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Effect of pre-cooling in extending the shelf life of banana cv. Grand naine stored under different storage conditions

Madhusudan Ravikumar, Chirag S Desai, Raghavendra HR and Naik Pooja

Abstract
Banana is one of the most important tropical fruit growing extensively in all over the tropical and sub-tropical regions. The perishable nature of banana became the major drawback in marketing of premium quality banana fruits due to lack of storage infrastructure. So proper post harvest pre-treatments plays utmost important in maintaining quality as well as in extending the shelf-life of banana fruits. With an aim to extend the post harvest life, the experiment was conducted at Department of Post-harvest Technology and Banana Pseudo stem Processing Unit, Navsari Agricultural University, Navsari-396-450, Gujarat during May 2017 to July 2017. The experiment consist of five different pre-cooling methods *viz*., P_0- Control, P_1- Forced air cooling (13 ^{0}C), P_2- Hydro-cooling (Spray at 13 ^{0}C), P_3- Slush-cooling and P_4- Hydro-cooling (Water dip) and three different storage conditions *viz*., S_1- Ambient temperature, S_2- Recommended cold storage temperature (13-14 ^{0}C) and S_3- Zero energy cool chamber. The experiment was laid out in a completely randomized design with factorial concept with three repetitions and 15 treatment combinations. The experiment results indicated that fruits pre-cooled with Hydro-cooling (Spray at 13 ^{0}C) (P_2) and stored in cold storage at 13 ^{0}C (S_2) attained the maximum shelf life in banana fruits. The lower Physiological loss in weight, ripening and spoilage were recorded for extended period in these treatments.

Keywords: Pre-cooling, extending, shelf life, banana cv. Grand naine

Introduction
Banana (*Musa paradisiaca*) is one of the most delicious and refreshing fruit of the world which provides nourishment and a well balanced diet to millions of people around the globe and contributes to livelihood through crop production, processing and marketing. Banana is commercially the fourth important global food commodity after paddy, wheat and milk in terms of gross value of production and of great socio-economic significance. In India, banana is so predominant crop and popular among people that is liked by both poor and rich alike. It grows well in humid tropical lowlands and is predominantly distributed between 30^0 N and 30^0 S of equator.

Due to its tendency towards fast ripening and texture breakdown, banana is difficult to keep well for longer period of time. Number of workers has made attempts to enhance the storage life of banana using different substances at the pre and postharvest stages. However, most of the synthetic chemicals being used for crop protection are reported to pose a serious threat to human health and have residual effect, beside being costly, therefore, all these factors have led to research for safer and more competitive alternatives to extend the shelf-life of banana fruits. The longer shelf life and less postharvest diseases of banana are needed to meet the export quality requirements in aboard and store for marketing in super market at different distance places. Proper postharvest handling ensures preservation of quality until the produce reaches the consumers (Liu, 2002) [14]. Post harvest management of banana includes harvesting at proper mature stage, immediate removal of field heat through suitable pre-cooling methods, post harvest application of fungicides/ growth regulators/growth inhibitors, and use of proper storage/ripening/packaging methods for both short distance and long distance transportation. Higher storage temperature increases the respiration rate of banana, which determines transit and postharvest life (Bachmann, 2000) [1].

There are a variety of different post-harvest technologies available, among them pre-cooling is considered to be a critical process. It is indicated that pre-cooling is critical in meeting consumer demands for high quality fresh produce. Pre-cooling was first introduced by Powell and his co-workers in the US Department of Agriculture in 1904. It is pointed out that, pre-cooling is likely the most important of all the operations used in the maintenance of desirable, fresh and salable produce (Baird and Gaffney, 1976) [2]. Pre-cooling can contribute to a great extent in increasing the shelf life of banana. Pre-cooling is a pre-treatment to cold storage, and meant for bringing the temperature from about 30-32 ^{0}C at harvest to recommended storage temperature of banana at 13-15 ^{0}C (Kader, 1992) [9]. The method of pre-cooling depends on physical and thermo chemical properties of the product. In India, banana is mostly harvested at mature green stage and ripened upon arrival at destination.

