Research Article

Effect of Different Blanching Treatments on Physicochemical, Phytochemical Constituents of Cabinet Dried Broccoli

Navneet Kaur[1*], Poonam Aggarwal[1] and Hradesh Rajput[2]

[1]Department of Food Science and Technology, Punjab Agricultural University, Ludhiana-141004, India
[2]Warner Collage of Dairy Technology, Sam Higginbottom University of Agriculture Technology and Science, Allahabad, Uttar Pradesh, India

Abstract

The present investigation was carried out to study the effect of different blanching treatments on physicochemical, phytochemical constituents of cabinet dried broccoli**.** Blanching treatments such as potassium metabisulphite 0.1 per cent, sodium bicarbonate 0.1 per cent, sodium chloride 1 per cent, calcium chloride 0.5per cent in water at 100ºC for 180 seconds and steam blanching for 300 seconds were found suitable for cabinet drying at 50ºC for 8 h on the basis of color. Results showed that the moisture, rehydration ratio, acidity and ascorbic acid were highest in potassium metabisulphite blanched sample while total phenols and antioxidant activity were highest in control (untreated sample) and total chlorophyll and color attributes were found maximum in sodium bicarbonate blanched sample, immediately after dehydration. During storage of six months significant ($p \leq 0.05$) decrease was observed in acidity, ascorbic acid, total phenols, antioxidant activity, rehydration ratio, total chlorophyll and color values in all the samples of dried broccoli but there was significant ($p \leq 0.05$) increase in moisture content. Six months storage showed best retention of moisture, rehydration ratio, acidity, ascorbic acid, total phenols and antioxidant activity in potassium metabisulphite blanched samples, while retention of total chlorophyll and color attributes were maximum in sodium bicarbonate blanched samples.

Keywords: blanching, broccoli, physicochemical, phytochemical and antioxidant activity

***Correspondence**
Author: Navneet Kaur
Email: hrdesh802@gmail.com

Introduction

Broccoli (Brassica oleracea italica) is a winter vegetable of Italian origin. It is one of the most important member of the Cole group of vegetables and widely considered to contain high level of phytochemicals including glucosinolates and flavonoids. Being rich in phytochemicals, it has been described as a vegetable with high nutritional values [1]. These phytochemicals and nutrients have gained renewed interest in preventing cancer, cardiovascular diseases and stimulate the immune system [2].

Broccoli florets have a shorter shelf-life as a result of high rates of respiration and metabolism, during which many chemical reactions occur [3]. Therefore, new approaches were developed to extend the shelf-life of intact or fresh-cut broccoli in order to control the senescence and quality decay by various means, like modified atmosphere packaging [4], UV-C treatments [5], heat treatments like hot water [6]. These treatments have been observed to effectively reduce yellowing of stored fresh broccoli. Some other scientists used dehydration technique for preservation of broccoli [7]. Food dehydration refers to the complete removal of water from foods under controlled conditions. During dehydration some important changes take place, as structural and physicochemical modifications that affect the final product quality and also result in lower shipping and container cost. Dehydrated foods have increased shelf life, inexpensive than the fresh ones or canned ones, and also leads to the production of convenience items. These processed products are excellent as emergency foods and widely used in army, military and hiking etc. Thus, dehydration techniques were used to maintain quality criteria like color, nutritional composition, shape or texture.

Typically, blanching is carried out by treating the vegetables with steam or hot water for 1-10 min at 75-95°C, the time/ temperature combination depending on the type of vegetable [8]. Blanching of foods involves mild heating in water and serves. Blanching can have negative effect on nutrients such, as vitamins and phenolic compounds which are relatively unstable when subjected to heat treatments [9]. Apart from processing, storage conditions and domestic cooking and preparation have significant effect on phytochemicals such as ascorbic acid and phenols [10]. Salt blanching can also be carried out to preserve the essential nutrients. Therefore, there is need to standardize the technique for drying of broccoli and to study the effect of different blanching treatments on physicochemical, phytochemical constituents and antioxidant activity of dried broccoli.

Material and Methods

Procurement of raw material

The present investigation was carried out in the Department of Food Science and Technology, Punjab Agricultural University, Ludhiana. Broccoli was procured during the month of February from Malerkotla. Chemicals were purchased from local market for analysis.

Optimization of processing parameters

The broccoli pieces were loosely tied in a muslin cloth and held in hot water at 100° C for different blanching time i.e. 30, 60, 90, 120,150 and 180 seconds for optimization of water blanching and broccoli pieces were kept on muslin cloth tied to stainless steel vessel and held at temperature of 100° C for 60, 120, 180, 240 and 300 seconds for optimization of steam blanching and analyzed for the peroxidase enzyme activity test. Broccoli was blanched with different concentrations of salts such as potassium metabisulphite, sodium bicarbonate (0.1%, 0.2%, 0.3%) and sodium chloride, calcium chloride (0.5%, 1%, 1.5%) in hot water at 100° C for 180 seconds and optimized on the basis of color test.

Drying of broccoli

Preparation of the samples

Broccoli obtained from local market was weighed, washed thoroughly under running tap water and surface water was dried. Broccoli was cut into thin pieces. These pieces were kept for various treatments of blanching. Control and other pretreated blanched samples were kept for further cabinet drying.

