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Response of strawberry fruits to low temperature and ambient storage conditions

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ABSTRACT

The fruit of 'Winter Dawn' and 'Chandler' strawberries were harvested at commercial maturity on the attainment of the full red ripe stage and packed in 200g plastic punnets. The fruits were then stored under two different environmental conditions: cold storage (5±1°C; 90-95% RH) and at ambient temperature (28-30°C; 60-65% RH). Fruits were evaluated for transformation in physical and biochemical attributes during the storage period. Results revealed that fruits stored under cold temperature conditions significantly reduced PLW, fruit firmness and rotting and also maintained various quality traits, viz., total soluble solids, sugars, acidity, ascorbic acid, anthocyanin content, antioxidant properties and sensory quality as compared to ambient temperature during the storage period. In addition, the studies highlighted that fruits of both cultivars could be stored for up to 6-9 days and 2 days at low temperature and ambient conditions, respectively.

Keywords: *Fragaria* × *ananassa* Duch., Cold storage, Ambient condition, Quality parameters

INTRODUCTION

Strawberry is an important fruit crop of sub-tropical and temperate agro climatic regions of the world and production of 8.33 million MT is realized from an area of 3.72 lakh ha. According to FAOSTAT (7), Asia continent contributes about 46.6%, America 26.1%, Europe 20.2%, Africa 6.3% and Oceania 0.7% of the total world production. In India, strawberry cultivation is confined to an area of 690 ha with the production of 4900 MT and productivity 7.6 MT/ha. Strawberry fruit has higher high nutritional and phytochemical properties; unique taste, pleasant flavour, juicy aril and attractive pericarp colour. Because of economical and commercial importance, there is rapid area extension under strawberry cultivation in the vicinity of metropolitan cities of the country. It is the need of the country to shift the area from the traditional crops under cultivation in different ecosystems to high value annual horticultural crops for attaining nutritional security and generation of employment opportunities. Strawberry cropping system gives better returns to the growers as compared to other fruit crops. The fruits are ready for harvest within 60 to 155 days after the date of runners planting on the raised beds in the fields (Singh *et al*., 16).

Strawberry fruit confronts with two major problems *viz*., perishable nature and browning of tissues. Both the problems occur due to low membrane integrity as well as higher polyphenol oxidase activity (Jiang, 9). It also shows fast physiological and biochemical changes after fruit harvest, and causes rapid fruit decay and deterioration of quality, thus affecting its market value. Several studies were undertaken to maintain the fruit quality, appearance, perception of sweetness and flavour, firmness and chemical attributes during storage under different temperature regime and RH in strawberry cultivars (Pelayo *et al*., 12). Red pericarp colour is mostly concerned with the appearance of strawberry fruit which develops due to the accumulation of anthocyanin content. These parameters substantially determine the market price and also acceptability by consumer. Most of the biochemical constituents such as anthocyanins, vitamin C, antioxidant, total phenolic contents and flavour are greatly influenced by the cultivar, stage of harvest, handling practices and storage conditions. The aim of the present study endeavours to examine the physiological and biochemical changes of two predominantly grown cultivars of strawberries *viz*., 'Winter Dawn' and 'Chandler' during storage under low temperature with controlled RH as well as ambient temperature in order to ascertain their shelf life.

MATERIALS AND METHODS

The experiment was conducted at Punjab Horticultural Postharvest Technology Centre, Punjab Agricultural University, Ludhiana for two successive years (2016-17 and 2017-18). Strawberry fruits of 'Winter Dawn' and 'Chandler' were harvested at commercial maturity. The diseased and misshapen fruits were sorted-out, and only healthy and uniform sized fruits were selected for the study. Berries were

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packed in 200g punnets, thereafter; the packed fruits were stored under cold storage (5±1°C and 90-95% RH) and ambient conditions (28-30°C and 60-65% RH). The various physiological and biochemical attributes of the fruits were recorded at 3-days intervals up to 12 days under cold storage and at 2-days intervals at ambient conditions up to 4 days. The physiological loss in weight (PLW) of stored fruit was calculated by subtracting final weight from the initial weight of the fruits and expressed in per cent. The fruit firmness was measured with the help of a penetrometer (Model FT 02 FT 18, UK) using 3 mm stainless steel probe and expressed in terms of pound force pressure (lb force). The overall sensory quality of the fruits was evaluated by a panel of ten judges on the basis of external appearance of fruits, texture, taste, and flavour and overall acceptance where rating was calculated making use of Hedonic scale (Amerine *et al*., 4).

