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Effect of packaging materials and calcium chloride on storage and shelf life of broccoli under cold storage condition

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Abstract
A study conducted on the effect of packaging materials and calcium chloride on storage quality and shelf life of broccoli under cold storage conditions during the Rabi (January-February) 2022 at Department of Horticulture, B. A. College of Agriculture, Anand Agricultural University, Anand, Gujarat. The fresh quality produce of uniform size and mature broccoli were subject to post harvest treatments. The treatments comprised of different packaging materials like Polyethylene without perforation, Polyethylene with perforation, Polypropylene without perforation, Polypropylene with perforation and without packaging and calcium chloride (1.0%), calcium chloride (1.5%) and no dipping. Periodic observations on 4th, 8th, 12th and 16th day of storage were taken. The study results revealed that broccoli heads dipped in $CaCl_2$ (1.5%) solution and packed individually in polypropylene without perforation was the most effective treatment in reducing physiological loss in weight, lowering fungal decay percentage with more retention of ascorbic acid and extending shelf life up to 16th day of storage at 5±1°C and RH 95% under cold storage condition. However treatment of polyethylene without perforation with calcium chloride 1.5% retained maximum chlorophyll with minimum yellowing and good appearance.

Keywords: Post-harvest, packaging materials, calcium chloride, shelf life, broccoli

Introduction
Broccoli (*Brassica oleracea* var. *italica*) is an edible green plant in the family of Cruciferae, whose large flowering head, stalk and small associated leaves are eaten as a vegetable. In India, it is not so much popular yet; it is still grown in a very limited scattered area nearer to metropolitan cities and at many high altitudes. However, it is mostly cultivated in U.P., Jammu and Kashmir, Nilgiri hills and northern plains of India (Chadha, 2001) [8]. From the last few years, there has been increased demand of broccoli.

Broccoli is a particularly rich source of vitamin C and vitamin K contents of its characteristic sulphur containing and health-promoting phytochemicals (Anonymous, 2021) [4]. It is with high nutritional value and health benefits, due to its abundance in vitamins, antioxidants, anti-carcinogenic substance (Caleb *et al.*, 2016) [7].

Postharvest treatments that utilize packaging have been shown to preserve nutritional and quality attributes (flavor, texture and colour). Different films provide varying permeability to O_2, CO_2, C_2H_4 and H_2O vapour (Barth *et al.*, 1992) [5]. Packaging helps to keep vegetables from drying out. For broccoli and other green vegetables, the retention of green colour during storage has been assessed as a measure of quality (Barth *et al.*, 1992) [5]. Because of low water vapour permeability of polyethylene and polypropylene, both films and bags are sometimes perforated to allow the product to 'breathe' (Sunil, 2017) [15]. So, it is essential to minimize physical damage to fresh broccoli in order to obtain optimum shelf-life. The use of suitable packaging is vital in this respect (Thompson, 1996) [16].

Calcium treatments are known as a potential post-harvest approach used to maintain quality and to extent shelf life of fresh commodities because of its effects in controlling physiological disorders and delaying senescence in fresh commodities (Lester and Grusak, 1999) [11]. Calcium contributes in improving the rigidity of cell walls; retard tissue softening also reduces the accessibility of cell wall degrading enzymes to their substrates (Vicente *et al.*, 2009) [17] Hence, Calcium chloride dipping can maintain visual quality by keeping the integrity of the cell wall and resulting in the longer shelf life of fresh-cut. (Shehata *et al.*, 2009) [14].

Even though the crop is very nutritious and remunerative (Chanbisana and Banik, 2019) [9]. In order to maintain eating and market quality, it is important to include all sensory character i.e. taste, compactness, browning and texture as well as appearance. There is lack of research regarding post-harvest treatment and packaging information of the crop, so the experiment

is carried out to study the treatment effect on broccoli under cold storage condition.