Cabinet drying of Broccoli

The cabinet dryer was used for drying with the capacity of twelve trays. The dryer was equipped with an exhaust outlet. The broccoli was spread evenly in a single layer on trays. The trays were placed inside the hot air (cabinet) dryer maintained at 50 ºC and dried till they attained similar amount of moisture content. The position of trays was interchanged periodically. Pretreated dried broccoli was kept for analysis.

Storage studies

Dried broccoli was packed in polythene bags and stored in bins for six months. The effect of storage on the physicochemical, phytochemical constituent and antioxidant activity of dried broccoli was studied at fixed interval of one month upto six months.

Analytical methods

Moisture and titratable acidity was determined according to [11] method. Rehydration ratio was calculated using the method of [12]. Color of broccoli was measured by using Minolta Spectrophotometer in the hunter lab color mode in terms of 'L', 'a', 'b' values. Standard method given by [13] was followed for ascorbic acid determination and aliquot was titrated against dye (2, 6-dichlorophenol indo-phenol). Total phenols were determined using Folin-Ciocalteu reagent according to the modified method of [14]. Total chlorophyll of broccoli sample was determined by using the colourimetric method of [15]. Antioxidant activity was estimated using the method spectrophotometer method. Results collected were analyzed statistically with the help of factorial design in completely randomized design using the software CPCS-1 [16].

Results and Discussion

Physicochemical, phytochemical constituents and antioxidant activity of raw broccoli

Moisture content in fresh broccoli was found to be 86.5% as shown in **Table 1**. Earlier, [17] also reported 88% moisture content in fresh broccoli. Later on, according to [18] discovered that the moisture content in fresh broccoli ranged between 83.87% and 90.27%. Color attributes of (L value, a value and b value) fresh broccoli is shown in Table 1. L value of fresh broccoli was found as 39.95, a value 3.26 and b value 2.54. [19] L value for fresh broccoli was 29.5. The acidity in fresh broccoli was found as 0.42 %. [20] 0.49% of titratable acidity in fresh broccoli.

During the analysis of fresh broccoli 99.2 mg/100g ascorbic acid was found in present study Similarly, [21] found 130 mg/100 g of ascorbic acid content in fresh broccoli florets. Vitamin C level in broccoli ranged from 60.1 to 179.7

mg/100g as studied [22, 23], later on [18] the ascorbic acid value ranged from 57.35–131.35 mg/100g. The total phenols in fresh broccoli noted as 112.4mg GAE/100g shown in Table 1. [19] total phenolic content of 446 mg GAE/100 g in fresh broccoli. Similarly, [24] fresh broccoli had a total phenol content of 101.63 mg/100 g. [18] the value of phenol content ranged within 48.15 to 157.77 mg/100g in raw broccoli. Total chlorophyll in fresh broccoli was found to be 19.23 mg/100g. [25] 26 mg/100g of total chlorophyll in fresh broccoli. The fresh broccoli contained 37% antioxidant activity presented in Table1. [26] 40.3±0.7% antioxidant activity in fresh broccoli.

Table 1 Physicochemical and phytochemical constituents of fresh broccoli

Parameters		**Fresh Broccoli**
Moisture (%)		86.5
Acidity (%)		0.42
Ascorbic acid (mg/100g)		99.2
Total phenols (mg/100g)		112.4
Antioxidant activity (%)		37
Total chlorophyll (mg/100g)		19.23
Color	L value	39.95
	a value	-3.26
	b value	2.54

Optimization of method and time of blanching of broccoli

Water blanching for 180 seconds was chosen as the optimized time for blanching of broccoli. Steam blanching for 300 seconds was chosen as the optimized time for blanching of broccoli. Sodium bicarbonate with concentration of 0.1per cent and potassium metabisulphite with concentration of 0.1per cent was selected for salt blanching of broccoli on the basis of color and peroxidase enzyme activity test.

Effect of blanching treatments on the color of broccoli

In the present study, water, steam and salt blanching were applied as a pre treatment to the fresh broccoli. Steam blanching with the plain water while water blanching with plain water as well as with different salts at different concentration were used for the retention of physicochemical, phytochemical constituents and antioxidant activity during drying. Salt concentrations (sodium chloride, calcium chloride, Potassium metabisulphite and sodium bicarbonate) in water blanching at 100^{o}C for 180 seconds was standardized by comparing the color values as shown in **Table 2**.