Another approach directed towards enhancing shelf life is low temperature storage. Temperature control is very important as it can affect the rate of fruit respiration. Higher temperatures increases and lower temperature decreases the fruit respiration rates. Low temperature storage has great importance and wider applicability in tropical and subtropical regions of India but its installation costs are very heavy which may not be economical to the small and marginal farmers. Therefore, it is necessary to develop less expensive methods of storage which are convenient, economical and within the reach of a common grower or trader. In this direction, zero energy cool chamber can play important role since it is on farm, low cost, environment friendly and rural oriented storage structure which operates on the principle of direct evaporative cooling. In the present study, Forced air cooling (13 ^{0}C), Hydro-cooling (Spray at 13 ^{0}C), Slush-cooling and Hydro-cooling (Water dip) methods were considered for pre-cooling along with the control. To see the effects and extent of potential shelf life, three storage environments with different temperatures viz. room, zero energy cool chamber (evaporative) and cold storage were considered. It is very much important to develop low cost technology for enhancing the shelf life of banana *cv*. Grand naine which is most needed for the farmers as well as the banana enterprisers.

Materials and method:

Bunches of ‘Grand naine’ banana grown with recommended fertilizers and irrigation at the field of Soil and Water Management Research Unit, NAU. Navsari were harvested early in the morning during the month of May. The hands with blemish-free uniform fingers were cut from upper, middle and a lower part of bunches, taken to the laboratory in plastic crates (530 x 350 x 300 mm) with banana leaves as cushioning material for handling. These hands were randomly divided in different groups for forced air cooling, hydro cooling, dipping, slush cooling along with control treatment. Accordingly, the pre-cooling treatments were given by recording the time and temperature of cooling media as well as the fruit core.

A large scale walk-in type forced air pre-cooling unit with internal dimensions of 1.5m (L) x 1.5m (W) x 2.4m (H), 2 T capacity having the total load of 3.5 hp with provision to adjust the temperature of cooling air between 0 to 25 ^{0}C and humidity of cooling air between 50 to 90% was used. Similarly, a large scale walk-in type hydro pre-cooling unit with the batch capacity of 1 T was used. The temperature of cooling water that could be sprayed on the product was adjustable from 0 to 25 ^{0}C. The dipping system of hydro cooling consisted of a stainless steel vessel in which the desired water temperature of 13 ^{0}C was maintained by adding ice. The banana fruits to be pre-cooled were immersed in the vessel. Using latent heat of ice (80 kcal/kg), preliminary trials were conducted to find out expected time and quantity of ice required, and accordingly the temperature of cooling media maintained. Water and fruit pulp centre temperatures were recorded using PT-100 temperature sensors connected to the data logger at an interval of 1minute till the pre-cooling temperature was achieved. The pre-cooling time for banana fruits using different pre-cooling methods was recorded. The change of temperature of fruit centre from the initial value of 30 ± 1 ^{0}C to the final desired value of 14.0 ± 1 ^{0}C was monitored, and the time required for pre-cooling was noted.

The pre-cooled samples were stored in a well-ventilated room at ambient condition (30 ± 3 ^{0}C); in zero energy cool chamber (25 ± 1 ^{0}C, 90 – 95% RH) and cold storage (13 ± 0.5 ^{0}C, 85-90% RH). The temperature and RH inside the room were monitored using dry and wet bulb thermometers. Samples for zero energy cool chamber storage conditions were kept in a double walled, portable evaporative cooling storage structure having moist sand in between walls. The shelf-life of banana fruits was determined by considering peel colour, aroma, appearance, PLW, ripening and spoilage during the storage.

For determining weight loss, individual hands were weighed at regular interval of 3 days and cumulative PLW at the end of the experiment was calculated as:

PLW (%) = (Original weight – Final weight) × 100/ Original weight

The fruits were observed regularly at 3 days interval for spoilage count. Any fruit or part thereof, if rotten or damaged with fungus, mould or any type of deterioration was considered as spoilage and the number of such fruits spoiled till the end of the experiment was expressed in percentage. Meanwhile, the ripening percentage of banana fruits were calculated based on the physiological as well as biochemical changes occurred during storage along with the peel colour referred with standard ripening colour chart.