Total soluble solids (TSS) of the fruit juice were determined by a temperature compensated digital refractometer (Atago PAL-1, model 3810, Japan) and expressed as percent Brix. The total sugars, titratable acidity and ascorbic acid were estimated as per standard procedures (AOAC, 1). Total anthocyanin content of berries was determined with ethanolic HCl as the extraction solvent and absorbance was measured at 535 nm using spectrophotometer (Spectronic 200+, Thermo Scientific). Total phenols were estimated by Folin–Ciocalteu method, based on colorimetric oxidation/reduction reactions of phenols (Slinkard and Singleton, 17). Phenol extraction was carried out with 80% ethanol and the absorbance was measured at 765 nm against a blank using a spectrophotometer (Spectronic 200+, Thermo Scientific). Total antioxidants were estimated by DPPH method (Pisoschi and Negulescu, 14). The experiment consisted of four treatments and five storage intervals that laid out in completely randomized design with three replications for each treatment and at each storage interval. There were twenty four punnet boxes and each contained 200 g fruits. The data were pooled and analyzed for variance by using the SAS (V 9.3, SAS Institute Inc., Cary, NC, USA) software package.

RESULTS AND DISCUSSION

The physiological loss in weight (PLW) for both the strawberry cultivars 'Winter Dawn' and 'Chandler' increased at slow rate initially but at a faster rate with the advancement of storage irrespective of the storage conditions (Table 1). The average PLW was higher under ambient condition (0 to 12.25 % in 'Winter Dawn' and 0 to 15.10 % in 'Chandler') within 4 day of storage; whereas, fruit stored at low temperature registered the lowest PLW of 0-7.25 % and 0-7.85%, respectively in both the cultivars throughout the storage period. The acceptable limit of weight loss in strawberry is about 5%. Keeping this value in consideration, it was noticed that both the cultivars have shelf-life of 6-9 days and 2 days, respectively under low temperature and ambient conditions. The higher storage temperature significantly enhances the rate of respiration and also reduces storage life resulting in the loss of fruit quality attributes (Falah *et al*., 6).

Firmness in strawberry fruits decreased with storage period in both the cultivars. It ranged from

Table 1: Effect of low temperature storage and ambient conditions on PLW, firmness, sensory score and rotting in strawberry.

	PLW (%)		Firmness (lb)		Sensory score		Rotting (%)	
				Low temperature storage				
Storage (days)	Winter dawn	Chandler	Winter dawn	Chandler	Winter dawn	Chandler	Winter dawn	Chandler
0	0.00^{d}	0.00^{d}	2.12^{a}	2.17^{a}	8.23^{a}	8.28^{a}	0.00^{e}	0.00^{e}
3	1.79^{c}	2.25^{c}	2.07^{b}	2.10^{b}	7.64^{b}	7.77^{b}	5.25^{d}	5.10^{d}
6	1.80^{c}	2.57^{c}	1.98^{c}	2.01^{c}	7.55^{b}	7.45^{c}	5.56^{c}	6.22^{c}
9	3.57^{b}	4.88^{b}	1.90^{d}	1.99^{cd}	7.00^{c}	7.01^{d}	10.32^{b}	10.23^{b}
12	7.25^{a}	7.85^{a}	1.81^{e}	1.85^{d}	6.01^{d}	6.15^{e}	98.5^{a}	99.5^{a}
SE±	0.31	0.27	0.05	0.08	0.04	0.05	0.39	0.15
				Ambient condition (days)				
0	0.00^{c}	0.00^{c}	2.10^{a}	2.17^{a}	8.20^{a}	8.31^{a}	0.00^{c}	0.50^{c}
2	7.95^{b}	8.25^{b}	1.95^{b}	1.99^{b}	7.01^{b}	7.01^{b}	8.25^{b}	9.60^{b}
4	12.25^{a}	15.10^{a}	1.84^{c}	1.82^{c}	6.09^{c}	6.02^{c}	22.31^{a}	17.25^{a}
SE±	0.52	0.32	0.02	0.02	0.08	0.05	1.13	0.46