Table 2 Effect of blanching treatments on the color of broccoli

Blanching Treatments	**Salt concentration**	**Color**		
		L	**a**	**b**
Unblanched Control	-	39.95	-3.26	2.54
Plain Water	-	39.90	-3.23	2.43
Steam	-	39.41	-4.23	2.10
Sodium Chloride	0.5%	38.09	-4.81	1.63
	1%	37.91	-4.96	1.58
	1.5%	38.15	-4.78	1.65
Calcium Chloride	0.5%	38.22	-4.73	1.83
	1%	38.43	-4.68	1.88
	1.5%	38.49	-4.54	1.91
Potassium Metabisulphite	0.1%	37.77	-5.13	1.20
	0.2%	37.80	-5.00	1.26
	0.3%	37.86	-4.92	1.33
Sodium Bicarbonate	0.1%	37.51	-6.12	1.06
	0.2%	37.65	-5.52	1.13
	0.3%	37.72	-5.34	1.19

Sodium chloride with concentration of 1per cent showed more greenness, which depicts negative a value (-4.96) as compared to other concentrations at 0.5 and 1.5per cent while in calcium chloride blanching at concentration of

0.5per cent showed maximum greenness i.e. a value of -4.73 than other concentrations at 1 and 1.5 per cent. During, blanching with sodium bicarbonate and potassium metabisulphite maximum negative a value (-6.12 and -5.13) was seen in 0.1per cent concentration as compared to others at 0.2 and 0.3 per cent. Therefore, it can be concluded that concentrations of salts for salt blanching such as sodium chloride 1 per cent, calcium chloride 0.5 per cent, potassium metabisulphite 0.1 per cent, sodium bicarbonate 0.1 per cent was found suitable as a pretreatment for fresh broccoli.

Effect of different blanching treatments on physicochemical, phytochemical constituents and antioxidant activity of cabinet dried broccoli

The physicochemical, phytochemical constituents and antioxidant activity of cabinet dried broccoli at 50ºC is tabulated in **Table 3**.

Table 3 Effect of different blanching treatments on physicochemical, phytochemical constituents and antioxidant activity of cabinet dried broccoli

Treatment	Moisture (%)	Re-hydration ratio	Color			Acidity (%)	Ascorbic acid (mg/ 100g)	Total phenol (mg/ 100g)	Total Chlorophyll (mg/ 100g)	Yield (%)	Anti oxidant activity (%)
			L	a	b						
Control	6.98	5.90	37.14	-1.04	-0.56	2.34	424	506.32	14.98	20.48	39.47
Water	5.87	5.97	39.21	-1.15	-0.71	2.30	180	293.64	22.41	19.55	27.63
Steam	6.95	5.91	38.57	-1.22	-0.83	2.32	289	481.37	27.36	20.25	37.52
KMS (0.1%)	5.84	5.99	36.85	-1.52	-1.12	2.36	602	459.35	38.10	19.34	36.13
$NaHCO_3$ (0.1%)	5.85	5.98	36.56	-1.63	-1.21	2.35	587	456.58	41.07	19.34	35.57
NaCl (1%)	5.85	5.98	36.98	-1.44	-1.09	2.35	567	433.86	35.56	19.35	33.41
$CaCl_2$ (0.5%)	5.86	5.97	37.02	-1.36	-1.01	2.34	558	419.97	33.27	19.36	32.08
CD ($p \leq 0.05$)	0.075	0.05	0.077	0.061	0.073	NS	8.88	0.0000015	0.36	0.059	0.069

Moisture and rehydration ratio

The moisture content was found to be maximum in control sample (6.98per cent) followed by steam blanching (6.95per cent), water blanching (5.87per cent), calcium chloride blanching (5.86per cent), sodium chloride blanching, sodium bicarbonate blanching (5.85per cent) and KMS blanched samples (5.84 per cent) as shown in Table 3. Results of this study were in accordance with [27] who reported the effect of pre treatments on cabinet dried samples. They found that control samples retain more moisture than salt treated samples due to osmosis. The lowest rehydration ratio (5.90) was recorded for untreated sample while the highest (5.99) in KMS treated samples. Similarly, [28-30] found that pretreatments, such as dipping in solution of sodium chloride, sodium bisulphite and starch improved the reconstitution of the dried carrots.

Acidity

Acidity differs non significantly and ranged from 2.30 to 2.36 per cent as shown in Table 3. After drying, analysis of dried broccoli was done, from which it was concluded that maximum acidity was retained in KMS pre treated sample (2.36per cent) and minimum in plain water blanched samples (2.30 per cent). From all the blanched samples, salt treated samples retained almost similar acidity i.e as in sodium bicarbonate treated samples 2.35 per cent acidity was recorded which was almost near about to the 2.36 per cent acidity found in KMS treated samples Similar per cent difference of acidity was observed in sodium chloride and calcium chloride.

Ascorbic acid

Ascorbic acid, being an important constituent for biological functions in human body, is one of the most important nutrients in broccoli as well as in many other horticultural crops [31]. Losses of ascorbic acid in fresh, processed and their products were well known. The ascorbic acid content retained after the pre treatment during drying has been

presented in Table 3.

From data it can be depicted that ascorbic acid retention was more in control samples (424mg /100g) than steam (289 mg/100g) and water (180 mg/100g) blanching. Steam blanching was considered better than water blanching because the loss of ascorbic acid was maximum during leaching than the heat treatment. The results of present study were in accordance to the [32, 33], who reported that steam cooking of broccoli has less influence on vitamin C, whereas cooking in water significantly lowered its content due to the leaching. Among all chemically blanched broccoli samples the maximum retention of ascorbic acid content (602 mg/100g) was observed in KMS treated samples which was significantly ($p \leq 0.05$) higher than the other blanched treated samples (Table 3) due to antioxidant effects of sulphites which minimize the losses of ascorbic acid in dried fruits [34, 35].

