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ORIGINAL ARTICLE

Effect of harvesting season and cultivars on storage behaviour, nutritional quality and consumer acceptability of strawberry (*Fragaria × ananassa* Duch.) fruits

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Abstract
This study focuses on the effect of weather conditions during fruit growth and ripening on functional components and storage life of strawberry. Two newly adopted commercial strawberry cultivars Camarosa and Winter Dawn were tested for their bioactive compounds and storage life in relation to harvesting months February(winter) March(spring) and April(summer). Fruits were harvested at commercial maturity, packed in plastic punnets and stored at 5 ± 2 °C temperature and 85 ± 5% relative humidity up to 12 days. During storage, March–April harvested fruits showed higher retention of total soluble solids (TSS), total sugars, functional components and consumer acceptability over winter produce. Between varieties, Camarosa showed better storage response over Winter Dawn in terms of overall quality. In conclusion. strawberries harvested during March–April have lower acidity, higher TSS, antioxidant capacity and consumer acceptability over February picking.

Keywords Strawberry · Sequential harvesting · Storage · Functional quality · Consumer acceptability

Introduction

Strawberry (*Fragaria × ananassa* Duch.) is known for its tantalizing taste, soothing fragrance, high nutritional value and quick return to growers (Giampieri et al. 2012; Ulukanli and Oz 2015). Strawberry is basically a temperate fruit, but the availability of day-neutral varieties have popularized its cultivation in tropical and subtropical regions (Ruan et al. 2013; Asrey et al. 2008). It was introduced in India during the sixties but could not be popularized due to lack of improved agro techniques and slow adoptive response of farmers and consumer's demand (Asrey et al. 2008). During the last one and a half decades, this crop has registered impressive growth in terms of area, production and consumption pattern. This could have been possible due to improved agro-techniques, such as fertigation, application of mulch, raised bed planting and availability of virus-free healthy runners (Shiukhy et al. 2015). Besides, consumer's awareness towards low calorific and high mineral containing protective food, increasing inclination of younger population towards exotic taste also supported the steady growth of strawberry in India. All these factors contributed towards increase in demand and brighter prospects of strawberry cultivation in India. Looking into impressive progress and potential of this crop, several researchers have attempted production aspects of strawberry in India. On the postharvest aspect, major research emphasis has been given to production practices in relation to quality of freshly harvested strawberry fruits. Climate change has put forth new challenges before researchers to explore alternatives to the prevelant crop varieties, production region and preservation techniques with new strategies (Tessmer et al. 2016; Gunduz and Odzemir 2014). Characterization of storage potential of newly introduced/evolved crop/varieties is a new frontal area of research (Padula et al. 2013). As per our understanding, impacts of harvesting months (with varied average temperature regime- 15 to 25 ºC) on postharvest storage behavior of newly introduced Camarosa and Winter Dawn cultivars still remain unattended. Besides, these harvesting months

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viz. February, March and April pass through the winter, spring and beginning of summer. But, the impact of prevailing meteorological contions (temperature, humidity, cloud cover) during fruiting and harvesting on functional components of fruit has not been attended so far, which attracted us to take up this study. The objective of this study was to investigate the impact of harvesting months (winter, spring and summer) on storage behavior and nutritional quality of strawberry fruits.

Materials and methods

Experimental site and fruit material

Strawberry fruits were manually harvested in February (winter), March (spring) and April (summer) at commercial maturity stage from a strawberry farm near Delhi located at lat. 28.08° N, long. 77.12° E and 228.6 M above mean sea level. Selected fruits were brought to the Post Harvest Handling laboratory, Food Science and Postharvest Technology Division, Indian Agricultural Research Institute, New Delhi. Uniform healthy fruits of Camarosa and Winter Dawn varieties were packed in 200 g filling capacity of plastic punnets having four ventilating holes each at top and bottom. Packed fruits were placed in single layer CFB Box and kept in cold storage at 5 ± 2 °C and 85 ± 5% R.H. During storage, data were recorded from fruits of February, March and April samples at 4 days intervals on different quality parameters.

Meteorological observations

Data on temperature, relative humidity, rainfall, evaporation and cloud cover during the commencement of strawberry flowering and fruit harvesting were sourced from meteorological observatory of Agricultural Physics ICAR-Indian Agricultural Research Institute, New Delhi and presented as monthly average (Table 1).

