects with metabolic syndrome. Nutr. Res. 30: 462-469.
14. Trevino-Garza M, Garcia S, Flores-Gonzalez M, Arevalo-Nino K (2015) Edible active coatings based on pectin, pullulan, and chitosan increase quality and shelf life of strawberries (*Fragaria × ananassa*). J. Food Sci. 8: 1823-1830.
15. Afrin S, Gasparrini M, Forbes-Hernandez TY, Reboredo-Rodriguez P, Mezzetti B, et al. (2016) Promising health benefits of the strawberry: a focus on clinical studies. J. Agric. Food Chem. 64: 4435-4449.
16. Grzelak-Błaszczyk K, Karlińska E, Grzęda K, Rój E, Kołodziejczyk K (2017) Defatted strawberry seeds as a source of phenolics, dietary fiber and minerals. LWT84. 18-22.

References

17. Basu A, Nguyen A, Betts NM, Lyons TJ (2014) Strawberry as a Functional Food. An Evidence-Based Review. *Crit. Rev. Food Sci. Nutr.* 54: 790-806.
18. Sun J, Chu YF, Wu X, Liu RH (2002) Antioxidant and antiproliferative activities of common fruits. *J. Agric. Food Chem* 50: 7449-7454.
19. Halvorsen BL, Carlsen MH, Phillips KM, Bohn SK, Holte K, et al. (2006) Content of redox-active compounds (ie, antioxidants) in foods consumed in the United States. *Am. J. Clin. Nutr* 84: 95-135.
20. Giampieri F, Tulipani S, Alvarez-Suarez JM, Quiles JL, Mezzetti B, et al. (2012) The strawberry. Composition, nutritional quality, and impact on human health. *Nutrition* 28: 9-19.
21. Erlund I, Koli R, Alfthan G, Marniemi J, Puukka P, et al. (2008) Favorable effects of berry consumption on platelet function, blood pressure, and HDL cholesterol. *Am. J. Clin. Nutr* 87: 323-331.
22. Clifford MN (2000) Anthocyanins – nature, occurrence and dietary burden. *J. Sci. Food Agric.* 80: 1063-1072.
23. Lopes-da-Silva F, de Pascual-Teresa S, Rivas-Gonzalo JC, Santos-Buelga C (2002) Identification of anthocyanin pigments in strawberry (cv. Camarosa) by LC using DAD and ESI-MS detection. *Eur. Food Res. Technol* 214: 248-253.
24. Dreiseitel A, Schreier P, Oehme A, Locher S, Rogler G, et al. (2008) Inhibition of proteasome activity by anthocyanins and anthocyanidins. *Biochem. Biophys. Res. Commun* 372: 57-61.
25. Pérez-Jiménez J, Neveu V, Vos F, Scalbert A (2010) Identification of the 100 richest dietary sources of polyphenols. An application of the Phenol-Explorer database. *Eur. J. Clin. Nutr* 64: 112-120.
26. Alvarez-Suarez JM, Giampieri F, Tulipani S, Casoli T, et al. (2014) One-month strawberry-rich anthocyanin supplementation ameliorates cardiovascular risk, oxidative stress markers and platelet activation in humans. *J. Nutr. Biochem* 25: 289-294.
27. Cordenunsi BR, Nascimento JRO, Lajolo FM (2003) Physicochemical changes related to quality of five strawberry fruit cultivars during cool-storage. *Food Chem* 83: 167-173.
28. Kafkas E, Kosar M, Paydas S, Kafkas S, Baser KHC (2007) Quality characteristics of strawberry genotypes at different maturation stages. *Food Chem* 100: 1229-1236.
29. Krüger E, Josuttis M, Nestby R, Toldam-Andersen TB, Carlen C, et al. (2012) Influence of growing conditions at different latitudes of Europe on strawberry growth performance, yield and quality. *J. Berry Res* 2: 143-157.
30. Cocco C, Magnani S, Maltoni ML, Quacquarelli I, Cacchi M, et al. (2015) Effects of site and genotype on strawberry fruits quality traits and bioactive compounds. *J. Berry Res* 5: 145-155.
31. Diamanti J, Capocasa F, Mezzetti B, Tulipani S, Battino M (2009) The interaction of plant genotype and temperature conditions at ripening stage affects strawberry nutritional quality. *Acta Hort* 838: 183-186.
32. Vittori di L, Mazzonia L, Battino M, Mezzetti B (2018) Pre-harvest factors influencing the quality of berries. *Sci. Hort* 233: 310-322.
33. Terry LA, Chope GA, Bordonaba JC (2007) Effect of water deficit irrigation and inoculation with *Botrytis cinerea* on strawberry (*Fragaria × ananassa*) fruit quality. *J. Agric. Food Chem* 55: 10812-10819.
34. Valentinuzzi F, Mason M, Scampicchio M, Andreotti C, Cesco S, et al. (2015) Enhancement of the bioactive compound content in strawberry fruits grown under iron and phosphorus deficiency. *J. Sci. Food Agric* 95: 2088-2094.
35. Ulrich D, Olbricht K (2014) Diversity of metabolite patterns and sensory characters in wild and cultivated strawberries. *J. Berry Res* 4: 11-17.
36. Olsson ME, Andersson CS, Oredsson S, Berglund RH, Gustavsson K (2006) Antioxidant levels and inhibition of cancer cell proliferation in vitro by extracts from organically and conventionally cultivated strawberries. *J. Agric. Food Chem* 54: 1248-1255.
37. Abul-Soud MA, Emam MSA, El-Rahman N (2015) The Potential Use of Vermicompost in Soilless Culture for Producing Strawberry. *Int. J. Plant Soil Sci* 8: 1-15.
38. Diel MI, Pinheiro MVM, Thiesen LA, Altissimo BS, Holz E, et al. (2018) Cultivation of strawberry in substrate. Productivity and fruit quality are affected by the cultivar origin and substrates. *Cienc. Agrotec* 42: 229-239.
39. Jafamia S, Hatamzadeh A, Tehranifar A (2010) Effect of different Substrates and Varieties on Yield and Quality of Strawberry in Soilless Culture. *Adv. Environ. Biol* 4: 325-328.
40. Ameri A, Tehranifar A, Shoor M, Davarynejad GH (2012) Effect of substrate and cultivar on growth characteristic of strawberry in soilless culture system. *Afr. J. Biotechnol* 11: 11960-11966.
41. Tariq R, Qureshi KM, Hassan I, Rasheed M, Qureshi US (2013) Effect of Planting Density and Growing Media on Growth and Yield of Strawberry. *Pakistan J. Agric. Res* 26: 113-123.
42. Kuisma E, Palonen P, Yli-Halla M (2014) Reed canary grass straw as a substrate in soilless cultivation of strawberry. *Sci. Hort* 178: 217-223.
43. Grunert O, Hernandez-Sanabria E, Vilchez-Vargas R, Jauregui R, Pieper HD, et al. (2016) Mineral and organic growing media have distinct community structure, stability and functionality in soilless culture systems. *Sci. Rep.* 6: 18837.
44. Adak N, Tozlu I, Gubbuk H (2018) Influence of Different Soilless Substrates to Morphophysiological Characteristics and Yield Relations in Strawberries. *Erwerbs-Obstbau* 60: 341-348.
45. Giampieri F, Alvarez-Suarez JM, Mazzoni L, Romandini S, Bompadre F, et al. (2013) The potential impact of strawberry on human health. *Nat. Prod. Res* 27: 448-455.
46. Bhat R, Geppert J, Funken E, Stamminger R (2015) Consumers Perceptions and Preference for Strawberries - A Case Study from Germany. *Int. J. Fruit Sci* 15: 405-424.
47. Nunes M, Brecht J, Morais A, Sargent S (2006) Physicochemical changes during strawberry development in the field compared to those that occur in harvested fruit during storage. *J. Sci. Food Agric* 86: 180-190.