Materials and methods

The research experiment was carried out during Rabi (January-February) 2022 at Horticultural Research Farm and P. G. Laboratory Department of Horticulture, B. A. College of Agriculture, Anand Agricultural University, Anand. The fresh good quality produce of uniform size and mature broccoli heads harvested were subjected to post harvest treatment. The heads were dipped in calcium chloride for 5 minutes and packed in size of (36 × 25 cm) in polyethylene (15 micron) and polypropylene (20 micron) with 1% perforation.

Treated 6 heads were then placed in crates of size (533 × 360 × 305 mm) then after in cold storage (5±1°C and 95% RH). The experiment was laid out in Completely Randomized Design with Factorial concept (FCRD) having fifteen treatments combination. The treatments were repeated thrice. An experiment comprised with two factors (1) Packaging materials comprised (P_1) Polyethylene without perforation, (P_2) Polyethylene with perforation, (P_3) Polypropylene without perforation, (P_4) Polypropylene with perforation and (P_0) Without packaging and (2) Calcium chloride with levels of (C_1) Calcium chloride (1.0%), (C_2) Calcium chloride (1.5%) and (C_0) No dipping

Observations recorded at initial and every four (4) days intervals (i.e., 4th, 8th, 12th and 16th days) up to 16th days during storage. Samples were recorded for Physiological loss in weight (%), Fugal decay (%), Shelf life (days), Firmness (Kgcm^{-2}), Yellowing (%), Sensory evaluation (compactness, appearance, taste, texture, browning) (9 point Hedonic scale) and Moisture content (%).

Physiological loss in weight (%): Initial weight of broccoli was recorded just before storage. To assess the physiological loss in weight, further weight of broccoli was recorded at 4th, 8th, 12th and 16th day of storage and subtracted from initial weight to calculate loss in weight.

Fungal decay (%) and yellowing (%): Whole green broccoli head was divided into four equal parts (out of 100 percent). The area which becomes shown fungal decay and yellowing is recorded visually according to the parts divided on 4th, 8th, 12th and 16th day of storage period.

Shelf life (days): The shelf life of broccoli was calculated by counting the number of days taken from harvesting to optimum edible stage.

Firmness (Kgcm^{-2}): Broccoli firmness was measured by means of a pocket penetrometer.

Moisture content (%): The moisture content of floret was determined by gravimetric method.

Sensory evaluation (9-point hedonic scale): Organoleptic evaluation of the broccoli for assessing the taste, texture, appearance, compactness, browning of the broccoli was done by a panel of experts who scored on point hedonic scale 9 to 1(like extremely to dislike extremely) (Amerine *et al.* 1965) [3].

Statistical analysis

The data collected for different observations were statistical analysised as described by Panse and Sukhatme (1967) [12].

Result and discussion

Physiological loss in weight (%)

The physiological loss in weight was increased continuously with the advancement of storage period irrespective of treatments. It is evident from the table (1) and table (2) that application of P_3 (Polypropylene without perforation) (0.88, 1.29, 1.50, and 2.27%) and C_2 (*calcium* chloride 1.5%)(1.20, 1.82, 2.78, 4.82%) individually recorded minimum physiological loss in weight on 4th, 8th, 12th and 16th day of storage, respectively. At the end of storage, heads packed in Polypropylene without perforation with calcium chloride 1.5% showed minimum PLW (2.14%) as compared to control (without packaging with no dipping) (7.96%). Polypropylene without perforation with calcium chloride 1.5% was effective in creating a physical barrier to moisture loss, hence reduced weight loss observed for the treated heads (0.81 to 2.14%) than for non-treated heads (1.98 to 7.96%). Weight loss of vegetable is mainly due of water loss because of transpiration while dry matter is lost by respiration. Hence, the lowest PLW of the heads could be effect of $CaCl_2$ dipping on respiration, which probably lowered the rate of transpiration, water loss and oxidation reactions and related to modified atmosphere created by packaging. These results were in accordance with the finding of Ahmed and Tariq (2014) [2] tomato, Kapsiya *et al.* (2015) [10] in tomato.