Physical parameters

Fruit firmness was recorded individually using a Texture Analyzer (model: TA + Di, Stable micro systems, UK) coupled with a cylindrical probe of 2 mm diameter under compression test. This probe was advanced at a pre-test speed of 2 mm s^{-1} and test speed of 0.5 mm s^{-1}. First peak force (N) in the force deformation curve was taken as firmness of the sample and the results were expressed in Newton (N) (Jha et al. 2010).

Pathological parameters

The % fruit decay was calculated using the formula, the number of decayed fruits divided by a total number of fruits and multiplied by 100 (Goncalves et al. 2010).

Physiological parameters

During storage, fruits were weighed at regular intervals with the help of an electronic balance. Physiological loss in weight was calculated as the difference between the initial weight of the fruits and the weight of the fruits at the time of measurement and expressed as a percentage (% of initial weight of the fruit). Respiration rate was estimated by adopting the static headspace technique using gas analyzer (Model: Checkmate 9900 O_2/CO_2, PBI Dansensor, Denmark) as followed by Kannaujia et al. (2014) and results were expressed in mL CO_2 kg^{-1} h^{-1}.

Biochemical and functional parameters

The total soluble solids of samples were estimated using FISHER Hand Refractometer having score of 0–50°brix as

Table 1 Average monthly temperature, relative humidity, rainfall, evaporation and cloud cover during commencement of strawberry flowering and fruit harvesting

Months	Temperature (°C)			RH (%)	Rainfall (mm)	Cloud cover (Okta)	Evaporation (mm/day)
	Maximum	Minimum	Average				
January 2018	21.33	7.20	14.26	68.03	0.23	2.18	1.4
February 2018	25.75	9.65	17.70	70.39	1.81	2.34	1.2
March 2018	28.62	13.5	21.06	68.96	0.20	1.41	2.9
April 2018	36.04	17.51	26.77	44.75	0.12	0.68	3.8
January 2019	19.20	5.22	12.21	72.59	0.47	2.67	1.1
February 2019	23.80	7.94	15.87	54.39	0	1.20	1.5
March 2019	27.70	12.70	20.2	50.88	0.62	0.89	2.5
April 2019	35.16	18.30	26.73	50.76	0.28	0.80	3.5

Monthly data are the mean of particular months

RH relative humidity

earlier adopted by (Barman et al. 2014). Total sugars (%) were determined by taking a known quantity of strawberry pulp titrated with boiling Fehling's solution using methylene blue indicator till brick red colour appeared (AOAC 2006). The titratable acidity was determined by a known volume of filtered strawberry juice titrated with standard sodium hydroxide (0.1 N) using phenolphthalein as an indicator and expressed as percent of anhydrous citric acid (AOAC 2006). Ascorbic acid was estimated by volumetric method using 2, 6-dicholorophenol–indophenol dye (Ranganna 1999). The titre value was used for calculation of ascorbic acid content in the sample and results were expressed in mg 100 g^{-1} of fresh weight of the pulp. Total anthocyanins in strawberry were estimated by the method described by Ranganna (1999). One gram strawberry pulp was blend with known amount of ethanolic acid (95% ethanol and 1.5 N HCL in the ratio of 85:15). Prepared samples were centrifuged for 20 min at 4 °C at 10,000 rpm and later absorbance was recorded at 435 nm in a spectrophotometer (Model: Jasco V-670 UV–Vis–NIR spectrophotometer, Japan). Total anthocyanins were measured and expressed in mg 100 g^{-1} of strawberry pulp. Antioxidant capacity was determined by cupric reducing antioxidant capacity method (Apak et al. 2004). The measured quantity was expressed as µmol trolox equiv. 100 g^{-1} FW. The analysis of total phenolic was carried out by Folin–Ciocalteau spectrophotometric method suggested by (Singleton et al. 1999). Absorbance was recorded on a spectrophotometer (Model: Jasco V-670 UV–Vis–NIR spectrophotometer, Japan) and results were expressed in µg GAE/100 g of extract.

