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Research Article

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Studies on the Post Harvest Life of Fresh Cut Broccoli Florets

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ABSTRACT

The study was undertaken to standardize treatments for developing fresh cut produce of broccoli which can be stored for a certain period of time. For this, the broccoli heads were cut into small florets and were dipped in various treatment combinations for ten minutes. After that the florets were dried under a fan and then packaging was carried out by Low Density Poly Ethylene with storage in refrigerated condition. Various physical, chemical and microbial parameters were studied and analyzed throughout the storage period. From the study it was found that the combination treatment of calcium hypochlorite, calcium chloride and citric acid was most suitable. The florets treated with this treatment were able to retain various physical and chemical attributes during the study, with least microbial contaminations.

Keywords: *Broccoli, Pretreatments, Packaging, Storage, Analysis*

INTRODUCTION

Broccoli (*Brassica oleracea* var.*italica*) is a very important vegetable where the head is the edible portion. Broccoli is not only consumed in India but appreciated all over the world. The vegetable apart from its good and attractive outer appeal, have been found possessing many appreciable consumable qualities also. The vegetable have tremendous nutritional potential with different isothiocyanates acting as chemo preventive agents against cancer (Ravikumar, 2015). It has also good impact against asthma and allergic diseases (Heber et al., 2014). Today everyone's life is moving very fast. People don't have time to go to vegetable markets, purchase vegetables, chop them in their kitchens and cook them. So because of less time, the fresh cut vegetable technology is rapidly developing. It aims in minimal processing of the vegetable without altering the nutrient reserves and fresh attributes. It is becoming an interesting alternative for convenience, freshness, and nutrition (Bhattacharjee et al., 2014). The minimal processing or fresh cut technique helps in sustenance of various attributes of the commodity at the post harvest stage. Fresh cut technology provide vegetables with certain pre-treatments helping in reducing the senescence during the storage life which otherwise is triggered during harvest, provoking the disruption of the nutrient and hormonal levels.

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So keeping in mind the rich nutritive status of broccoli and people emerging affinity towards fresh cut technology, the present study is undertaken to standardize treatments for developing fresh cut produce of broccoli and analyzing certain post harvest parameters during storage.

MATERIALS AND METHODS

The present investigation was undertaken in the Department of Post-Harvest Technology of Horticultural Crops under the faculty of Horticulture, Bidhan Chandra Krishi Viswavidyalaya, Nadia, West Bengal during autumn winter season of 2014-15 and 2015-16. The fruits were collected from farmer's field located in Nadia district of West Bengal which was grown by following all required cultivation practices. The experiment was carried out with broccoli variety Galaxy (F_1 hybrid). In the laboratory the broccoli heads were washed with water and dried under fan to remove the excess water on the surface. All equipment including knives, cutting boards and stainless steel containers were immersed in cold chlorinated water for sanitization. The heads were chopped from stem and cut into small florets using a stainless steel knife. The treatments in the study were T_1- Calcium hypochlorite -100 ppm, T_2- Calcium chloride - 0.2%, T_3-. Citric acid -0.2%, T_4- Calcium hypochlorite -100 ppm + Calcium chloride- 0.2%, T_5- Calcium hypochlorite- 100 ppm + Citric acid- 0.2%, T_6– Calcium hypochlorite- 100 ppm + Calcium chloride- 0.2% + Citric acid- 0.2%, T_7– Calcium chloride- 0.2% + Citric acid- 0.2%, T_8– Control (water).

Broccoli florets in different treatments were dipped for 10 minutes and kept on trays under fan to remove the excess water. After that, the treatments were pre-packed separately in low-density polyethylene packets (50 micron). Each packet was filled with 60-80 gm of sample. Then the packages after sealing were then stored at low temperature of 8 ± 2^0 C and relative humidity of 80-85%. The treatments were replicated 3 times and Completely Randomized Design (Gomez, & Gomez, 1984) and Duncan's Multiple Range Test (Duncan, 1955) were used for statistical analysis. Also the help of SPSS Version 16 (S.P.S.S., 2007) and online software (Sheoran et al., 1998) were taken. Following physical and chemical parameters were analyzed at 0, 3 6 and 9 days respectively.