Table 1: Effect of packaging materials and calcium chloride on Physiological loss in weight (%), Firmness (Kgcm^{-2}), Marketability (%) and Shelf life (days) of broccoli under cold storage condition

Treatment	Physiological loss in weight (%)				Firmness (Kgcm^{-2})				Shelf life (days)
	Storage period in days								
	4th	8th	12th	16th	4th	8th	12th	16th	
Packaging materials (P)									
P_0- Without packaging	1.77	2.70	4.69	7.29	9.34	8.94	8.38	7.66	11.00
P_1- Polyethylene without perforation	0.90	1.31	1.51	2.28	9.68	9.36	8.80	8.24	15.00
P_2- Polyethylene with perforation	1.56	1.94	3.61	6.67	9.58	9.29	8.72	8.22	13.89
P_3- Polypropylene without perforation	0.88	1.29	1.50	2.27	9.70	9.37	8.83	8.32	15.78
P_4- Polypropylene with perforation	1.42	2.12	3.47	6.30	9.60	9.28	8.77	8.19	14.89
CD at 5%	0.02	0.02	0.02	0.03	0.08	0.08	0.07	0.07	0.43
Chemical (C)									
C_0- No spray	1.41	1.93	3.17	5.16	9.42	9.21	8.61	8.05	13.33
C_1- *Calcium* chloride (1.0%)	1.31	1.87	2.92	4.91	9.63	9.24	8.73	8.13	14.20
C_2- Calcium chloride (1.5%)	1.20	1.82	2.78	4.82	9.69	9.29	8.77	8.20	14.80
CD at 5%	0.01	0.01	0.01	0.02	0.06	0.06	0.05	0.05	0.33
Interaction (P×C)	Sig,	Sig,	Sig,	Sig,	NS	NS	NS	NS	Sig.
C.V.%	1.21	0.83	0.58	0.55	0.55	0.82	0.73	0.78	3.17

Table 2: Interaction effect of packaging materials and calcium chloride on Physiological loss in weight (%), Firmness (Kgcm^{-2}) and Shelf life (days) of broccoli under cold storage condition

Treatments	Physiological loss in weight (%)						Firmness (Kgcm^{-2})				Shelf life (days)
	Storage period in days										
	Initial	4th	8th	12th	16th	Initial	4th	8th	12th	16th	Days
P_0C_0	0.00	1.08	3.22	5.43	7.96	9.70	9.23	8.93	8.20	7.50	9.33
P_1C_0		0.96	1.38	1.56	2.33		9.50	9.33	8.73	8.23	14.33
P_2C_0		1.66	1.46	3.72	6.77		9.50	9.23	8.63	8.17	13.67
P_3C_0		0.95	1.37	1.56	2.34		9.43	9.37	8.77	8.23	15.33
P_4C_0		1.51	2.20	3.56	5.42		9.43	9.17	8.70	8.13	14.00
P_0C_1		1.70	2.37	4.46	6.96		9.33	8.83	8.40	7.67	11.67
P_1C_1		0.93	1.31	1.51	2.28		9.73	9.37	8.83	8.20	14.67
P_2C_1		1.58	2.24	3.64	6.68		9.63	9.30	8.77	8.23	14.00
P_3C_1		0.88	1.29	1.50	2.33		9.80	9.37	8.83	8.33	15.67
P_4C_1		1.44	2.13	3.51	6.28		9.67	9.33	8.80	8.20	15.00
P_0C_2		1.63	2.51	4.19	6.94		9.47	9.07	8.53	7.80	12.00
P_1C_2		0.82	1.23	1.46	2.24		9.80	9.37	8.83	8.30	16.00
P_2C_2		1.44	2.14	3.48	6.55		9.60	9.33	8.77	8.27	14.00
P_3C_2		0.81	1.21	1.45	2.14		9.87	9.37	8.90	8.40	16.33
P_4C_2		1.31	2.02	3.35	6.22		9.70	9.33	8.80	8.23	15.67
S.Em. ±		0.009	0.009	0.010	0.016		0.05	0.04	0.04	0.04	0.26
CD at 5%		0.026	0.026	0.029	0.046		NS	NS	NS	NS	0.75
C.V.%		1.21	0.83	0.58	0.55		0.85	0.82	0.73	0.78	3.17