Sensory evaluation

Sensory evaluation of fruits of two cultivars harvested in different months was performed by semi-trained panel of judges. For sensory evaluation of fruits, coded samples were given to 10 judges and they were asked to rinse their mouth before or in between tasting the two given samples. Each sample was evaluated using 9-point hedonic scale with (1) dislike extremely; (2) dislike very much; (3) dislike moderately; (4) dislike slightly; (5) neither like nor dislike; (6) like slightly; (7) like moderately; (8) like very much and (9) like extremely. Scores of above 6 out of 9 was considered acceptable for commercial purposes. The evaluated parameters were sweetness, colour, texture, juiciness and overall acceptability. To draw the spider web diagram, sensory scores were taken for each attributes out of total score of 9.

Statistical analysis

Present experiment was conducted in Completely Randomized Design (CRD) with three replications each having 25 fruits. Consecutive 2 year data from different treatments with respect to various physical, physiological, biochemical and functional parameters were pooled and subjected to analysis of variance using SAS 9.3 software (2) and significant effects ($p < 0.05$) were noted.

Results and discussion

Fruit firmness

Firmness difference was found much higher in April produce and registered ≈ 18% fruit firmness reduction over February produce (Table 2). Irrespective of the harvesting months, there was a sharp decline in firmness after 4th day of storage, however; firmness reduction was much higher in February produce (2.01 N) over March (1.70 N) and April (1.63 N) harvest. Irrespective of harvesting months Camarosa cultivar outperformed Winter Dawn in fruit firmness retention.

Fruit firmness is governed by multiple factors. The acceptance of any fruit by consumers is largely dependent on its firmness. It is even more in case for strawberry as it is a delicate fruit. Firmness in strawberry fruit is mainly governed by weather condition during fruit growth period, cell wall composition (pectin, calcium), intracellular material and activity of degrading enzymes (Seymour et al. 1993; Shiow and Camp 2000). Higher cell wall degrading enzyme activity during summer months could have contributed to faster softening of April harvested fruits. Increased softening in fruit harvested durin April might also have been due to lower level of phenolics, higher respiration rate and fruit decay. Higher firmness in February fruit may be attributed to higher pectin content and fruit peel thickness of winter produce (Pelayo et al. 2003; Shin et al. 2007).

Fruit decay (%)

At 12th day storage; April harvested fruits showed higher decay loss (5.51%) followed by March and February (Table 2). The decay loss showed a definite rising trend with the advancement of storage period; however rate of progression was found much lower in February produce. The cultivar Camarosa consistently showed its superiority over Winter Dawn with respect to lower decay loss. At the 12th day of storage the cumulative decay loss was found varying from 3.80 to 4.86% in Camarosa and 4.05 to 5.51% in case of Winter Dawn.

Warmer day and cooler nights (35/22 °C) favours the growth of decay causing fungi (*Botrytis* rot and *Rhizhopus* rot) in strawberry (Wang et al. 2016). Also, the defence mechanism of the fruits against microbes depends on skin thickness, lenticels density and opening, phenols, terpenoids, furanones, alcohol (Prasad et al. 2016; Tessmer et al. 2016; Self et al. 2006). The higher decay loss recorded in

Table 2 Effect of harvesting months and cultivars on physical and physiological properties of strawberry fruits stored at 5 ± 2 °C temperature and 85 ± 5% relative humidity