Result and discussion

Shelf-life

The combined effect of pre-cooing and storage had significantly affected the shelf-life of banana fruit (Table-1). Among the five different pre-cooling techniques, the shelf life at entire period of fruit storage observed significantly maximum (17.09 days and 22.49 days) in fruits treated with Hydro-cooling Spray at 13 ^{0}C (P_2) and those stored in (S_2) cold chamber at 13 ^{0}C, while the fruits with no pre-cooling treatment (P_0) and those stored in ambient condition (S_1) recorded minimum shelf life of 14.75 days and 10.69 days respectively. Also the effect due to interaction showed higher shelf life of (24.33 days) in treatment combination P_2S_2 (Hydro-cooling (Spray at 13 ^{0}C) + cold storage) and the minimum shelf life of (9.50 days) in treatment combination P_0S_1 (control + ambient storage) followed by P_4S_1 (Hydro-cooling (Water dip) + ambient storage) *i.e*., 10.53 days.

Rapid removal of field heat from the freshly harvested commodities retards respiration, ripening, senescence, water loss and decay thus helped to maintain the optimum quality and prolonged shelf life in climacteric fruits. Also, the pre-climacteric respiration was inhibited at lower temperature and simultaneously reduced the ethylene production and ultimately extends the shelf life in banana fruits. These findings are in agreement with Kapse (1993) [11] and Galathia (2004) [7] in mango Tandel (2009) [23] in sapota and Borse

(2011) [3] in aonla. Hardenberg *et al.*, 1990 [8] reported that the combined effect of pre-cooling and storage helps in reduction of field heat in shortest possible time, lower moisture loss, restricted metabolic and respiratory activities and inhibition in water loss and reduction in ethylene production in fruits. The similar finding reported by Padhye (1997) [17], Devani *et al.*, (2011) [6] and Khanbarad *et al.*, (2013) [13].

Physiological loss in weight (%):

The Physiological loss in weight was significantly affected by pre-cooling and storage methods (Table-2). The minimum PLW was recorded in fruits treated with P_2-hydro-cooling at 13 ^{0}C and P_1- Forced air cooling at 13 ^{0}C and stored under S_2-cold storage and S_3-ZECC whereas, the maximum PLW was recorded in un-treated fruits (P_0) and those stored in ambient condition (S_1). Although, the interaction effect also differed significantly with minimum physiological loss in weight in both the treatment combinations P_1S_2 (Forced air cooling at13 ^{0}C) + cold storage) and P_2S_2 (Hydro-cooling (Spray at 13 ^{0}C) + cold storage) and the maximum physiological loss in weight was observed in treatment combination P_0S_1 (control + ambient storage) which was at par with the treatment combination P_4S_1 (Hydro-cooling (Water dip) + ambient storage). The minimum PLW in treated fruits might be due to reduction in rate of respiration and evapotranspiration as well delaying in ripening due to restricted ethylene accumulation in the treated fruits. Patel (2006) [18] reported that the physiological loss in weight in mango could be decreased by pre-cooling treatment. The highest weight loss in ambient condition was mainly due to excess energy produced from the respiration process is released from the tissue by the vaporization of water, which will subsequently be transpired from the fruit, causing weight loss. Some of the moisture loss through the peel could be observed through shrinkage on the peel. This observation substantiate to the earlier reports by Nootrudee (2004) [16].

Also reported that the reduction in weight of fruits in storage was attributed to the physiological loss in weight due to respiration, transpiration and other biological changes taking place in the fruit. These results were attributed to shrivelling of fruits due to higher water loss of fruits stored at high temperature (Rathore *et al.*, 2007).

Ripening (%) and spoilage (%)

Fruit ripening is a highly coordinated, genetically programmed, and an irreversible phenomenon involving a series of physiological, biochemical and organoleptic changes that finally leads to the development of a soft edible ripe fruit with desirable quality attributes (Prasanna *et al.*, 2007) [19].