Firmness (Kgcm^{-2})

The result are presented in Table (1) and Table (2) reported that maximum firmness (9.70, 9.37, 8.83 and 8.32 Kgcm^{-2}) was recorded with P_3 (Polypropylene without perforation) and C_2 (*Calcium* chloride 1.5%) (9.69, 9.29, 8.77 and 8.20 Kgcm^{-2}) individually on 4th, 8th, 12th and 16th day of storage, respectively. This might be due to calcium pectate was formed after treatment with $CaCl_2$, which increased the rigidity of the cell wall and reduced the content of PG, PME, b-Gal, etc. These substances are located in the middle layer of the cell wall and are closely related to the activity of enzymes related to vegetable softening. In addition, calcium serves as an intermolecular binding agent. Packed broccoli were more firm than control, this can be attributed mainly due to more loss of moisture from the control heads. Result revealed that all the treatments exhibited non-significant effect for firmness up to 16th day of storage. At the end of storage (16th day) it was highest in treatment (P_3C_2) and lowest in control treatment (P_0C_0).

Shelf life (days)

The data presented in Table (1) and table (2) indicate that the highest shelf life (15.78 days) was recorded with the application of P_3 (Polypropylene without perforation). This might be due to carbon dioxide and depletion of oxygen around the broccoli packed in without perforated polypropylene, which prolong the storage life. Data with respect to calcium chloride revealed that highest shelf life (14.80 days) was recorded by C_2 (*Calcium* chloride 1.5%). This might be due to calcium helps in structural integrity of both the cell wall and plasma membrane thus delaying ripening and extending storage life. The longest shelf life (16.33 days) was recorded in treatment P_3C_2 (Polypropylene without perforation with calcium chloride 1.5%). whereas, shortest shelf life (9.33 days) was recorded in treatment P_0C_0 (Without packaging without dipping). Further it was observed that treatment P_3C_2 significantly exhibited 7 days more shelf life than P_0C_0. PLW, yellowing, firmness and visual quality determines the shelf life of broccoli.

Yellowing (%)

The result was presented in figure (1) shows lowest yellowing was found in treatment of polyethylene without perforation might be due to low decrease in chlorophyll concentrations during storage. Packaging decreases the chlorophyll degradation. These results were in accordance with the findings of Chanbisana and Banik (2019) [9] in broccoli, Yan and Liu (2012) [18] in broccoli, Beer and crouch (2013) [6] in broccoli. The minimum yellowing (3.28, 7.63, 27.40 and 58.60%) was recorded with application of C_2 (*Calcium* chloride 1.5%) on 4th, 8th, 12th and 16th day of storage, respectively. This might be due to soaking freshly cut broccoli with $CaCl_2$ solution can effectively lower the activity of chlorophyll decomposing enzymes, reduce the loss of chlorophyll and protein in vegetables, delay the loss of greenness so, reduce the rate of yellowing. These results were in accordance with the findings of Abou El-Wafa (2020) [1] in broccoli. Data presented in figure (1) revealed that there was no yellowing found on 4th days of storage in T_{14}, T_{12}, T_9, T_7, T_4 and T_2. The yellowing percentage was found in increasing trend in all the treatments with advancements of storage period. The minimum yellowing (1.60, 11.33, 25.33%) was recorded in treatment P_1C_2 (Polyethylene without perforation with Calcium chloride 1.5%) on 8th, 12th and 16th day of storage respectively. Whereas, the maximum yellowing (10.15, 17.70, 50.00 and 98.33%) was noted with treatment P_0C_0 (Without packaging without calcium chloride) on 4th, 8th, 12th and 16th day of storage respectively. Delayed in

yellowing was found in treated broccoli head with calcium chloride (1.5%) when packed with non-perforated polyethylene bag. Atmospheric air leads to senescence and loss of green color. Hence, the packaging technology used lead to different respiration rates and thus color changes in packaged broccoli and $CaCl_2$ solution can effectively lower the activity of chlorophyll decomposing enzymes. This both packaging materials and $CaCl_2$ (1.5%) shown to be effective at retarding senescence. These results were in accordance with the findings of Abou El-Wafa (2020) [1] in broccoli.