Total phenol

Total phenol and antioxidant activity differs significantly ($p \leq 0.05$) after drying. Fresh broccoli was found to have 112.4 mg/100g phenolic. The hydroxycinnamic acid derivatives and flavonoids are the main phenolic compounds present in broccoli. [36]. There was a significant ($p \leq 0.05$) reduction in phenolic content of broccoli after blanching. Maximum phenol content was recorded in control samples than any other because during blanching prior to drying the phenolic content was lost due to the leaching. Similar, results were reported by [37]. They observed that reduction in phenols may be attributed to the leaching of polyphenols in water, from the vegetable tissues. Hence, the maximum phenolic content 506.32 mg/100g was recorded in control followed by KMS treated sample (459.35 mg/100g), sodium bicarbonate (456.35 mg/100g), sodium chloride (433.86 mg/100g), calcium chloride (419.97 mg/100g) and water blanched samples (293.64 mg/100g). The loss of phenolic content in salt blanching was less as compared to water and steam blanching and that might be due to salts which prevent the loss of it in water, but in case of KMS and sodium bicarbonate the retention was almost similar as sulphites and bicarbonates acts as antioxidant [35].

Antioxidant activity

The antioxidant activity of pre treated samples differs significantly ($p \leq 0.05$) after drying. The decrease in antioxidant activity may be due to decrease in polyphenol content due to leaching. Similarly, [38], found that antioxidant activity correlated to phenolic content concentration, as determined by Folin-Ciocaltoeu method. Thus, the data in the Table 3 also depicted that antioxidant activity relates to the phenol content. Antioxidant activity of control was found to be higher similarly, as phenolic content and was followed by KMS, sodium bicarbonate, sodium chloride and calcium chloride treated sample. According to [39] conducted a study on bioactive compounds and antioxidant capacity of raw and blanched vegetables. From the study, they concluded that after blanching the phenolic content and antioxidant activity either decreased or increased depending on the type of vegetables. Total phenolic content was positively correlated with the antioxidant activity to some extent but not with ascorbic acid. Similar, results related to ascorbic acid and antioxidant were shown in the Table 3.

Chlorophyll and color

Highest chlorophyll content was obtained in sodium bicarbonate blanched samples i.e. 41.07 mg/100 g thereby exhibited more greenness value i.e. a value of -1.63 followed by KMS blanched samples i.e. 38.1 mg/100 g thereby exhibited more greenness value i.e. a value of -1.52 which was significantly higher than the other treated samples. [40] Reported improvement in chlorophyll retention with magnesium oxide, potassium metabisulphite and sodium bicarbonate blanching, while improved chlorophyll retention with sulphite treatment was reported by [41].

Yield per cent was observed in all the treatments in cabinet dried broccoli at 50°C is shown in **Figure 1**. It was clear from figure that highest yield was obtained in control sample (20.48) followed by steam blanching (20.25), water blanching (19.55), calcium chloride blanching (19.36), sodium chloride blanching(19.35) and almost similar in sodium bicarbonate blanching (19.347) and KMS blanching(19.34).

Effect of storage of different blanching treatments on physicochemical, phytochemical constituents and antioxidant activity of cabinet dried broccoli

Effect of storage on moisture content and rehydration ratio of dried broccoli

The effect of storage on the moisture content was observed during 6 months of storage is represented in **Table 4**. Storage was found to have a noticeable influence on the moisture content of dried broccoli. The mean initial moisture content was 6.17% at zero month, which increased significantly to 8.46% after 6 months of storage as shown in Table 4. Among the various blanching treatments highest mean moisture content was observed in control sample and lowest

in KMS blanched samples. Rehydration ratio of the entire dried broccoli owing to be affected by storage is also shown in Table 4. During storage the mean rehydration ratio was 5.96 at 0 month and 5.83 after 6 months of storage. The rehydration ratio declined by 2.18% during 6 months of storage and that might be due to micro-structural changes during storage. Highest mean rehydration ratio was observed in KMS blanched samples due to least moisture content.

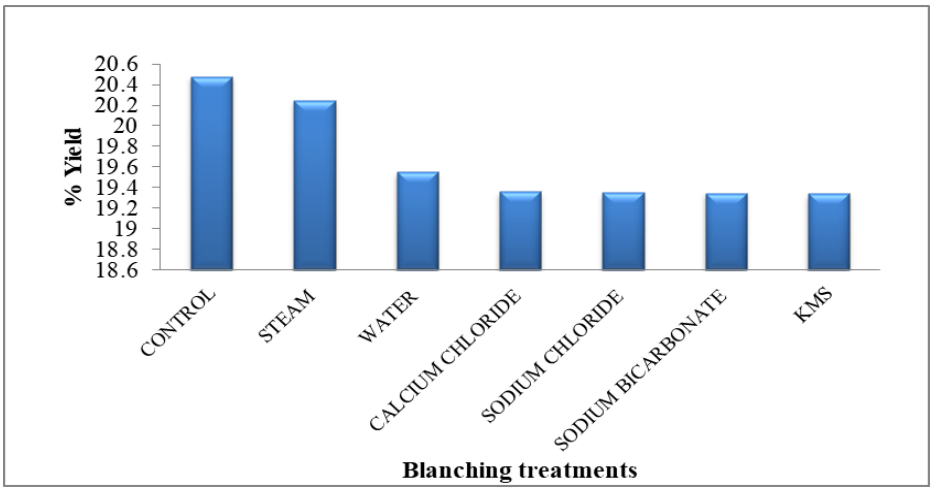

Figure 1 Effect of blanching treatments on the yield (%) of broccoli in cabinet drying (50°C)