Months	Days	Fruit firmness (*N*)			Decay (%)			PLW (%)			Respiration rate (ml CO_2 kg^{-1} h^{-1})		
		Variety		Mean	Variety		Mean	Variety		Mean	Variety		Mean
		Camarosa	Winter Dawn		Camarosa	Winter Dawn		Camarosa	Winter Dawn		Camarosa	Winter Dawn	
February	0	3.09	1.69	2.39	0.00	0.00	0.00	0.00	0.00	0.00	97.33	103.00	100.17
	4	2.46	1.62	2.04	1.87	1.99	1.93	0.65	0.78	0.72	101.20	107.97	104.59
	8	2.40	1.40	1.90	3.52	3.89	3.71	2.99	3.10	3.05	111.12	115.22	113.17
	12	2.12	1.32	1.72	9.82	11.33	10.58	3.49	3.98	3.74	107.78	111.29	109.54
	Mean	2.52	1.51	2.01	3.80	4.30	4.05	1.78	1.97	1.87	104.36	109.37	106.87
March	0	2.25	1.41	1.83	0.00	0.00	0.00	0.00	0.00	0.00	103.51	106.16	104.84
	4	2.21	1.39	1.80	2.24	2.81	2.53	0.79	0.95	0.87	106.01	111.33	108.67
	8	2.02	1.18	1.60	4.82	5.67	5.25	3.80	4.10	3.95	114.11	119.67	116.89
	12	1.99	1.11	1.55	10.11	12.67	11.39	4.21	4.93	4.57	110.77	114.67	112.72
	Mean	2.12	1.27	1.70	4.29	5.29	4.79	2.20	2.50	2.35	108.60	112.96	110.78
April	0	2.30	1.37	1.84	0.00	0.00	0.00	0.00	0.00	0.00	114.67	118.50	116.59
	4	2.22	1.29	1.76	2.87	3.12	3.00	0.91	1.02	0.97	118.45	121.26	119.86
	8	1.97	1.19	1.58	4.21	5.87	5.04	3.99	4.38	4.19	123.32	127.66	125.49
	12	1.68	1.01	1.35	12.37	15.60	13.99	4.68	5.41	5.05	120.77	124.15	122.46
	Mean	2.04	1.22	1.63	4.86	6.15	5.51	2.40	2.70	2.55	119.30	122.89	121.10
CD $_{(P=0.05)}$	Months	0.023			0.076			0.032			1.175		
	Variety	0.019			0.062			0.026			0.959		
	Storage days	0.026			0.088			0.037			1.357		
	Variety × months	0.032			0.108			0.045			1.662		

Data are mean of three replications ($n = 3$). $CD_{(P=0.05)}$ (Significant at 5% level)

N newton, *PLW* physiological loss in weight, *CD* critical difference fruits harvested during April could be due to lower concentration of defense related secondary metabolites, such as phenolics, anthocyanins and ascorbic acid (Table 4). On the contrary, lower fruit decay in February harvested fruits might be due to higher phenolics, lower PLW and restricted lenticels opening. This difference in the decay might be due to variation in phytochemical profile (phenols, pectins, vitamins) and fruit peel thickness by the virtue of environmental conditions prevailing during bloom and harvesting months (Shiow and Camp 2000).

Physiological loss in weight (PLW %)

April harvested fruits shown rapid surge in PLW followed by March and February produce (Table 2). Initially, rate of PLW was higher upto 4th day of storage thereafter it shows slow down. At 12th day of storage, the average PLW of April month produce was 2.55% followed by March and February (1.87%). Among the varieties, Camarosa proved better over Winter Dawn in respect of lower PLW of fresh as well as stored fruits.

Physiological loss in weight (PLW) is governed by substrate present in fruits and its storage environment. It is an important criteria for deciding the shelf life of fruits and vegetables (Sorensen et al. 1994). Higher PLW during April month in Winter Dawn cultivar could be due to single or multiple interactive responses of genotypes and substrates (dry matter, carbohydrates, organic acid, vitamins and minerals) present within the fruits (Vaz Monteiro et al. 2016). In strawberry, low temperature during flowering and fruit development greatly favours starch, carbohydrate and dry matter accumulation (Wang and Camp 2000). Our result is in line with Shiow and Camp (2000), who recorded higher PLW in strawberry produced under higher post-bloom temperature. Moreover, higher respiration rate, carbohydrate degrading enzymes activities and secondary metabolites responsible for ethylene biosynthesis might have contributed towards higher weight loss (Hernández-Muñoz et al. 2006).

Respiration rate

April harvested fruits showed higher cumulative respiration rate (121.10 mL CO_2 kg^{-1} h^{-1}) followed by March and February (Table 2). Winter Dawn cultivar showed a higher respiration rate over Camarosa in all the harvesting months and storage intervals. Fruit respiration rate difference within the varieties was much higher in February produce over March and April. February produce of both the cultivars showed ≈ 11.0% lower respiration over April produce at 12th day of storage.

Respiration rate, ethylene evolution, PLW and fruit firmness are interlinked characters. Deviation in any above individual character affects another physiological activity. Also, prevailing temperature both in field and storage affects the respiration rate of the produce (Nunes et al. 1995). Similarly, we also recorded higher respiration rate in April (summer) harvested fruits. The reason for higher respiration in summer produce during storage might be attributed to higher presence of simple sugars, low amount of organic acids and higher activity of respiratory enzymes (Fagundes et al. 2013). It is well established that higher temperatures (≈35 °C) favour fungal growth (Wang et al. 2016); therefore, a higher incidence of decay in the April harvest might also be contributed to a higher respiration rate. The difference in respiratory rates of Camarosa and Winter Dawn cultivars was likely due to their varied composition and genetic makeup (Castro et al. 2002; Tulipani et al. 2011).