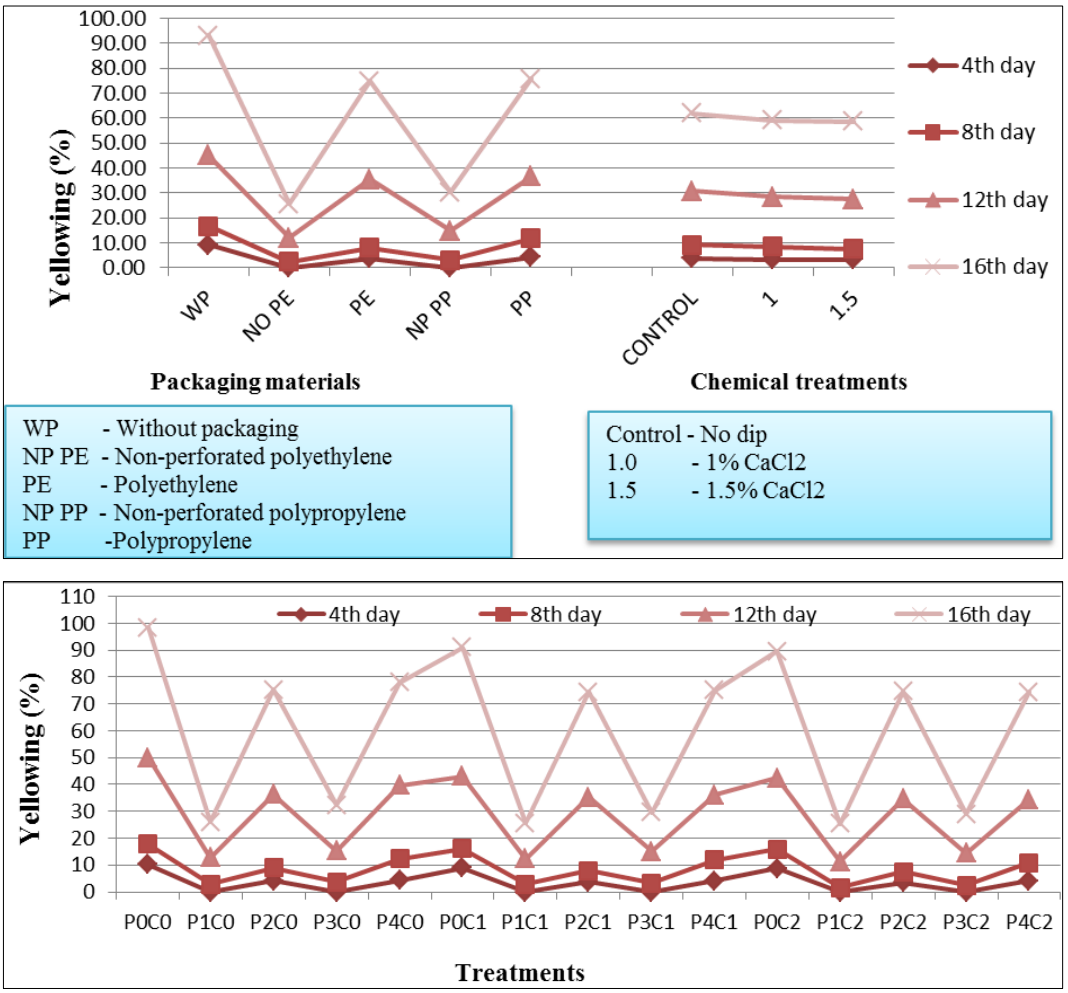

Fig 1: Effect of packaging materials and calcium chloride on yellowing of broccoli under cold storage condition

Fungal decay (%)