Table 4 Effect of storage on moisture content (%) and rehydration ratio of cabinet dried broccoli

Storage months	Cabinet drying 50°C (Moisture content)								Cabinet drying 50°C (Rehydration ratio)							
	Control	Steam	H_2O	KMS	$NaHCO_3$	NaCl	$CaCl_2$	Mean	Control	Steam	H_2O	KMS	$NaHCO_3$	NaCl	$CaCl_2$	Mean
0	6.98	6.95	5.87	5.84	5.85	5.85	5.86	**6.17**	5.90	5.91	5.97	5.99	5.99	5.98	5.97	**5.96**
1	7.20	7.15	6.16	6.09	6.10	6.11	6.12	**6.42**	5.89	5.89	5.96	5.98	5.98	5.96	5.96	**5.94**
2	7.59	7.52	6.52	6.43	6.45	6.47	6.48	**6.78**	5.88	5.88	5.93	5.95	5.95	5.94	5.94	**5.92**
3	7.93	7.89	6.91	6.82	6.82	6.85	6.87	**7.15**	5.87	5.87	5.89	5.94	5.93	5.91	5.91	**5.90**
4	8.47	8.43	7.30	7.27	7.28	7.30	7.32	**7.62**	5.83	5.84	5.86	5.91	5.89	5.86	5.85	**5.86**
5	8.94	8.87	7.85	7.81	7.82	7.84	7.86	**8.14**	5.83	5.83	5.85	5.88	5.88	5.85	5.85	**5.85**
6	9.22	9.18	8.17	8.13	8.15	8.18	8.18	**8.46**	5.81	5.82	5.83	5.86	5.86	5.82	5.83	**5.83**
Overall mean	**8.05**	**8.00**	**6.97**	**6.91**	**6.92**	**6.94**	**6.95**		**5.85**	**5.86**	**5.90**	**5.93**	**5.92**	**5.90**	**5.90**	

Effect of storage on titratable acidity and ascorbic acid of dried broccoli

Table 5 represents the effect of storage on the titratable acidity of dried broccoli. There was significant ($p \leq 0.05$) reduction of acidity during storage period. The mean per cent acidity at beginning of storage was 2.34per cent, which declined by 3.41 per cent after 6 months of storage. The decrease in acidity noticed in the present study might have been due to reaction of acid with basic minerals present in the dried sample or also due to any other biochemical interactions resulting in binding of acid with the other components with the passage of time [12]. Acidity decreased from 2.36 to 2.28per cent in KMS treated dried samples as shown in Table 5. The reduction in the acidity during storage might be due to disappearance of SO_2 and intake of the moisture from environment [42].

The effect of storage on the ascorbic acid retention in dried broccoli is also presented in Table 5. During storage, there was a significant ($p \leq 0.05$) reduction of the mean ascorbic acid content by 50 per cent of the initial ascorbic acid content after 6 months of storage. The maximum mean among all the treated samples was observed in KMS blanched sample (488 mg/100g) and minimum in water blanched sample (93 mg/100g). [43] reported that vitamins in sulphured fruits were preserved better than control ones. On drying the loss of ascorbic acid was observed as it is heat sensitive bioactive compound. Similarly, [44] also reported decrease in the concentration of ascorbic acid (the predominant form of vitamin C) in broccoli.

Table 6 represents the effect of storage on the total chlorophyll content of dried broccoli. There was significant ($p \leq 0.05$) reduction of chlorophyll content during storage period. Maximum chlorophyll content was found in sodium bicarbonate blanched samples followed by KMS blanched samples, NaCl blanched samples, $CaCl_2$ blanched samples, steam blanched samples, water blanched samples and minimum in control sample. The mean of chlorophyll content at beginning of storage was 30.17, which declined by 24.10 per cent after 6 months of storage. [45] from their experiments conducted found that total chlorophyll decreased with both drying and storage but the decrease was

negligible. The color profile of dried broccoli affected by storage is given in Table 6 and 7. There was significant ($p \leq 0.05$) increase in L value from 37.47 - 39.71 as shown in Table 6 and significant decrease was observed in the a value observed during storage as shown in **Table 7**. During storage, the a values vary from -1.33 (at 0 month) to 0.41 (after 6 months) such that a value increases with storage. The negative a value represents degree of greenness in the product, which declines during progressive storage. The mean a values of dried broccoli was found to be significantly higher in case of sodium bicarbonate blanched samples (-1.17) followed by KMS (-0.99), NaCl (-0.93), $CaCl_2$ (-0.92), steam (-0.29), water blanched samples (-0.03) and lower in control samples (0.13). Significant ($p \leq 0.05$) increase in the b value was also observed during storage, which varies from -0.89 (at 0 month) to 1.78 (after 6 months).