Total soluble solids

April month picked fruits showed higher TSS retention (9.02 ºBrix) over February produce (6.93 ºbrix) at 12th day of storage (Table 3). Irrespective to harvesting months, Camarosa showed higher TSS over Winter Dawn during storage. Although, there was steady decline in TSS from 8th day onward, but Winter Dawn registered much faster rate of TSS loss over Camarosa.

TSS is the most reliable index used for judging the fruit maturity. It encompasses soluble minerals, organic acids and polysaccharides present in the fruits. The synthesis, solubility and concentration of TSS fractions are influenced by the growing environment, genotype and storage environment (Crecente-Campo et al. 2012; Coyago-Cruz et al. 2018; Ertan et al. 2018; Kannaujia et al. 2019). High temperature affects photosynthesis which may cause alteration in sugars and other TSS contributing secondary metabolites (Moretti et al. 2010). A comparatively higher temperature during April accelerated fruit ripening which has also contributed to higher TSS in April harvested fruits. Generally TSS content of the fruits initially increased and afterward starts declining during storage and we also got the same trend (Shin et al. 2007). These findings are in agreement with Domínguez et al. (2016); who reported higher soluble solid concentrations in late harvested fruits of strawberry.

Total sugars

Both Camarosa and Winter Dawn cultivars produced during March shown a higher level of sugars in fruits (Table 3). It is also interesting to note that the depletion rate of the total sugars was faster in the fruits harvested during April over March and February produce. The retention of total sugars was found little better in case of Camarosa (5.52%) compared to Winter Dawn (5.10%) at the end of storage of 12th day.

Table 3 Effect of harvesting months and cultivars on chemical properties of strawberry fruits stored at 5 ± 2 °C temperature and 85 ± 5% relative humidity

Months	Days	T.S.S (°Brix)			Total sugars (%)			Titratable acidity (%)		
		Variety		Mean	Variety		Mean	Variety		Mean
		Camarosa	Winter Dawn		Camarosa	Winter Dawn		Camarosa	Winter Dawn	
February	0	6.90	6.65	6.78	3.48	3.38	3.43	0.76	0.74	0.75
	4	7.20	7.03	7.12	3.82	3.46	3.64	0.68	0.66	0.67
	8	7.37	7.53	7.45	4.03	3.67	3.85	0.62	0.61	0.62
	12	6.45	6.32	6.39	3.85	3.18	3.52	0.58	0.52	0.55
	Mean	6.98	6.88	6.93	3.80	3.42	3.61	0.66	0.63	0.64
March	0	7.90	8.36	8.13	5.19	4.89	5.04	0.71	0.69	0.70
	4	9.23	9.77	9.50	6.15	5.18	5.67	0.62	0.65	0.64
	8	8.43	9.01	8.72	6.68	6.01	6.35	0.59	0.60	0.60
	12	7.25	7.95	7.60	4.95	4.42	4.69	0.51	0.52	0.52
	Mean	8.20	8.77	8.49	5.74	5.13	5.44	0.61	0.62	
April	0	9.05	8.67	8.86	5.14	4.57	4.86	0.47	0.48	0.48
	4	9.75	9.23	9.49	5.97	5.63	5.80	0.41	0.41	0.41
	8	9.29	9.70	9.50	6.29	6.00	6.15	0.34	0.38	0.36
	12	8.45	8.03	8.24	4.69	4.20	4.45	0.30	0.32	0.31
	Mean	9.14	8.91	9.02	5.52	5.10	5.31	0.38	0.40	
$CD_{(P=0.05)}$	Months	0.097			0.056			0.006		
	Variety	0.079			0.046			0.005		
	Storage days	0.112			0.065			0.007		
	Variety × months	0.138			0.080			0.008		

Data are mean of three replications ($n = 3$). CD $_{(P=0.05)}$ (Significant at 5% level)

TSS total soluble solids, *CD* critical difference

The higher sugar content in March picking may be due to increase both in day length and temperature. Exposure of the fruits to prolonged sunshine and high temperature hasten ripening and solid contents in fruits (Woolf et al. 1999; Bordonaba and Terry, 2010). The day–night temperature was increased during April (36/18 °C). This suboptimal increase in temperature might have caused lesser accumulation and faster sugar depletion in April produce (Aaby et al. 2012; Ares et al. 2009). The increase in temperature enhances the photosynthetic process, but due to the rise in fruit respiration rate photosynthesis: respiration ratio comes down and ultimately lowers the fruit sugar content.