The result for fungal decay represented in figure (3) and figure (4) revealed that all the treatments exhibited non-significant effect for fungal decay up to 16th day of storage. There was no spoilage found on 4th, 8th and 12th day of storage in all the treatments and no spoilage found on 16th day in perforated polyethylene bag and perforated polypropylene bag. Maximum spoilage percentage (20.36%) was noted with P_0 (Without packaging) on 16th day of storage. No fungal growth in perforated bags may be due to optimum level of humidity and modified gaseous composition inside the bags which did not favor the growth of fungus, but in polyethylene bags without perforation, which favors fungal growth. However decay was less evident up to 16 days storage in the non-perforated packages possibly because it was inhibited by the accumulated CO_2. With respect to data on calcium chloride, it was observed that minimum fungal percentage (8.70%) was found in C_2 (*Calcium* chloride 1.5%) on 16th day of storage as compared (9.62%) was found in C_0 (No dipping). This might be due to slow release of free water on an effect of reduced metabolism and rate of transpiration in calcium treated heads. Maximum decay percentage (%) was noted with P_0C_0 (Without packaging with no dipping) on 16th day of storage. These results were in accordance with the finding of Chanbisana and Banik (2019) [9] in broccoli.

Moisture (%)

The result for moisture percentage represented in figure (3) and figure (4). The moisture was decreased in all the treatments throughout the storage. The maximum moisture retention (88.47, 87.37, 85.71 and 82.51%) was recorded with P_3 (Polypropylene without perforation). Packed broccoli recorded less moisture loss due to maintenance of high humidity surrounding broccoli, which in turn lower rate of transpiration. These results were in accordance with the findings of Raseetha and Nadirah (2018) [13] in broccoli. The maximum moisture retention (87.00, 86.90, 81.00 and 77.80%) was recorded with application of C_2 (*Calcium* chloride 1.5%). Loss of total water in broccoli was mainly due to the reduction of free water. $CaCl_2$ treatment contributed to the conservation of the free water content. This is due to the hygroscopic characteristic of $CaCl_2$. At the end

of storage (16th day) it was highest in treatment (P_3C_2) and lowest in control treatment (P_0C_0).

Sensory evaluation (9-point hedonic scale)

Sensory evaluation was recorded and presented in figure (2) for 16th days found non-significant effect of calcium chloride found on taste, compactness, browning and texture on table (3). However, the application of in treatment P_1C_2 (Polyethylene without perforation with calcium chloride 1.5%) had significantly highest maximum appearance (9.00, 9.00, 8.00 and 7.00 score) on 4th, 8th, 12th and 16th day of storage. While, minimum appearance (6.33, 4.67, 3.33 and 2.00 score) was recorded in treatment P_0C_0 (Without packaging with no dipping) on 4th, 8th, 12th and 16th day of storage, respectively. The pronounced effect of polyethylene without perforation packaging and calcium chloride (1.5%) was found in appearance i.e. freshness, greenness, compactness due to combine effect of packaging materials that provide modified atmospheric and calcium chloride plays an important role in the protest of cell integrity and positive effect on inhibiting the degradation of chlorophyll. The present results are in agreement with the findings of Abou El-Wafa (2020) [1] in broccoli.