Significantly, the slower rate of ripening (Table-3) and spoilage (Table-4) was recorded in the treatment combination P_2S_2 (Hydro-cooling (Spray at 13 ^{0}C) + cold storage) followed by P_1S_2 (Forced air cooling at 13 ^{0}C) + cold storage) and the maximum ripening and spoilage percent was observed in treatment combination P_0S_1 (control + ambient storage) which was at par with the treatment combination P_4S_1 (Hydro-cooling (Water dip) + ambient storage).

The pre-cooling treatments immediately after the harvest inhibit the growth of decay producing microorganisms, restrict enzymatic and respiratory activities and reduce the water loss and ethylene production which in turn delays the ripening process in banana fruits (Hardenburg *et al.*, 1990) [8]. Also, the lower temperature showed an antagonistic effect on ethylene biosynthesis and inhibits the respiration rate which helped in delaying ripening. Deepashree *et al.*, (2010) [4] also reported that delayed ripening in zero energy cool chamber is mainly due to low temperature and relative humidity inside the evaporative cool chamber. Talane *et al.*, (2016) [22] also reported that delay in ripening might be due to the storage of fruits under controlled condition resulting into delay in conversion of starch. The most striking bio-chemical changes which occurred during the post-harvest ripening of banana are the hydrolysis of starch and accumulation of sugars. The decay percent of fruits were increased with the advancement of storage period, initial decay generally started from the stem end and later covered remaining portion. However, the pre-cooled fruits stored under cold storage showed the lower incidence of decay than untreated fruits. This might be due to the effect of pre-cooling, which helped in removing field heat and decay causing organisms from fruits. These results conform to the results of Puttaraju and Reddy (1997).

Makwana *et al.*, (2014) [15] also stated that the spoilage symptoms were minimum in fruits treated with pre-cooling at 13 ºC temperature during all the storage period. It reduces the spoilage percentage by prolonging keeping quality. The antisenescent properties help in maintaining the fruits on fresh condition during storage. Also stated that Spoilage of fruits due to rotting during storage reduced substantially by pre-cooling. The spoilage in banana fruit was reduced as the storage temperature was reduced. Had reported that cold storage slows respiration, breakdown by enzymes, water loss, wilting, and stops decay due to ethylene production. Kanade *et al.*, (2017) [10] reported that the maximum spoilage may be due to high temperature congenial for growth of microorganism which was available at ambient storage. Present findings are in agreement with the results reported by Khanbarad *et al.*, (2013) [13] and Makwana *et al.*, (2014) [15] in mango.

Table 1: Effect of pre-cooling and storage conditions on shelf life (days) in banana *cv.* Grand Nain

	S_1	**S_2**	**S_3**	**Mean**
P_0	9.50	21.10	13.64	14.75
P_1	11.00	23.00	15.00	16.33
P_2	11.45	24.33	15.50	17.09
P_3	10.96	22.00	15.33	16.10
P_4	10.53	22.00	13.55	15.36
Mean	10.69	22.49	14.60	15.93
	P	S	P X S	
S.Em. ±	0.16	0.13	0.28	
CD at 5%	0.47	0.37	0.82	
CV %	3.08			

Table 2: Effect of pre-cooling and storage conditions on physiological loss in weight (%) in banana *cv.* Grand Nain