Table 5 Effect of storage on acidity (%) and ascorbic acid (mg/100g) of cabinet dried broccoli

Storage months	Cabinet drying 50°C (Acidity)								Cabinet drying 50°C (Ascorbic acid)							
	Control	Steam	H_2O	KMS	$NaHCO_3$	NaCl	$CaCl_2$	Mean	Control	Steam	H_2O	KMS	$NaHCO_3$	NaCl	$CaCl_2$	Mean
0	2.34	2.32	2.30	2.36	2.35	2.35	2.34	**2.34**	424	289	180	602	587	567	558	**458**
1	2.32	2.29	2.27	2.34	2.33	2.32	2.31	**2.31**	386	251	158	565	550	528	520	**422**
2	2.31	2.29	2.26	2.33	2.32	2.31	2.29	**2.30**	349	214	126	528	511	493	480	**385**
3	2.31	2.28	2.26	2.33	2.31	2.30	2.28	**2.29**	309	172	90	487	481	450	443	**347**
4	2.30	2.27	2.25	2.31	2.30	2.29	2.28	**2.28**	271	138	52	451	444	414	406	**310**
5	2.28	2.26	2.25	2.30	2.29	2.28	2.27	**2.27**	228	104	33	412	400	377	363	**273**
6	2.26	2.25	2.23	2.28	2.27	2.27	2.27	**2.26**	193	71	16	371	337	330	291	**229**
Overall mean	**2.30**	**2.28**	**2.26**	**2.32**	**2.31**	**2.30**	**2.29**		**308**	**177**	**93**	**488**	**472**	**451**	**437**	

Effect of storage on chlorophyll and color of dried broccoli

Table 6 Effect of storage on total chlorophyll (mg/100g) and color (L value) of cabinet dried broccoli

Storage months	Cabinet drying 50°C (Total chlorophyll)								Cabinet drying 50°C (L value)							
	Control	Steam	H_2O	KMS	$NaHCO_3$	NaCl	$CaCl_2$	Mean	Control	Steam	H_2O	KMS	$NaHCO_3$	NaCl	$CaCl_2$	Mean
0	14.98	27.36	14.96	38.10	41.07	37.43	37.31	**30.17**	37.14	38.57	39.24	36.85	36.56	36.87	37.05	**37.47**
1	12.60	26.61	12.54	37.82	40.68	36.12	36.03	**28.91**	37.48	38.90	40.01	37.02	36.63	37.19	37.43	**37.81**
2	10.28	25.47	12.02	37.06	40.13	34.01	34.21	**27.60**	37.69	39.12	40.68	37.28	36.95	37.38	37.60	**38.10**
3	8.69	23.19	11.00	36.54	39.45	32.45	32.30	**26.32**	38.20	39.33	40.93	37.64	37.12	37.71	38.11	**38.43**
4	7.06	22.64	10.33	36.12	38.57	31.33	31.28	**25.33**	38.57	39.63	41.12	37.92	37.59	38.08	38.33	**38.75**
5	5.36	21.32	10.00	35.63	38.05	29.72	28.64	**24.10**	39.19	40.11	41.27	38.23	37.88	38.45	38.86	**39.14**
6	3.50	20.35	9.78	33.09	37.46	28.10	28.00	**22.90**	40.02	40.54	41.96	38.41	38.36	38.97	39.69	**39.71**
Overall mean	**8.92**	**23.85**	**11.60**	**36.34**	**39.34**	**32.74**	**32.54**		**38.33**	**39.46**	**40.74**	**37.62**	**37.30**	**37.81**	**38.15**	

Table 7 Effect of storage on color (a and b value) of cabinet dried broccoli

Storage months	Cabinet drying 50°C (a value)								Cabinet drying 50°C (b value)							
	Control	Steam	H_2O	KMS	$NaHCO_3$	NaCl	$CaCl_2$	Mean	Control	Steam	H_2O	KMS	$NaHCO_3$	NaCl	$CaCl_2$	Mean
0	-1.04	-1.22	-1.01	-1.52	-1.63	-1.47	-1.45	**-1.33**	-0.56	-0.83	-0.51	-1.12	-1.21	-1.00	-0.98	**-0.89**
1	-0.53	-1.02	-0.47	-1.34	-1.48	-1.30	-1.31	**-1.06**	-0.22	-0.41	-0.18	-0.66	-0.72	-0.60	-0.60	**-0.48**
2	-0.36	-0.81	-0.39	-1.27	-1.36	-1.21	-1.19	**-0.94**	0.74	0.66	0.87	0.42	0.37	0.47	0.50	**-0.57**
3	-0.09	-0.58	-0.19	-1.10	-1.29	-1.03	-1.00	**-0.75**	1.72	0.85	1.93	0.67	0.41	0.70	0.72	**1.00**
4	0.62	-0.22	-0.07	-0.85	-1.15	-0.79	-0.82	**-0.47**	1.96	1.24	2.43	0.79	0.63	0.84	0.85	**1.25**
5	0.91	0.44	0.53	-0.54	-0.72	-0.53	-0.51	**-0.06**	2.36	1.68	2.59	1.18	0.75	1.24	1.30	**1.58**
6	1.41	1.34	1.37	-0.29	-0.58	-0.21	-0.17	**0.41**	2.55	1.91	2.71	1.32	1.19	1.39	1.42	**1.78**
Overall mean	**0.13**	**-0.29**	**-0.03**	**-0.99**	**-1.17**	**-0.93**	**-0.92**		**1.22**	**0.73**	**1.40**	**0.37**	**0.20**	**0.43**	**0.44**	