Appearance quality during storage was studied on the basis of 9 point hedonic scaling (Peryam & Girardot, 1952, Peryam & Pilgrim, 1957). Oven drying method was used to estimate the moisture content of the fresh produce. For this fresh samples were dehydrated a in a hot air oven at a temperature of 70^0C till the final weight of the produce becomes constant (A.O.A.C., 2000). For Physiological loss in weight the final values were expressed in percentage with respect to the actual fresh weigh of individual treatment (Ranganna, 2003). The content of ascorbic acid was calculated by using 2, 6-dichlorophenol indophenols which is a standard dye for titration against the extract sample. The titration was stopped when an endpoint of rose pink colour which lasted for 5 seconds was observed (Ranganna, 2003). For chlorophyll determination samples were extracted using 80% acetone. Optical density was measured at 645 and 663 nm in the spectrophotometer. The results were expressed as mg/g (Ranganna, 2003). Radical scavenging activity (RSA) was determined by calculating the scavenging ability of the antioxidant present in the sample against 2, 2-diphenyl-1-picrylhydrazyl radical assay (Brand-Williams, et al., 1995). Folin-Ciocalteu reagent was used for estimation of total phenol content. The results were demonstrated as mg gallic acid equivalents (GAE) per gram fresh weight (Singleton, et al., 1999). The total flavanoid content was also calculated (Zhishen et al., 1999). The final content of total flavanoids was shown as mg catechin equivalents (CE) per gram of fresh mass. And estimation of fungal and bacterial population (Microbial load) on the samples was done by standard dilution plate count method (Allen, 1953). For fungus Martin's Rose Bengal Agar medium and for bacteria Nutrient Agar medium was used. The results were shown as colony forming units per gram (cfu/g).

RESULTS AND DISCUSSION

The weight loss increased for all the treatments throughout the storage period (Table 1). Among the different treatments broccoli florets treated with combination of calcium hypochlorite, calcium chloride and citric acid documented lower weight loss at different stages in storage compared to other treatments.

As compared to the initial day of processing (cutting the whole fruit for fresh cut and preparation into florets) of the broccoli florets, no huge difference was noted in the moisture percentage levels among the treatments (Table 2). Broccoli florets treated with 100 ppm calcium hypochlorite, 0.2% calcium chloride and 0.2% citric acid was able withhold the maximum moisture levels of 83.80% at the end of the experiment.

Table 3 shows appearance quality with reference to hedonic scaling. Throughout the storage the appearance score decreased considerably for all treatments. The lowest score was recorded for control and the score of broccoli florets treated with combination of calcium hypochlorite, calcium chloride and citric acid was significantly superior from other treatments.

Chlorophyll concentration (a, b and total chlorophyll) gradually decreased during storage at 8 ± 1^0C in all the treatments (Table 4). On the 3rd day of storage, significant levels of chlorophyll were retained in all the treatments. However subsequent degradation was seen for all the chlorophyll types (*viz.* a, b and total chlorophyll levels) at 6th and 9th days of storage. Broccoli florets treated with 100 ppm calcium hypochlorite, 0.2% calcium chloride and 0.2% citric acid maintained the highest levels of chlorophyll with 5.12 mg/g of total chlorophyll, followed by broccoli florets treated with 100 ppm calcium hypochlorite and 0.2% calcium chloride.

Ascorbic acid content decreased during storage up to 9th day, with 0 days of storage recording the highest of 97.30 mg/100g for all the treatments (Table 5). On 3rd day ascorbic acid content of broccoli florets treated with combination of calcium hypochlorite, calcium chloride and citric acid remained significantly high (78.73 mg/100g) compared to control. Further decrease in the levels of ascorbic acid was seen in the 6th day of storage which significantly lowered further till 9th day of storage. Though broccoli florets treated with combination of 100 ppm calcium hypochlorite, 0.2% calcium chloride and 0.2% citric acid was able to retain the highest levels of ascorbic acid of 59.10 mg/100g at the end of storage.