Means that do not share a letter are significantly different ($p < 0.05$)

2.12 to 1.81 lbf in 'Winter Dawn' and 2.17 to 1.85 lb in 'Chandler' cultivars under low temperature storage conditions. In this fact, Perkins-Veazie (13) observed that strawberry fruit were softened considerably due to break down of pectic substances in the middle lamella of fruit cell wall under ambient and controlled temperature conditions.

The sensory acceptance of colour, flavour, glossy appearance, intention to purchase, and overall acceptance of strawberries stored at variable temperature conditions revealed significant differences ($p < 0.05$). The sensory quality of strawberries for both the cultivars linearly declined with the advancement of storage period (Table 1). Strawberries stored at low temperature (5±1°C & 90-95% RH) contributed higher value of 8.23 in 'Winter Dawn' and 8.28 in 'Chandler' strawberry cultivars for sensory attributes at harvest according to Hedonic scale. However, both the cultivars retained the acceptable sensory quality of 7 up to 9 days at low temperature and upto 2 days of storage under ambient conditions. Thereafter, sensory values declined sharply up to final storage intervals. Sensory score of 7 is considered as moderately desirable and below this value, the quality of the fruit starts deteriorating. The decay of strawberry increased with the advancement of storage periods. Under low temperature storage, the highest percentage of fruit rotting was observed on 12th day i.e. 98.5 % in 'Winter Dawn' and 99.5 % in 'Chandler' due to occurrence of *Botrytis* rot. Under ambient conditions, highest decay was observed after 4th day of storage. The temperature between 20° to 35°C generally promotes the grey mould (*Botrytis cinerea*) which in turn causes the decay of strawberry before and after fruit harvest (Abushaala, 2).

The maximum total soluble solids content of 8.85% in 'Winter Dawn' and 8.95% in 'Chandler' strawberries was observed at the time of storage (Fig. 1 A). The minimum TSS content in 'Winter Dawn' and 'Chandler' cultivars was reported on 12th day and values were 6.04 and 6.20%, respectively under cold storage and 6.15 and 6.18 %, respectively on 4th day of storage at ambient conditions (Fig. 1B). Furthermore, fruit stored upto 9th and 12th days were statistically non-significant with each other. The TSS content steadily declined