Titratable acidity

Among varieties, Camarosa retained lower titratable acidity (TA) during all three harvesting months and entire course of storage period (Table 3). February produce retained almost double acidity (0.63–0.66%) over April harvest (0.38–0.40%). Irrespective of varieties, the TA depletion rate was faster in March produce over February and April produce during storage.

Malic, citric and ellagic acids are major acids present in strawberry fruits (Shiow and Camp 2000). As the day temperature decreased, the fruit acidity also decreased. The least value of TA in February picking could be due to less accumulation and slower depletion of organic acids reserve through respiration (Kallio et al. 2000). Furthermore, Wang and Camp (2000) also reported similar trend and found that amount of organic acids increased in strawberry fruits with increasing monthly temperature.

Ascorbic acid

February harvested fruits retained higher average ascorbic acid (51.54 mg 100 g^{-1} FW) followed by March and April picked fruits, but the cumulative loss of ascorbic acid content was much faster in March harvested fruit (Table 4). It indicates that higher initial vitamin-C content leads to faster loss during storage. On the 12th day of storage, the cumulative ascorbic acid values of February, March and April produce were recorded as 51.54, 50.48 and 48.02 mg 100 g^{-1} FW, respectively.

Generally, vitamin C in fruits is considered as most stable at lower temperature. April produce showed a higher rate of water loss (PLW) in stored fruits; this may have enhanced vitamin C loss due to increased oxidation (Nunes et al. 1995; Asami et al. 2005). Increase in day–night temperatures

Table 4 Effect of harvesting months and cultivars on functional properties of strawberry fruits stored at 5 ± 2 °C temperature and 85 ± 5% relative humidity

Months	Days	Anthocyanin content (mg 100 g^{-1})			Total antioxidants (μmol trolox equiv 100 g^{-1})			Total phenolics (μg GAE 100 g^{-1})			Ascorbic acid (mg 100 g^{-1})		
		Variety		Mean	Variety		Mean	Variety		Mean	Variety		Mean
		Camarosa	Winter Dawn		Camarosa	Winter Dawn		Camarosa	Winter Dawn		Camarosa	Winter Dawn	
February	0	257.63	224.47	241.05	53.88	36.90	45.39	470.87	439.53	455.20	75.08	53.76	64.42
	4	245.87	218.76	232.32	52.62	28.55	40.59	547.33	464.07	505.70	57.30	47.89	52.60
	8	231.13	217.33	224.23	45.37	25.60	35.49	414.43	403.83	409.13	45.76	46.50	46.13
	12	211.65	199.25	205.45	36.11	21.67	28.89	395.95	375.67	385.81	44.67	41.33	43.00
	Mean	236.57	214.95	225.76	47.00	28.18	37.59	457.15	420.78	438.96	55.70	47.37	51.54
March	0	334.52	269.62	302.07	39.97	37.68	38.83	353.30	269.67	311.49	71.17	72.66	71.92
	4	295.31	242.56	268.93	38.54	27.65	33.10	635.83	356.03	495.93	46.81	45.29	46.05
	8	278.65	212.61	245.63	32.20	24.50	28.35	409.60	278.73	344.17	44.61	43.34	43.98
	12	245.23	184.33	214.78	27.23	21.37	24.30	390.22	256.88	323.55	40.67	39.31	39.99
	Mean	288.43	227.28	257.85	34.49	27.80	31.14	447.24	290.33	368.78	50.82	50.15	50.48
April	0	328.86	200.65	264.755	55.17	44.60	49.89	383.27	385.17	384.22	60.19	52.99	56.59
	4	286.55	168.19	227.37	52.80	41.98	47.39	362.07	357.54	359.81	55.03	46.75	50.89
	8	240.12	159.65	199.88	48.06	35.03	41.55	344.84	301.54	323.19	46.06	40.85	43.46
	12	224.67	148.67	186.67	42.15	30.23	36.19	318.57	285.86	302.22	42.60	39.67	41.14
	Mean	270.05	169.29	219.67	49.55	37.96	43.75	352.19	332.53	342.36	50.97	45.07	48.02
$CD_{(P=0.05)}$	Months	2.877			0.475			5.017			0.565		
	Variety	2.349			0.388			4.096			0.461		
	Storage days	3.322			0.548			5.793			0.653		
	Variety × months	4.069			0.671			7.095			0.799		