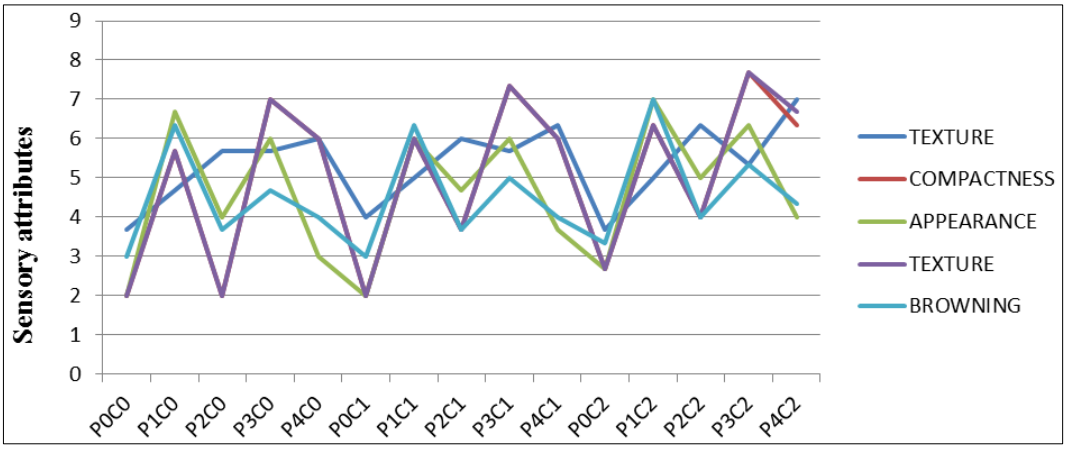

Fig 2: Interaction effect of packaging materials and calcium chloride on yellowing of broccoli under cold storage condition

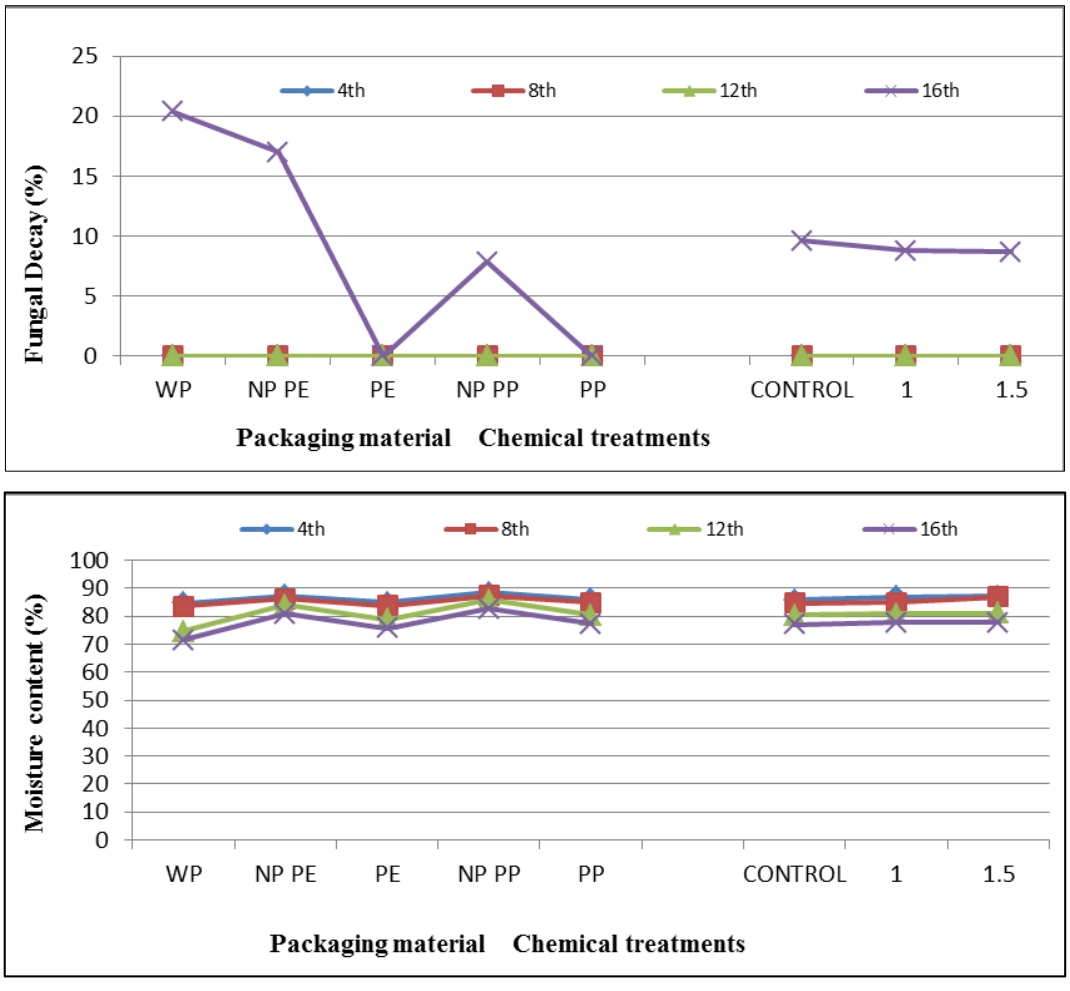

Fig 3: Effect of packaging materials and calcium chloride on, fungal decay and moisture content of broccoli under cold storage condition