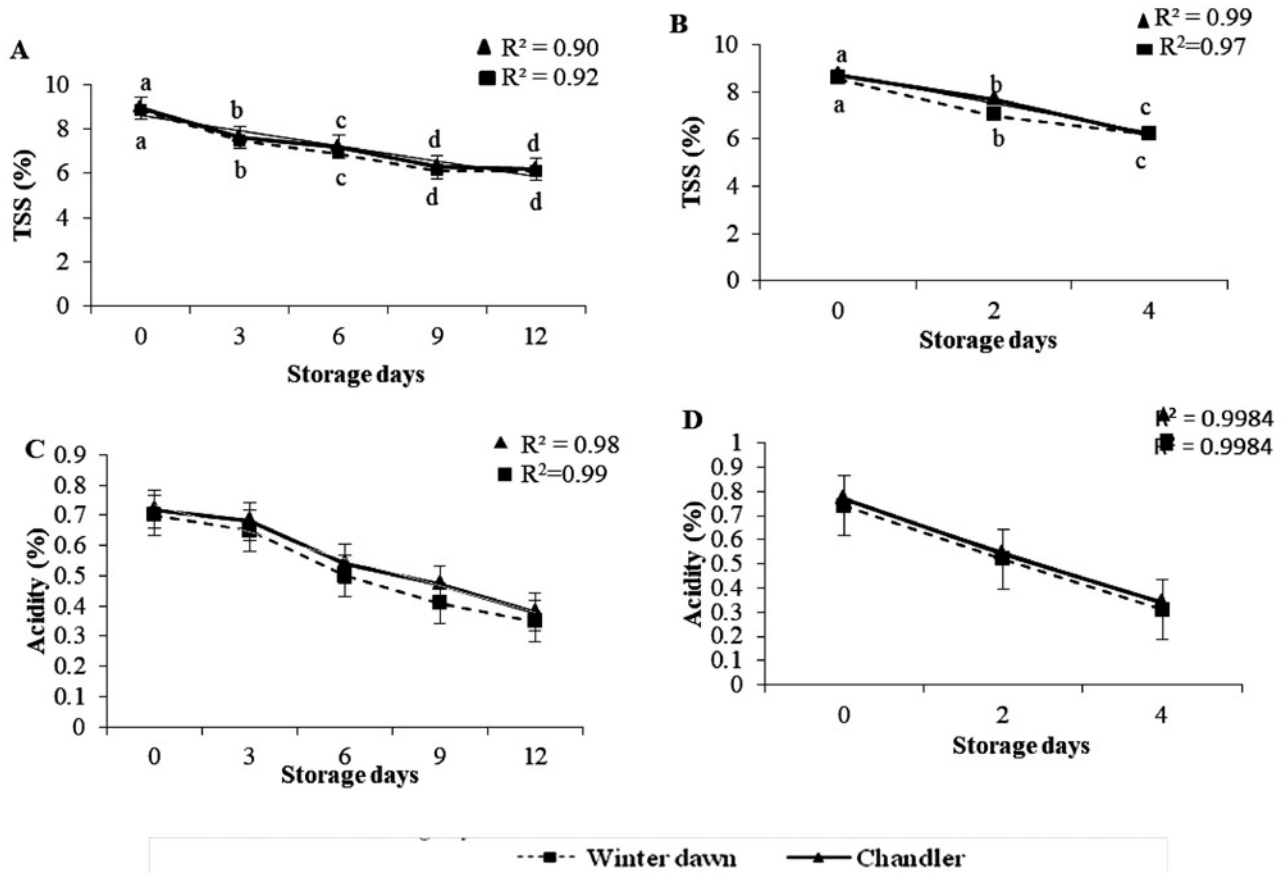

Fig. 1: Effect of storage and ambient conditions on Fruit TSS (A and B), Acidity (C and D) respectively on strawberry. Means that do not share a letter are significantly different ($p < 0.05$).Vertical bars represents SE± of pooled value.

with the advancement of storage period, which may be due to utilization of sugars during respiratory process of fruits (Dong *et al*., 5).

At storage temperature of 5±1°C and 90-95% RH, juice titratable acid content (TA) decreased gradually and attained values of 0.38% in 'Winter Dawn' and 0.35% in 'Chandler' after 12 days of storage (Fig. 1C). Similarly, under ambient conditions, trend was a linear in the downward direction and TA declined during storage in both the cultivars (Fig. 1D). Likewise, TA in strawberry was maintained under low temperature and effectively retarded the degradation as compared with ambient conditions. Decreasing trend in juice acid content during progression of storage period under both storage conditions especially at ambient conditions is due to higher respiration rate after harvest lead to a concomitant decrease in acid content of fruit. These results are in accordance with the observations noted by Montero *et al.,* (11). The decrease in titratable acids during storage may be attributed to remarkable increase in malic acid utilization during the period of climacteric as a result of pyruvate decarboxylation reaction (Hulme and Rhodes, 8). The maintenance of higher acidity at low temperature stored fruits may be due to slower degradation of organic acids owing to decreased respiration rate.