At 0 days of storage the concentration of total phenols, flavanoids and antioxidants were marked at their maximum (Table 6, 7, 8). Thereafter the concentrations were reduced in all the treatments throughout the storage period. Successively during the storage interval of 3 days, 6 days and 9 days broccoli florets treated with combination of 100 ppm calcium hypochlorite, 0.2% calcium chloride and 0.2% citric acid showed the least degradation for total phenols, flavanoids and antioxidants which were followed by broccoli florets treated with 100 ppm calcium hypochlorite and 0.2% calcium chloride. Control suffered the maximum loss.

Bacterial and fungal (unicellular and filamentous types) population on broccoli florets during storage period is shown in Table 9 and 10. Initial day (0 DAS) recorded the least microbial population of both fungus (unicellular and filamentous type) and bacteria. The microbial population continuously increased during the storage period. However broccoli florets treated with combination of calcium hypochlorite, calcium chloride and citric acid was able to register least fungal and bacterial colonies at the end of storage. Broccoli florets for control were severely affected by fungal and bacterial attack.

In the experiment the chemical combination of calcium hypochlorite, calcium chloride and citric acid helped in maintaining various attributes during the storage period. Some of the chemicals used here were according to previous works (Ediriweera et al., 2012, Rinaldi et al., 2010). Furthermore packaging in LDPE 50 micron pouches created

a modified atmospheric situation which helped in retaining the colour and texture of the broccoli florets by lowering the oxygen levels. Earlier findings (González-Aguilar et al., 1997) also showed that celery sticks with MAP packaging was able to retain different sensory properties.

It was also observed that the content of ascorbic acid of the fresh cut samples during the period of study decreased however proper post harvest handling procedures can minimize such loses (Serrano et al., 2006, Lemoine et al., 2008). The experiment showed that the broccoli samples in which citric acid were used as a treatment retained more concentration of ascorbic acid throughout the storage. These findings were similar to a previous work (Altunkaya & Gokmen, 2009). Apart from this the phenolic concentration or the total phenol content during the experiment also deteriorated gradually during the storage period. This might be because of loss of membrane integrity, cellular compartmentation and enzymatic activities caused by polyphenol oxidase and peroxidase (Baltacig et al., 2011). The utilization of calcium chloride as a treatment for treating the fresh cut samples of broccoli florets was found beneficial which might be because of the inhibitory action of chloride ions against polyphenol oxidase both these findings are as per to the previous reports of (Rinaldi et al., 2010).

Also from the present study it was seen the both the bacterial and fungal contamination which were measured by counting their colonies increased. This increase in the bacterial and microbial population in the broccoli florets may because of contamination from adjoining environment. In an earlier experiment (Nguyen-the, & Carlin, 1994) it was reported that bacterial population varies at a range of 10^3-10^6 cfu/g and fungal population at a range of 10^3-10^4 cfu/g for fresh cut vegetables.

Table 1: Physiological loss in weight of fresh cut broccoli at different days in storage

Treatments	Physiological loss in weight (%)		
	3 DAS	**6 DAS**	**9 DAS**
T_1	0.91 **e** (1.38)	2.9 **e** (1.97)	3.92 **e** (2.21)
T_2	1.16 **g** (1.47)	3.51 **g** (2.12)	4.67 **g** (2.38)
T_3	1.03 **f** (1.42)	3.24 **f** (2.06)	4.31 **f** (2.31)
T_4	0.51 **c** (1.23)	2.07 **c** (1.75)	3.05 **c** (2.01)
T_5	0.35 **b** (1.16)	1.92 **b** (1.71)	2.69 **b** (1.92)
T_6	0.23 **a** (1.11)	1.64 **a** (1.62)	2.09 **a** (1.75)
T_7	0.73 **d** (1.31)	2.71 **d** (1.92)	3.19 **d** (2.04)
T_8	1.19 **g** (1.48)	3.92 **h** (2.21)	5.01 **h** (2.45)
C.D. (0.05 %)	**0.068**	**0.103**	**0.119**
SE m ±	**0.023**	**0.034**	**0.040**