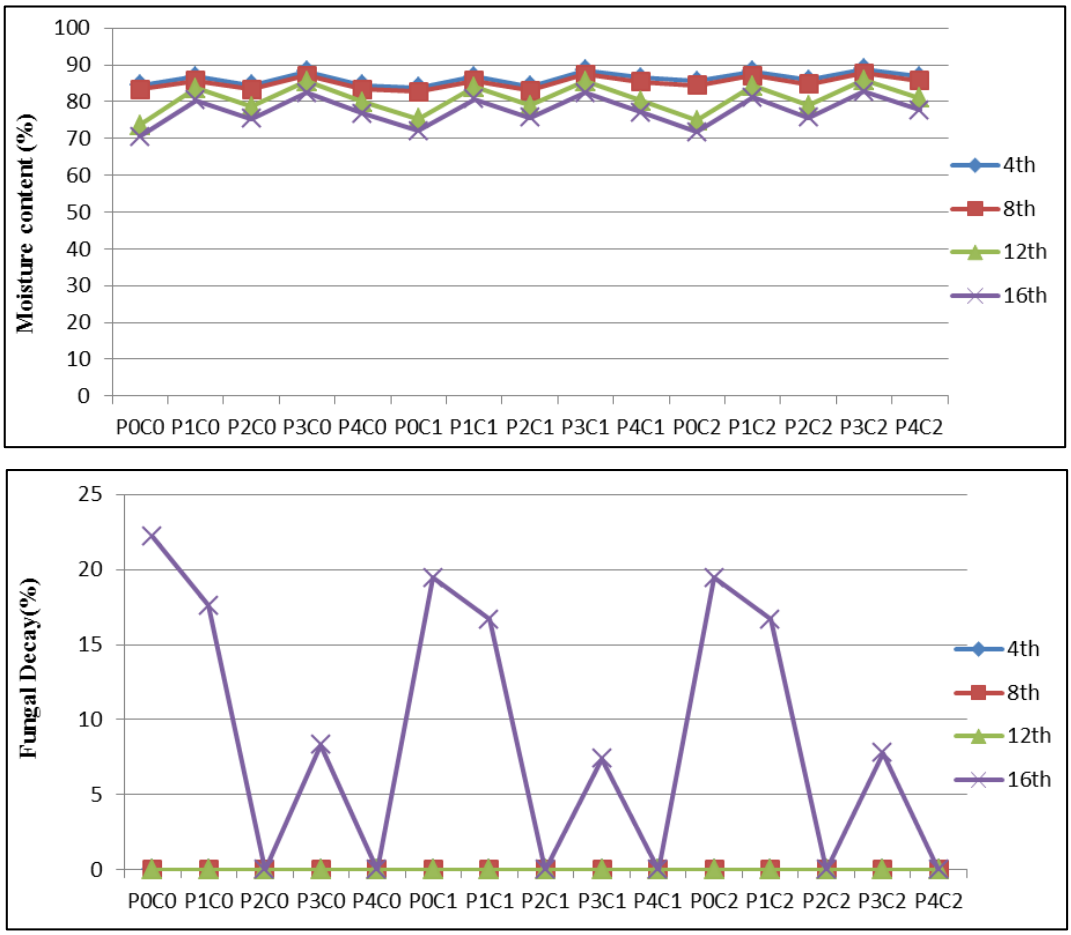

Fig 4: Interaction effect of packaging materials and calcium chloride on shelf life, moisture content, firmness and fungal decay of broccoli under cold storage condition

Conclusions

From the above results, it could be concluded that polypropylene without perforation with $CaCl_2$(1.5%) the most effective treatment in reducing weight loss percentage, maintain marketability, lower fungal decay, lower yellowing, retention of ascorbic acid and good appearance with extended shelf life at 16th day of storage at 5 ±1 °C and 95% RH under cold storage.

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