Total sugars content of strawberries decreased and showed a decline trend in both the cultivars. Significantly higher sugar content (8.75 % in 'Winter Dawn' and 8.72 % in 'Chandler') were noted during 0 day of storage and the lowest (7.80 and 7.64 %) on 12th day of storage. In strawberry cultivar 'Winter Dawn', the values were statistically at par during 9th and 12th day of storage period; whereas, in 'Chandler strawberries' the total sugars reflected on 3rd and 6th days after storage were statistically non-significant with each other (Fig. 2A). Moreover, fruits stored under ambient conditions also exhibited similar trends (Fig. 2B). The reducing sugars content declined linearly during storage irrespective of low and ambient temperature conditions in both the cultivars. The fruit stored at 0 day had maximum values of 6.57 % in 'Winter Dawn' and 6.70 % in 'Chandler' for reducing sugars and minimum (5.75 % in 'Winter Dawn' and 5.18 % in 'Chandler') during 12th day of storage (Fig. 2C). Under room temperature, significantly ($p < 0.05$) maximum reducing sugars content was registered at 0 day and minimum on 4th day of storage irrespective of both the cultivars (Fig. 2D). Non-reducing content was maximum (2.07 %) in 'Winter Dawn' and 2.35 % in 'Chandler' strawberries observed at 0 day and being lowest (1.78 %) in 'Winter Dawn' and 1.75 % in 'Chandler' up to 12th and 9th day of storage respectively under low temperature conditions (Fig. 2E). The maximum non-reducing was reported at 4th day of storage and minimum at 0 day in both the cultivars (Fig. 2F). These results are in commensurate with the findings of Falah *et al.* (6), who suggested that sucrose content of strawberries converted to glucose and fructose contents during storage, thereby exhibits the change in reducing sugars of strawberries. Likewise, a decline in sugar content may be attributed to the utilization of sugars along with other organic acids as substrate in respiration process.

Pericarp colour in strawberry determines the appearance, freshness, consumer perception and market price. During storage the retention of deep red is essential to meet the quality parameters and to earn higher profit. Anthocyanin content of strawberries was retained up to 6th day of storage and thereafter, subsequently declined during the progression of storage intervals in both the cultivars. Mean maximum anthocyanin content of 29.6 and 30.4 mg/100g in 'Winter Dawn' and 'Chandler' strawberries, respectively was noticed in fruits packed in punnet boxes at low temperature conditions. However, minimum anthocyanin content was registered on 12th day of storage (Fig. 3A). Fruit stored under ambient conditions, significantly had higher (29.28 and 30.15 mg/100 g) values at harvest (0 day) and subsequently declined in pericarp colour and other quality attributes were registered during storage (Fig. 3B). Fruit pericarp attained dark red colour at low temperature storage due to biosynthesis of anthocyanin pigment and later, it was degraded at final storage period. These results were corroborated with the findings of Sapis *et al*. (15) that oxidation of phenols *via* quinones to brown pigments occurred by the action of polyphenol oxidase. In the present studies, concentration of total phenols was decreased at final storage period which act as substrate for the enzyme and caused dehydration losses leading to browning of fruits.

Ascorbic acid content is an important quality parameter for food processing and storage (Turmanidze *et al.,* 18). Strawberries stored under ambient conditions and low temperature had shown declining trend in both the cultivars. At low temperature conditions, its value ranged between 36.5 to 27.4 mg/100g in 'Winter Dawn' and 37.48 to 30.15 mg/100g in 'Chandler' strawberries during storage period. Whereas, fruit stored upto 6th and 9th days were statistically non-significant and reduction of 14.91 and 15.22 per cent respectively was registered for ascorbic content whereas 'Chandler' stored upto 9th and 12th day also showed equivalent relationships with each other (Fig 3C). Average maximum ascorbic acid of 35.44 mg/100g in 'Winter Dawn' and 36.20 mg/100g in 'Chandler' strawberries were obtained at 0 days and it showed linear decreasing trends up to 4th days of ambient storage conditions (Fig. 3D). The decrease in ascorbic acid during storage may be due to the oxidation of L-ascorbic acid into dehydroascorbic acid (Lin *et al*., 10).