Figures in parenthesis indicates square root transformed values (means in the column followed by the same alphabet do not differ significantly by DMRT at 5%)

Table 2: Moisture content of fresh cut broccoli at different days in storage

Treatments	Moisture content (%)			
	0 DAS	3 DAS	6 DAS	9 DAS
T_1	88.40	86.13 **d**	80.70 **d**	80.13 **d**
T_2		85.13 **b**	78.33 **b**	77.16 **b**
T_3		85.33 **c**	78.73 **c**	77.83 **c**
T_4		86.60 **f**	81.80 **f**	81.20 **f**
T_5		87.23 **g**	83.16 **g**	82.33 **g**
T_6		87.76 **h**	85.40 **h**	83.80 **h**
T_7		86.33 **e**	81.16 **e**	80.50 **e**
T_8		84.06 **a**	77.60 **a**	76.30 **a**
C.D. (0.05 %)	-	**0.133**	**0.142**	**0.142**
SE m ±	-	**0.044**	**0.047**	**0.047**

(means in the column followed by the same alphabet do not differ significantly by DMRT at 5%)

Table 3: Appearance quality of fresh cut broccoli at different days in storage

Treatments	Hedonic scaling			
	0 DAS	3 DAS	6 DAS	9 DAS
T_1	9.00	7.00 **cd**	5.66 **c**	4.00 **cd**
T_2		6.00 **ab**	4.66 **b**	2.66 **b**
T_3		6.66 **bc**	5.33 **bc**	3.33 **bc**
T_4		7.66 **de**	7.00 **de**	5.33 **ef**
T_5		8.33 **ef**	7.66 **ef**	6.00 **fg**
T_6		8.66 **f**	8.00 **f**	6.66 **g**
T_7		7.33 **cd**	6.66 **d**	4.66 **de**
T_8		5.66 **a**	3.66 **a**	1.33 **a**
C.D. (0.05 %)	**-**	**0.856**	**0.800**	**0.749**
SE m ±	**-**	**0.286**	**0.267**	**0.250**

(means in the column followed by the same alphabet do not differ significantly by DMRT at 5%)

Table 4: Chlorophyll levels (mg/g) of fresh cut broccoli at different days in storage

Treatments	0 DAS			3 DAS			6 DAS			9 DAS		
	Ch-a	Ch-b	Tot-ch	Ch-a	Ch-b	Tot-ch	Ch-a	Ch-b	Tot-ch	Ch-a	Ch-b	Tot-ch
T_1	7.81	2.63	10.4	6.11 **d**	2.09 **c**	8.11 **d**	4.34 **d**	1.44 **d**	5.79 **d**	2.75 **d**	0.91 **c**	3.63 **d**
T_2				5.98 **b**	1.92 **b**	7.88 **b**	3.92 **b**	1.32 **b**	5.21 **b**	2.34 **b**	0.74 **a**	3.11 **b**
T_3				6.03 **c**	2.11 **c**	8.06 **c**	4.15 **c**	1.36 **c**	5.55 **c**	2.62 **c**	0.88 **b**	3.47 **c**
T_4				6.57 **f**	2.21 **e**	8.76 **f**	4.63 **f**	1.55 **f**	6.13 **f**	3.54 **f**	1.18 **e**	4.72 **f**
T_5				6.65 **g**	2.24 **f**	8.91 **g**	4.74 **g**	1.59 **g**	6.37 **g**	3.64 **g**	1.22 **f**	4.86 **g**
T_6				6.85 **h**	2.27 **g**	9.02 **h**	5.65 **h**	1.89 **h**	7.56 **h**	3.85 **h**	1.29 **g**	5.12 **h**
T_7				6.32 **e**	2.14 **d**	8.42 **e**	4.43 **e**	1.49 **e**	5.92 **e**	3.05 **e**	1.03 **d**	4.13 **e**
T_8				5.74 **a**	1.85 **a**	7.71 **a**	3.64 **a**	1.22 **a**	4.89 **a**	2.25 **a**	0.72 **a**	2.97 **a**
C.D. (0.05)	-	-	-	**0.024**	**0.020**	**0.029**	**0.039**	**0.023**	**0.030**	**0.038**	**0.022**	**0.027**
SE m ±	-	-	-	**0.008**	**0.007**	**0.009**	**0.013**	**0.007**	**0.010**	**0.013**	**0.007**	**0.009**