Data are mean of three replications ($n = 3$). $CD_{(P=0.05)}$ (Significant at 5% level)

CD critical difference

during April may have negatively affected ascorbic acid synthesis and accumulation (Kader 2000; Wang and Zheng 2001). The varietal difference in relation to vitamin C retention at different temperatures during storage has also been demonstrated by Cordenunsi et al. (2005).

Total anthocyanin

Among the harvesting months, March produce gave the highest anthocyanin (302.07 mg 100 g^{-1} FW) in fresh as well as in stored fruit (257.85 mg 100 g^{-1} FW) at 12th day of storage (Table 3). Regardless of harvesting months and storage interval, Camarosa cultivar exhibited maximum anthocyanin content over Winter Dawn. Irrespective of varieties, our results showed about 12% higher anthocyanin contents in March produce than February and April one. Fruits of all three harvesting months showed a declining trend in anthocyanin content with the progression in storage period, but depletion rate was much faster in April produce.

The total anthocyanin concentration of strawberry fruits is greatly influenced by growing and storage conditions (Cordenunsi et al. 2005; Ruan et al. 2013; Garcia-Noguera et al. 2014). Congenial temperature (20–28 °C) favours anthocyanin synthesis and retention in fruits and vegetables (Tulipani et al. 2011). Higher anthocyanin in March produce might be due to favourable spring temperature than colder and warmer months of February and April. Pigment synthesis might have decreased with lower luminosity during February due to high cloud cover. Mild temperature conditions during March have increased Phenylalanine ammonia-lyase (PAL) and glucose regulatory enzyme activities, favoured higher anthocyanin accumulation (Crecente-Campo et al. 2012; Ertan et al. 2018).

Total antioxidants capacity

Irrespective of harvesting months, Camarosa cultivar exhibited higher antioxidant capacity and slow depletion rate than Winter Dawn during the entire storage period (Table 4). April harvested fresh fruit recorded higher antioxidant capacity (49.89 µmol trolox equiv.100 g^{-1} FW) followed by February (45.39 µmol trolox equiv. 100 g^{-1} FW) and March (38.83 µmol trolox equiv. 100 g^{-1} FW).

Preharvest conditions, such as crop genotype, temperature, humidity, rainfall and CO_2 concentration in atmosphere, affect the quantity and quality of antioxidant compounds (Wang 2006; Kannaujia et al. 2019). High temperature during April months (≈ 36 °C) could have enhanced total antioxidant capacity of the fruits. Wang (2006) also reported that higher antioxidant capacity was found under higher temperature (30 °C) condition grown strawberries. Generally, individual compounds (ascorbic acid, anthocyanin, phenolics, flavonoids, etc.) do not have a definite relation with total antioxidant capacity (Miller and Rice-Evans 1997). The lower antioxidant capacity in the February and March harvested fruit may be ascribed to unfavourable temperature for synthesis of secondary metabolites and numerous unknown factors that contribute to total antioxidant capacity (Kay 2010; Gunduz and Ozdemir 2014).

Total phenolics

Higher level of phenolic content was found in February harvested fruits (438.96 µg GAE 100 g^{-1}) followed by March (368.78 µg GAE 100 g^{-1}) and April produce (Table 4). Camarosa cultivar had phenolic rich fruits and retained higher phenolics upto 12th day of storage period. During storage, both the varieties showed a surge in phenolics content on 4th day and thereafter it started declining in February and March produce. April produce behaved differently and constantly registered a declining trend in phenolic throughout the storage span.