	Initial				**3 day**			
	S_1	**S_2**	**S_3**	**Mean**	**S_1**	**S_2**	**S_3**	**Mean**
P_0	0.36	0.36	0.36	0.36	6.13	5.75	5.97	5.95
P_1	0.37	0.37	0.36	0.37	4.81	2.83	3.44	3.69
P_2	0.37	0.36	0.38	0.37	3.85	2.17	2.45	2.82
P_3	0.36	0.37	0.36	0.36	5.14	3.18	3.64	3.99
P_4	0.36	0.37	0.36	0.37	5.42	3.55	3.91	4.29
Mean	0.36	0.37	0.36	0.37	5.07	3.50	3.88	4.15
	P	S	P X S		P	S	P X S	
S.Em. ±	0.003	0.002	0.005		0.02	0.01	0.03	
CD at 5%	NS	NS	NS		0.05	0.04	0.08	
CV %	2.52				1.14			
	6 day				9 day			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
P_0	12.93	10.75	11.97	11.88	21.12	19.15	20.55	20.27
P_1	10.81	6.83	7.44	8.36	18.75	17.15	17.95	17.95
P_2	10.12	6.77	7.45	8.11	17.12	15.23	16.45	16.27
P_3	11.14	8.18	8.94	9.42	19.13	18.12	18.68	18.64
P_4	12.42	9.55	10.11	10.69	20.45	18.68	19.48	19.54
Mean	11.48	8.42	9.18	9.69	19.31	17.67	18.62	18.53
	P	S	P X S		P	S	P X S	
S.Em. ±	0.07	0.06	0.13		0.03	0.02	0.05	
CD at 5%	0.21	0.17	0.37		0.09	0.07	0.16	
CV %	2.29				0.50			
	12 day				15 day			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
P_0	26.97	24.15	25.38	25.50	30.45	26.38	28.67	28.50
P_1	24.38	22.23	23.71	23.44	27.08	24.98	25.14	25.73
P_2	23.17	21.11	22.93	22.40	26.76	24.43	25.79	25.66
P_3	25.16	22.86	23.97	24.00	28.24	25.12	27.09	26.82
P_4	26.12	23.67	24.99	24.93	29.38	25.89	27.58	27.62
Mean	25.16	22.80	24.20	24.05	28.38	25.36	26.85	26.87
	P	S	P X S		P	S	P X S	
S.Em. ±	0.01	0.01	0.02		0.01	0.01	0.02	
CD at 5%	0.04	0.03	0.07		0.03	0.02	0.05	
CV %	0.16				0.12			

	S_2		
	18 day	21 day	24 day
P_0	28.40	29.49	30.48
P_1	27.98	29.46	30.40
P_2	26.41	27.54	28.57
P_3	27.28	27.99	29.19
P_4	27.90	30.12	29.14
Mean	27.60	28.92	29.56
S.Em. ±	0.26	0.19	0.21
CD at 5%	0.81	0.60	0.67
CV %	1.61	1.15	1.25

Table 3: Effect of pre-cooling and storage conditions on ripening (%) in banana *cv.* Grand Nain

	Initial				**3 day**		
	S_1	**S_2**	**S_3**	**Mean**	**S_1**	**S_3**	**Mean**
P_0	Nil	Nil	Nil	Nil	17.53 (9.07)	15.85 (7.46)	16.69 (8.27)
P_1	Nil	Nil	Nil	Nil	15.41 (7.07)	11.55 (4.01)	13.48 (5.54)
P_2	Nil	Nil	Nil	Nil	14.35 (6.15)	0.29 (0.00)	7.32 (3.07)
P_3	Nil	Nil	Nil	Nil	15.34 (7.00)	12.96 (5.03)	14.14 (6.01)
P_4	Nil	Nil	Nil	Nil	16.73 (8.30)	14.41 (6.20)	15.57 (7.25)
Mean	Nil	Nil	Nil	Nil	15.87 (7.52)	11.01 (4.54)	13.44 (6.03)
	P	S	P X S		P	S	P X S
S.Em. ±	-	-	-		0.07	0.04	0.09
CD at 5%	-	-	-		0.19	0.12	0.28
CV %	-	-	-		1.23		