Ch-a: Chlorophyll a, Ch-b: Chlorophyll b , Tot-ch: Total Chlorophyll

(means in the column followed by the same alphabet do not differ significantly by DMRT at 5%)

Table 5: Ascorbic acid content of fresh cut broccoli at different days in storage

Treatments	Ascorbic acid mg/100g			
	0 DAS	3 DAS	6 DAS	9 DAS
T_1	97.30	67.13 **d**	52.63 **d**	42.06 **d**
T_2		63.40 **b**	48.53 **b**	36.10 **b**
T_3		65.36 **c**	50.83 **c**	39.40 **c**
T_4		70.50 **f**	58.73 **f**	48.16 **f**
T_5		73.70 **g**	63.90 **g**	53.06 **g**
T_6		78.73 **h**	68.73 **h**	59.10 **h**
T_7		68.43 **e**	57.23 **e**	43.96 **e**
T_8		60.66 **a**	43.50 **a**	31.26 **a**
C.D. (0.05 %)	-	**0.656**	**0.877**	**0.866**
SE m ±	-	**0.217**	**0.290**	**0.286**

(means in the column followed by the same alphabet do not differ significantly by DMRT at 5%)

Table 6: Total content of phenols of fresh cut broccoli at different days in storage

Treatments	Total phenols (mgGAE/ g)			
	0 DAS	3 DAS	6 DAS	9 DAS
T_1	8.59	5.30 **d**	3.23 **d**	2.40 **d**
T_2		5.05 **b**	2.61 **b**	1.90 **b**
T_3		5.24 **c**	3.16 **c**	2.28 **c**
T_4		5.66 **f**	3.82 **f**	3.16 **f**
T_5		6.56 **g**	3.95 **g**	3.24 **g**
T_6		7.29 **h**	4.14 **h**	3.38 **h**
T_7		5.39 **e**	3.43**e**	2.47 **e**
T_8		4.68 **a**	2.09 **a**	1.42 **a**
C.D. (0.05 %)	-	**0.018**	**0.019**	**0.018**
SEm±	-	**0.006**	**0.006**	**0.006**

(means in the column followed by the same alphabet do not differ significantly by DMRT at 5%)

Table 7: Flavanoid contents of fresh cut broccoli at different days in storage

Treatments	Flavanoid (mgCE/g)			
	0 DAS	3 DAS	6 DAS	9 DAS
T_1	1.55	0.81 **d**	0.72 **c**	0.39 **d**
T_2		0.74 **b**	0.62 **b**	0.26**b**
T_3		0.78 **c**	0.71**c**	0.33**c**
T_4		0.93 **e**	0.81**e**	0.49**f**
T_5		1.01 **f**	0.83**f**	0.56 **g**
T_6		1.07 **g**	0.92 **g**	0.61**h**
T_7		0.82 **d**	0.75**d**	0.42**e**
T_8		0.72 **a**	0.59 **a**	0.17**a**
C.D. (0.05 %)	-	**0.007**	**0.011**	**0.011**
SEm±	-	**0.002**	**0.003**	**0.003**

(means in the column followed by the same alphabet do not differ significantly by DMRT at 5%)

Table 8: Antioxidant activity (percent inhibition of DPPH) of fresh cut broccoli at different days in storage