48. Silva MS, Dias MSC, Pacheco DD (2015) Productivity and quality of strawberry cultivars in the north of Minas Gerais. Hort. Bras 33: 251-256.
49. Galletta GJ, Maas JL, Enns JM, Draper AD, Swartz HJ (1995) 'Mohawk' strawberry. HortScience 30: 631-634.
50. Tehranifar A, Poostchi M, Arooei H, Nematti H (2007) Effects of seven substrates on qualitative and quantitative characteristics of three strawberry cultivars under soilless culture. ActaHortic 761: 485-488.
51. Cecatto AP, Calvete EO, Nienow AA, Costa RC da, Mendonça HFC, et al. (2013) Culture systems in the production and quality of strawberry cultivars. Acta Sci. Agron 35: 471-478.
52. Fan L, Yu C, Fang C, Zhang M, Ranieri M, et al. (2011) The effect of three production systems on the postharvest quality and phytochemical composition of Orleans strawberry. Can. J. Plant Sci 91: 403-409.
53. Josuttis M, Carlen C, Crespo P, Nestby R, Toldam-Andersen TB, Dietrich H, et al. (2012) A comparison of bioactive compounds of strawberry fruit from Europe affected by genotype and latitude. J. Berry Res 2: 73-95.
54. Mezzetti B, Balducci F, Capocasa F, Cappelletti R, Vittori di L, et al. (2016) Can we breed a healthier strawberry and claim it? ActaHortic 1117: 7-14.
55. Wang SY, Millner P (2009) Effect of different cultural systems on antioxidant capacity, phenolic content, and fruit quality of strawberries (*Fragaria × ananassa* Duch.). J. Agric. Food Chem 57: 9651-9657.
56. Tulipani S, Marzaban G, Herndl A, Laimer M, Mezzetti B, et al. (2011) Influence of environmental and genetic factors on health-related compounds in strawberry. Food Chem 124: 906-913.
57. Kurze E, Kock V, Scalzo RL, Olbricht K, Schwab W (2018) Effect of the Strawberry Genotype, Cultivation and Processing on the Fra a 1 Allergen Content. Nutrients 10: 857.
58. Karlsson AL, Alm R, Ekstrand B, Fjelkner-Modig S, Schiott A, et al. (2004) Bet v 1 homologues in strawberry identified as IgE-binding proteins and presumptive allergens. Allergy 59: 1277-1284.
59. Hartmann A, Patz CD, Andlauer W, Dietrich H, Ludwig M (2008) Influence of processing on quality parameters of strawberries. J. Agric. Food Chem 56: 9484-9489.

Citation: Prasad R, Lisiecka J, Raj K (2022) Strawberry– More than a Popular Summer Fruit: A Mini-Review. Adv in Nutri and Food Sci: ANAFS-230.