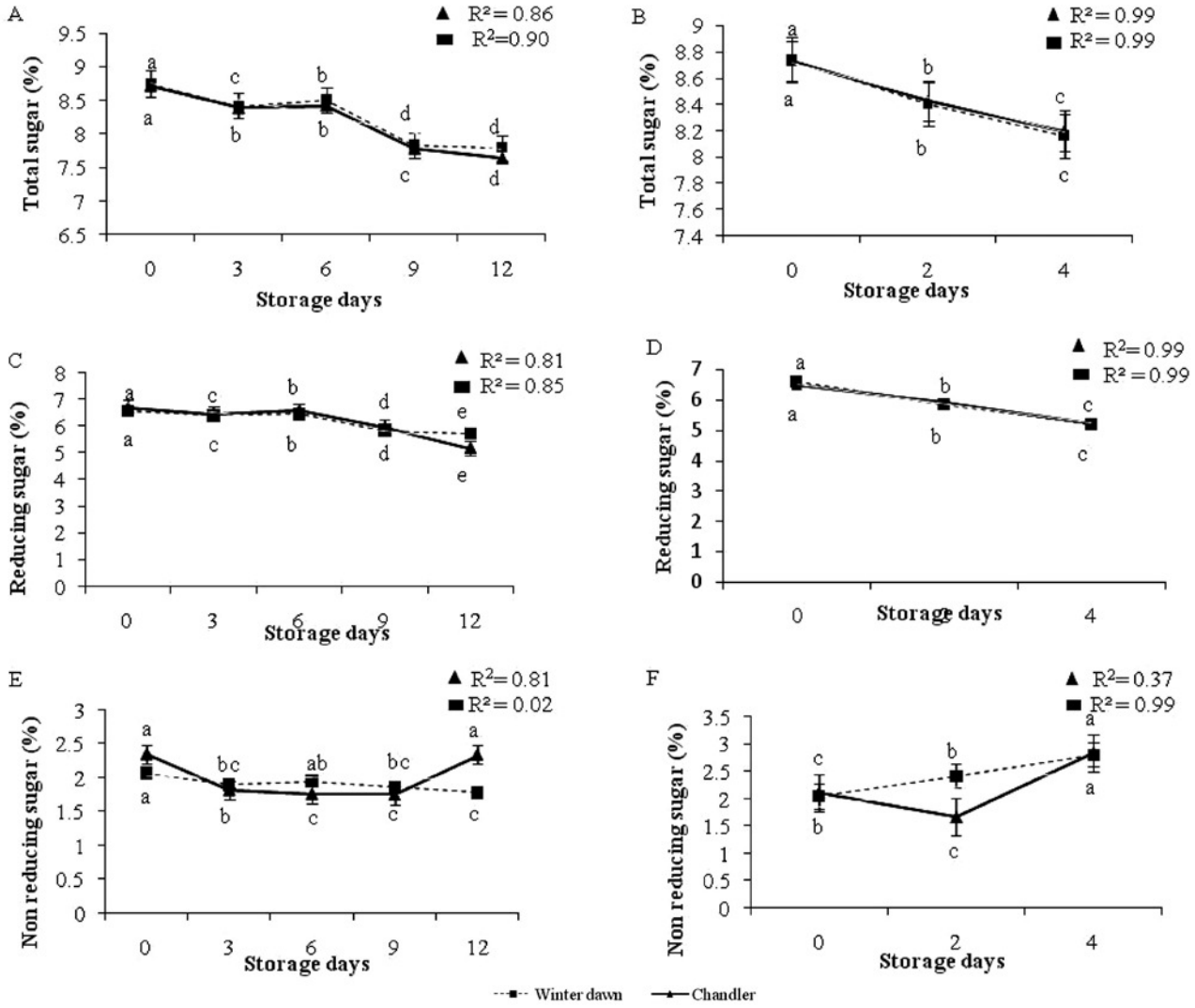

Fig. 2. Effect of low temperature storage and ambient conditions on total sugar (A and B), Reducing sugar (C and D) and Non-reducing sugar (E and F) respectively on strawberry. Means that do not share a letter are significantly different ($p < 0.05$).Vertical bars represents SE± of pooled value.