	6 day			9 day			
	S_1	S_3	Mean	S_1	S_2	S_3	Mean
P_0	29.55 (24.34)	27.34 (21.11)	28.44 (22.72)	55.50 (67.96)	17.55 (9.10)	52.06 (62.23)	41.70 (46.43)
P_1	23.73 (16.21)	21.29 (13.20)	22.51 (14.70)	48.14 (55.50)	14.41 (6.20)	45.90 (51.60)	36.15 (37.77)
P_2	21.99 (14.03)	17.45 (9.00)	19.72 (11.51)	46.93 (53.40)	13.30 (5.30)	42.70 (46.02)	34.31 (34.91)
P_3	26.91 (20.50)	23.02 (15.30)	24.96 (17.90)	51.53 (61.33)	16.42 (8.00)	58.91 (73.37))	42.29 (47.57)
P_4	26.05 (19.30)	25.39 (18.40)	25.71 (18.85)	52.57 (63.10)	17.78 (9.33)	51.12 (60.63)	40.49 (44.36)
Mean	25.64 (18.87)	22.90 (15.40)	24.27 (17.14)	50.93 (60.26)	15.89 (7.59)	50.14 (58.77)	38.99 (42.20)
	P	S	P X S	P	S	P X S	
S.Em. ±	0.10	0.06	0.13	0.08	0.06	0.13	
CD at 5%	0.28	0.18	0.40	0.22	0.17	0.39	
CV %	0.97			0.60			

- ❖ The figures in the parenthesis are original data.
- ❖ The treatment S_2 neglected on 6th day due to 0 % ripening.

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	12 day				**15 day**			
	S_1	**S_2**	**S_3**	**Mean**	**S_1**	**S_2**	**S_3**	**Mean**
P_0	81.84 (98.00)	26.84 (20.40)	66.12 (83.65)	58.27 (67.35)	89.67 (100.00)	38.18 (38.23)	89.67 (100.00)	72.50 (79.41)
P_1	73.72 (92.17)	22.78 (15.00)	55.99 (68.75)	50.83 (58.64)	89.67 (100.00)	34.08 (31.42)	73.67 (92.12)	65.80 (74.51)
P_2	70.79 (89.20)	20.26 (12.00)	51.98 (62.10)	47.67 (54.43)	89.67 (100.00)	31.38 (27.13)	69.11 (87.32)	63.38 (71.48)
P_3	77.31 (95.20)	24.43 (17.12)	58.97 (73.47)	53.57 (61.93)	89.67 (100.00)	35.20 (33.25)	77.59 (95.40)	67.49 (76.22)
P_4	77.05 (95.00)	25.09 (18.00)	60.37 (75.59)	54.17 (62.86)	81.72 (97.89)	36.41 (35.25)	89.67 (100.00)	69.26 (77.71)
Mean	76.14 (93.91)	23.88 (16.50)	58.69 (72.71)	52.90 (61.04)	88.08 (99.58)	35.05 (33.06)	79.93 (94.97)	67.69 (75.87)
	P	S	P X S		P	S	P X S	
S.Em. ±	0.08	0.06	0.14		0.16	0.12	0.27	
CD at 5%	0.24	0.19	0.42		0.45	0.35	0.79	
CV %	0.47				0.70			

	S_2		
	18 day	21 day	24 day
P_0	49.95 (58.63)	61.89 (77.83)	89.66 (100.00)
P_1	46.99 (53.50)	59.65 (74.50)	78.20 (95.83)
P_2	42.23 (45.20)	55.94 (68.67)	67.95 (85.93)
P_3	49.35 (57.60)	60.31 (75.50)	89.66 (100.00)
P_4	49.66 (58.13)	61.55 (77.33)	89.66 (100.00)
Mean	47.64 (54.61)	59.87 (74.77)	83.02 (96.35)
S.Em. ±	0.13	0.29	0.20
CD at 5%	0.42	0.90	0.63
CV %	0.49	0.83	0.42

- ❖ The figures in the parenthesis are original data.

Table 4: Effect of pre-cooling and storage conditions on spoilage (%) in banana *cv.* Grand Nain

	Initial				**3 day**			
	S_1	**S_2**	**S_3**	**Mean**	**S_1**	**S_2**	**S_3**	**Mean**
P_0	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
P_1	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
P_2	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
P_3	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
P_4	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Mean	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
	P	S	P X S		P	S	P X S	
S.Em. ±	-	-	-		-	-	-	
CD at 5%	-	-	-		-	-	-	
CV %	-	-	-		-	-	-	