The synthesis, retention, and bioavailability of phytochemicals is influenced by several factors (Wang 2006; Kay 2010). Lower total phenolics content in fruits harvested during April month might have been due to higher respiration rates and moisture loss (Ayala-Zavala et al. 2004). Cordenunsi et al. (2005) and Jin et al. (2011) have noted that production conditions (temperature, light intensity) affect the fruit phenolics content. Higher phenolics content were observed in strawberry by several workers who attributed it to cold stress during February month leading to higher phenolics synthesis, especially chlorogenic and ellagic acids (Aaby et al. 2012; Gunduz and Ozdemir 2014; Lee and Kader 2000).

Sensory evaluation

The higher overall acceptance score was recorded in Camarosa (8.25) and Winter Dawn (7.5) fruits, respectively, when harvested in the month of March (Fig. 1a, b). Camarosa cultivar exhibited better sensory score over Winter Dawn during all harvesting months and entire storage span of 12 days.

Sensory quality is a complex phenomenon and mainly represented by balance among physical appearance, taste (sugar, acidity) and aroma (Pelayo et al. 2005; Nunes et al. 2007). Amongst, all sensory quality contributing parameters, TSS and TA content and their ratio are the most important which influences the consumer preference. Congenial weather conditions during March have helped in optimum synthesis and preservation of sugars and acids in fruits. Volatile compounds are better synthesized in strawberry fruits at day/night temperature of 27/13 °C and gives a consistent high rating for consumer preference (Jouquand et al. 2008). We have also recorded the average day/night temperature of 28.16/13.1 °C during March. The combined effect of all

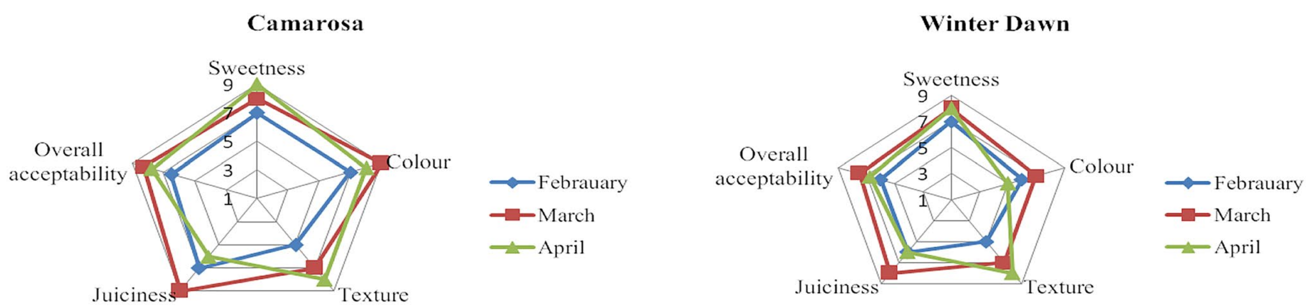

Fig. 1 Effect of harvesting season and cultivars, Camarosa (**a**) and Winter Dawn (**b**) on sensory attributes of strawberry fruits

these factors might have given a higher sensory score to March harvested fruits (Ares et al. 2009).

Conclusions

This study shows that physico-nutritional properties of strawberry fruits were greatly influenced by sequential harvesting months and cultivars. In the plains of North India, fruits harvested during spring (March) and early summer (April) had higher TSS, total sugars, functional components (anthocyanin and antioxidant) and overall consumer acceptability than in winter (February) harvested fruits. Cultivar Camarosa performed better over Winter Dawn with respect to overall fresh fruit quality and better retention of physico-chemical properties during storage. This study suggests that farmers can grow strawberries of high nutritional quality by manipulating growing conditions and varietal selection to gain more consumer acceptance and fetch higher profit. The findings can also help the processors and consumers in decision making while selecting the produce suitable for specific requirements.

Author contribution statement All authors contributed to this study “Harvesting season and cultivars have an effect on storage behaviour, nutritional quality and consumer acceptability of strawberry (Fragaria × ananassa Duch.) fruits”. Material preparation, data collection and analysis were performed by both the authors (Pankaj Kumar Kannaujia and Dr Ram Asrey). The first draft of the manuscript was written by Dr Pankaj Kumar Kannaujia. Dr Ram Asrey commented on first draft of the manuscript and improved it. Both the authors read and approved the final manuscript.

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Declarations

Conflict of interest The authors declare that there are no conflicts of interest.

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