Antioxidant activity increased continuously up to 12th day of storage under low and ambient temperature conditions. Highest (32.15 µ mol TE/g in 'Winter Dawn' and 31.82µ mol TE/g in 'Chandler') antioxidant activity was observed on 9th day of storage and the rest of storage periods values were ranged from 24.95 to 30.33 and 25.2 to 31.7 µ mol TE/g in respective cultivars (Fig. 4A). However, fruit stored under ambient conditions, it varied from 25.0 to 28.5 and 24.0 to 29.7 µ mol TE/g in 'Winter Dawn' and 'Chandler' strawberries (Fig. 4B). Total phenol and antioxidant content were substantially correlated with each other. Total phenol content increased during storage period in both the cultivars. Under ambient temperature, it showed sharp rise in phenol content than at low temperature conditions. Maximum antioxidant activity of 751.52 µ mol TE/g in 'Winter Dawn' and 780.80 µ mol TE/g in 'Chandler' strawberries for total phenol was reported on 12th day of storage rather than other time intervals and minimum of 381.40 µ mol TE/g in 'Winter Dawn' and 384.95 µ mol TE/g in 'Chandler') at 0 day of storage under low temperature conditions where total phenol content were statistically at par with 9th and 12th day of storage in 'Winter Dawn' strawberries (Fig. 4C). Under room temperature conditions, maximum (755.60 µ mol TE/g in 'Winter Dawn' and 765.62 µ mol TE/g in 'Chandler') total phenol content was attained on 4th day of storage and lowest at harvest (Fig. 4D). Our studies are contradictory to Ali et al (3) who observed a decrease in total phenols during storage of tomato. The

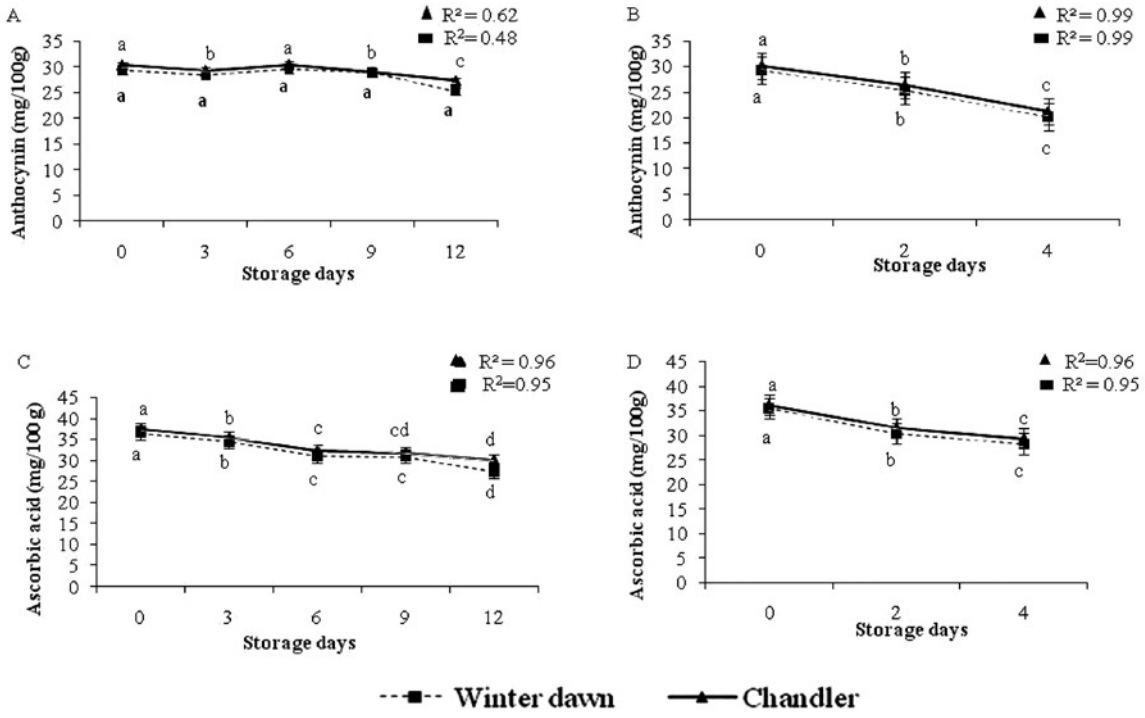

Fig. 3. Effect of low temperature storage and ambient conditions on Anthocynin (A and B) and Ascorbic acid (C and D) respectively on strawberry. Means that do not share a letter are significantly different ($p < 0.05$).Vertical bars represents SE± of pooled value.