	6 day			9 day			
	S_1	S_3	Mean	S_1	S_2	S_3	Mean
P_0	23.64 (16.10)	12.37 (4.60)	18.01 (10.35)	31.93 (28.00)	14.30 (6.11)	23.86 (16.38)	23.37 (16.83)
P_1	17.58 (9.13)	13.26 (5.27)	15.42 (7.19)	27.32 (21.08)	10.00 (3.02)	22.61 (14.80)	19.98 (12.97)
P_2	16.42 (8.00)	10.31 (3.21)	13.37 (5.60)	25.95 (19.17)	8.39 (2.13)	21.12 (13.00)	18.49 (11.43)
P_3	20.26 (12.00)	14.75 (6.49)	17.50 (9.24)	28.65 (23.00)	12.95 (5.03)	22.76 (14.98)	21.45 (14.34)
P_4	20.98 (12.83)	15.48 (7.13)	18.23 (9.98)	29.32 (24.00)	14.17 (6.00)	24.69 (17.47)	22.73 (15.82)
Mean	19.78 (11.61)	13.23 (5.34)	16.50 (8.48)	28.63 (23.05)	11.96 (4.46)	23.01 (16.33)	21.20 (14.28)
	P	S	P X S	P	S	P X S	
S.Em. ±	0.15	0.09	0.21	0.10	0.07	0.17	
CD at 5%	0.44	0.28	0.62	0.29	0.22	0.50	
CV %	2.20			1.43			

- ❖ The figures in the parenthesis are original data.
- ❖ The treatment S_2 neglected on 6th day due to 0 % spoilage.

Continue....

	12 day				15 day			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
P_0	42.21 (45.17)	19.36 (11.00)	29.36 (24.07)	30.31 (26.74)	81.88 (98.00)	24.38 (17.06)	42.88 (46.33)	49.71 (53.80)
P_1	38.04 (38.00)	17.48 (9.03)	27.49 (21.33)	27.67 (22.79)	74.72 (93.07)	22.77 (15.00)	35.05 (33.00)	44.18 (47.02)
P_2	36.25 (35.00)	15.70 (7.33)	27.26 (21.00)	26.40 (21.11)	66.46 (84.08)	21.46 (13.40)	32.57 (29.00)	40.16 (42.16)
P_3	39.41 (40.33)	19.41 (11.06)	31.29 (27.00)	30.03 (26.13)	78.56 (96.08)	23.57 (16.00)	40.56 (42.31)	47.56 (51.46)
P_4	39.41 (40.33)	18.42 (10.00)	32.57 (29.00)	30.13 (26.44)	81.71 (97.93)	22.79 (15.02)	41.54 (44.00)	48.68 (52.32)
Mean	39.06 (39.77)	18.07 (9.68)	29.59 (24.48)	28.91 (24.64)	76.67 (93.83)	22.99 (15.29)	38.52 (38.93)	46.06 (49.35)
	P	S	P X S		P	S	P X S	
S.Em. ±	0.16	0.13	0.29		0.18	0.14	0.31	
CD at 5%	0.48	0.37	0.83		0.51	0.40	0.89	
CV %	1.72				1.15			

	S_2		
	18 day	21 day	24 day
P_0	27.57 (21.43)	30.16 (25.27)	38.26 (38.37)
P_1	26.18 (19.48)	28.13 (22.24)	34.52 (32.14)
P_2	24.64 (17.40)	27.59 (21.47)	32.13 (28.31)
P_3	26.65 (20.13)	29.55 (24.34)	35.73 (34.12)
P_4	27.54 (21.40)	29.47 (24.22)	37.53 (37.14)
Mean	26.52 (19.97)	28.98 (23.51)	35.63 (34.02)
S.Em. ±	0.10	0.08	0.09
CD at 5%	0.30	0.24	0.28
CV %	0.61	0.46	0.44

- ❖ The figures in the parenthesis are original data.

Conclusion

From the present study, it can be concluded that the fruits pre-cooled with Hydro-cooling Spray at 13 ^{0}C and stored in cold storage at 13 ^{0}C attained the maximum shelf life in banana fruits. The lower Physiological loss in weight, ripening and spoilage were recorded for extended period in these treatments.

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