Treatments	Percent inhibition of DPPH			
	0 DAS	**3 DAS**	**6 DAS**	**9 DAS**
T_1	60.83	47.53 **d**	38.06 **d**	30.80 **d**
T_2		41.70 **b**	36.63 **b**	27.53 **b**
T_3		44.16 **c**	37.30 **c**	28.30 **c**
T_4		51.50 **f**	41.13 **f**	36.66 **f**
T_5		53.53 **g**	41.76 **g**	38.56 **g**
T_6		54.23 **h**	43.60 **h**	39.23 **h**
T_7		50.16 **e**	38.50 **e**	31.53 **e**
T_8		40.66 **a**	35.83 **a**	25.53 **a**
C.D. (0.05 %)	**-**	**0.295**	**0.210**	**0.302**
SE m ±	**-**	**0.098**	**0.070**	**0.100**

(means in the column followed by the same alphabet do not differ significantly by DMRT at 5%)

Table 9: Populations of bacteria on fresh cut broccoli at different days in storage

Treatments	Bacterial count (x 10^5 cfu/g)			
	0 DAS	**3 DAS**	**6 DAS**	**9 DAS**
T_1	4.00	4.67 **b**	7.00 **cd**	8.67 **cd**
T_2		5.00 **bc**	7.67 **de**	10.67 **e**
T_3		5.00 **bc**	7.00 **cd**	9.33 **d**
T_4		4.33 **ab**	6.00 **ab**	8.00 **bc**
T_5		3.67 **a**	5.67 **a**	7.33 **ab**
T_6		3.67 **a**	5.33 **a**	7.00 **a**
T_7		4.67 **b**	6.67 **bc**	8.67 **cd**
T_8		5.67 **c**	8.33 **e**	11.33 **e**
C.D. (0.05 %)	**-**	**0.873**	**0.878**	**0.873**
SE m ±	**-**	**0.289**	**0.289**	**0.289**

(means in the column followed by the same alphabet do not differ significantly by DMRT at 5%)

Table 10: Populations of unicellular and filamentous fungi on fresh cut broccoli at different days in storage

Treatments	Fungal Count (x 10^2 cfu/g)							
	0 DAS		**3 DAS**		**6 DAS**		**9 DAS**	
	Unicellular	Filamentous	Unicellular	Filamentous	Unicellular	Filamentous	Unicellular	Filamentous
T_1	1.67	0.67	4.67 **bc**	2.33 **bcd**	5.67 **cd**	3.33 **ab**	7.33 **d**	4.33 **bc**
T_2			5.00 **c**	2.67 **cd**	6.33 **de**	3.67 **b**	8.67 **e**	4.33 **bc**
T_3			4.67 **bc**	2.33 **bcd**	6.33 **de**	3.00 **ab**	8.33 **e**	4.33 **bc**
T_4			4.33 **abc**	1.67 **ab**	4.67 **b**	3.33 **ab**	6.00 **bc**	3.33 **ab**
T_5			3.67 **ab**	1.67 **ab**	4.67 **b**	2.67 **ab**	5.33 **ab**	2.67 **a**
T_6			3.33 **a**	1.33 **a**	3.67 **a**	2.33 **a**	5.00 **a**	2.67 **a**
T_7			4.33 **abc**	2.00 **abc**	5.00 **bc**	3.33 **ab**	6.67 **cd**	4.00 **bc**
T_8			5.33 **c**	3.00 **d**	7.00 e	3.67 b	10.33 **f**	4.67 **c**
C.D. (0.05 %)	-	-	**0.873**	**N/A**	**0.797**	**0.943**	**0.797**	**1.008**
SE m ±	-	-	**0.289**	**0.289**	**0.264**	**0.312**	**0.264**	**0.333**

(means in the column followed by the same alphabet do not differ significantly by DMRT at 5%)

CONCLUSION

From the experiment it can be thus concluded that broccoli florets after ongoing from certain minimal processing can be stored for more than a week in refrigerated condition. Among the different treatments used in the study for storing fresh florets of broccoli it was found that combination of calcium hypochlorite, calcium chloride and citric acid was most effective as florets treated with this combination documented lower weight loss, better appearance quality, good retainment of chlorophylls, phenols, flavanoids and antioxidants and suffered from least bacterial and fungal spoilage.

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