Effect of storage on total phenol and antioxidant activity of dried broccoli

The data pertaining to effect of storage on the total phenols of dried broccoli sample as investigated during 6 months of storage is presented in **Table 8**. There was significant ($p \leq 0.05$) reduction of total phenols during storage. The observations of our study were similar to [46, 47], who also reported that total phenols decreased due to the presence of enzymes which results in oxidation of the phenols. During the six months of storage period the mean of total phenols was found highest in KMS blanched samples and lowest in control samples. Significant ($p \leq 0.05$) decrease in the mean phenolic content i.e. 57.14per cent of the initial phenolic content was observed after 6 months of storage.

Effect of storage on antioxidant activity of dried broccoli sample as observed during 6 months of storage is also presented in Table 8. There was significant ($p \leq 0.05$) reduction of antioxidant activity during storage. The highest antioxidant activity was observed in control samples at initial storage period but at the end of 3 months storage least antioxidant activity was calculated in control among all the samples. This was due to the same trend of phenol content because antioxidant activity strongly relates to the phenolic content. [48] also reported that polyphenols are strongly correlated with the antioxidant activity. During the six months of storage period the mean of total phenols was found highest in KMS blanched samples and lowest in control samples. Significant ($p \leq 0.05$) decrease in the mean antioxidant activity i.e. 55.74% of the initial antioxidant activity was observed after storage of 6 months. The decrease in antioxidant activity might be due to decrease in the bioactive compounds during storage such as and total phenols and ascorbic acid [49].

Table 8 Effect of storage on total phenol (mg/100g) and antioxidant activity (% activity) of cabinet dried broccoli

Storage months	Cabinet drying 50°C (a value)								Cabinet drying 50°C (b value)							
	Control	Steam	H_2O	KMS	$NaHCO_3$	NaCl	$CaCl_2$	Mean	Control	Steam	H_2O	KMS	$NaHCO_3$	NaCl	$CaCl_2$	Mean
0	506.32	481.37	293.64	459.35	456.58	433.86	419.97	435.87	39.47	37.52	34.98	36.13	35.57	35.42	35.21	**36.33**
1	449.85	436.57	259.03	428.35	405.68	398.25	401.39	397.02	35.06	34.05	21.03	33.69	32.76	31.93	31.87	**29.96**
2	403.00	375.21	234.18	364.27	357.31	347.20	352.14	347.61	31.41	29.26	25.13	28.65	27.84	26.47	26.53	**27.90**
3	322.58	321.08	192.36	335.14	329.61	312.05	315.54	304.05	25.03	25.15	25.00	26.33	25.68	25.08	25.11	**25.34**
4	149.35	293.16	165.52	304.27	297.07	281.16	285.29	253.69	11.67	22.86	19.56	23.93	23.14	22.73	22.70	**20.94**
5	125.08	261.05	142.28	275.01	270.14	248.29	255.09	225.28	9.78	20.35	19.08	21.63	21.04	20.27	20.30	**18.92**
6	109.63	220.05	115.88	231.04	224.54	192.23	214.16	186.80	8.76	17.16	16.86	18.17	17.49	17.03	17.11	**16.08**
Overall mean	**295.11**	**341.21**	**200.41**	**342.49**	**334.42**	**316.15**	**320.51**		**23.02**	**26.62**	**23.09**	**26.93**	**25.74**	**25.04**	**25.02**	

Conclusion

Blanching time for broccoli i.e. water blanching for 180 seconds and steam blanching for 300 seconds was found suitable on the basis of peroxidase enzyme activity test. Salt concentrations used in blanched water were optimized i.e. potassium metabisulphite 0.1 per cent, sodium bicarbonate 0.1per cent, sodium chloride 1per cent and calcium chloride 0.5per cent on the basis of color. Effect of different blanching treatments on physicochemical, phytochemical constituents and antioxidant activity of cabinet dried broccoli was studied initially immediately after drying such that yield, total phenol and antioxidant activity obtained was highest in control sample (untreated) and potassium metabisulphite was found to have better retention of moisture, rehydration ratio, acidity and ascorbic acid in dried broccoli. Sodium bicarbonate was found to have better retention of total chlorophyll and color attributes in dried broccoli. During storage of six months significant ($p \leq 0.05$) decrease was observed in acidity, ascorbic acid, total phenols, antioxidant activity, rehydration ratio, total chlorophyll and color values in all the samples of dried broccoli but there was significant ($p \leq 0.05$) increase in moisture content. Among the various blanching treatments, potassium metabisulphite blanched samples were found to have better retention of moisture, rehydration ratio, acidity, ascorbic acid, total phenols, and antioxidant activity during storage of six months in dried broccoli. Sodium bicarbonate blanched samples were found to have better retention of total chlorophyll and color attributes during storage of six months in dried broccoli.