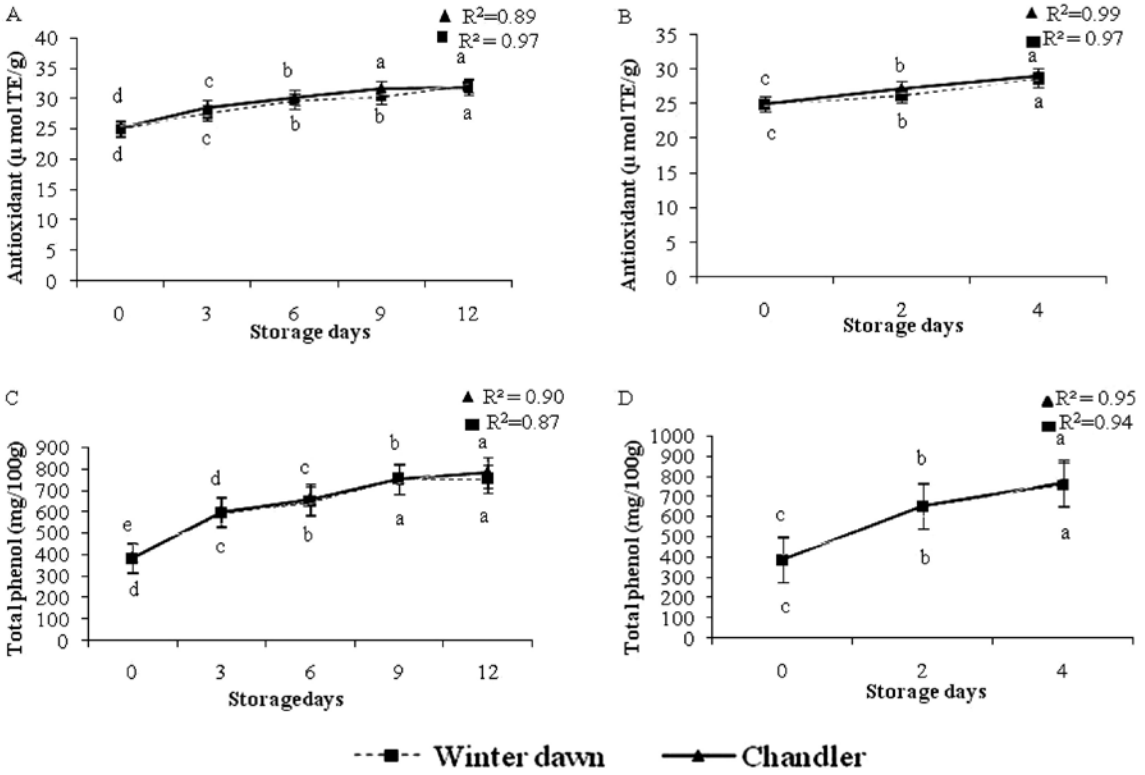

Fig. 4. Effect of storage and ambient condition on Antioxidant (A and B) and Total phenol (C and D) respectively on strawberry. Means that do not share a letter are significantly different ($p < 0.05$).Vertical bars represents SE± of pooled value.

increase in total phenols during storage of strawberry may be due to inherent potential of cultivars, stage of their harvest and storage conditions which affect the level of physiological activities during storage leading to differential response of phenolic after harvest of fruits.

The present study indicate that strawberries fruit packed in 200g punnets can be stored for 6-9 days at 5°C with 90-95 % RH as compared to 2 days at ambient conditions. This intervention can be helpful to maintain the fruit colour, cosmetic appearance for consumer acceptance and also minimize the postharvest losses of strawberry fruits during storage period.

AUTHORS' CONTRIBUTION

Conceptualization of research (Singh N. P.); Designing of the experiments (MAHAJAN B. V. C. and SINGH N. P.) materials (Singh S.); Execution of field/lab experiments and data collection (SINGH S., SINGH N. P. and MAHAJAN B. V. C.); Analysis of data and interpretation (SINGH S. and SIDHU G. S.); Preparation of the manuscript (Singh S., Singh N. P. and Mahajan B. V. C).

DECLARATION

The authors declare no conflict of interest.

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