References

[1] Cao G., Sofic E., Prior R.L., (1996): Antioxidant capacity of tea and common vegetables. Journal of Agricultural and Food Chemistry, 44: 3426-3431.

[2] Terry P., Terry J.B., Wolk A. (2001): Fruit and vegetable consumption in the prevention of cancer. Journal of Internal Medicine, 250: 280-290.

[3] Brennan P.S., Shewflet R.L., (1989): Effect of cooling delay at harvest on broccoli quality during postharvest storage. Journal of Food Quality, 12: 13-22.

[4] Rakotonirainy A.M., Wang Q., Padua G.W. (2001): Evaluation of zein films as modified atmosphere packaging for fresh broccoli. Journal of Food Science, 66: 108-111.

[5] Lemoine M.L., Civello M., Martinez G., Chaves A. (2007): Influence of a postharvest UV-C treatment on refrigerated storage of minimally processed broccoli. Journal of the Science of Food and Agriculture, 87: 1132-1139.
[6] Tian M.S., Woolf A.B., Bowen J.H., Ferguson I.B. (1996): Changes in color and chlorophyll fluorescence of broccoli florets following hot water treatment. Journal of the American Society for Horticultural Science, 121: 310- 313.
[7] Shahab S., Jayas D.S. (1987): Drying of foodstuffs. In A. S. Mujumdar (Ed.) Handbook of industrial drying 517-55 New York: Marcel Dekker.
[8] Cano M.P. (1996): Vegetables. In L.E. Jeremiah (Ed.), Freezing effects on food quality. pp. 520. New York: Marcel Dekker.
[9] Prochaska L.J., Nguyen X.T., Donat N., Piekutowski W.V. (2000): Effects of food processing on the thermodynamic and nutritive value of foods: literature and database survey. Medical Hypotheses, 54: 254-262
[10] Rawson A., Koidis A., Patras A., Tuohy M., Brunton N.P. (2010): Modelling the effect of thermal processing on polyacetylene levels in carrot disks. Food Chemistry 121:62-68.
[11] AOAC (2005) Official Methods of Analysis of AOAC International (18th Ed.) Offficial Association of Analytical Chemists, Washington, DC.
[12] Sra S.K., Sandhu K.S., Ahluwalia P. (2011): Effect of processing parameters on physico-chemical and culinary quality of dried carrot slices. Journal of Food Science and Technology, 48: 159-166.
[13] Ranganna S. (1997): Handbook of Analysis and Quality Control for Fruit and Vegetable Products.Tata Mc Graw Hill Pub Co. Ltd. New Delhi, India.
[14] Swain T., Hillis W.E. (1959): The phenolic constituents of Prunus domestica I. The quantitative analysis of phenolic constituents. Journal of the Science of Food and Agriculture, 10: 63-68.
[15] Singh U.R. (1977): Growth and maturity indices of banana. Indian Journal of Horticulture, 34:19-25.
[16] Singh S., Singh T., Bansal M.L., Kumar R. (1991): Statistical methods for research workers. Kalyani publishers, New Delhi.
[17] Redman C.T.P. (2009): Factors affecting the composition and quality of broccoli juice. M. Tech thesis, Massey University, Palmerston North, New Zealand.
[18] Koh E., Wimalasiri K.M.S., Chassy A.W., Mitchell A.E. (2009): Content of ascorbic acid, quercetin, kaempferol and total phenolics in commercial broccoli. Journal of Food Composition and Analysis, 22: 637-643.
[19] Patras A., Tiwari B.K., Brunton N.P. (2011): Influence of blanching and low temperature preservation strategies on antioxidant activity and phytochemical content of carrots, green beans and broccoli. LWT Food Science and Technology, 44: 299-306.
[20] Nadia G., Moez M.R.A. (2011): Broccoli growth, yield quantity and quality as affected by cobalt. Agriculture and Biology Journal of North America DOI: 2151-7517, ISSN Online
[21] Nath A., Bagchi B., Misra L.K., Deka B.C. (2011): Changes in post-harvest phytochemical qualities of broccoli florets during ambient and refrigerated storage. Food Chemistry, 127: 1510-1514.
[22] Albrecht J.A., Schafer H.W., Zottola E. A. (1990): Relationship of total sulfur to initial and retained ascorbic acid in selected cruciferous and non cruciferous vegetables. Journal of Food Science, 55: 181-183.
[23] Vallejo F., Barberan F.A.T., Viguera G.C. (2002): Glucosinolates and vitamin C content in edible parts of broccoli florets after domestic cooking. European Food Research and Technology, 215: 310-316.
[24] Chu Y. F., Sun J., Wu X., Liu R.H. (2002): Antioxidant and antiproliferative activities of common vegetables. Journal of Agricultural and Food Chemistry, 50: 3010-3014.
[25] Funamoto Y., Yamauchi N., Shigyo M. (2003): Involvement of peroxidase in chlorophyll degradation in stored broccoli (Brassica oleracea L.) and inhibition of the activity by heat treatment. Postharvest Biology and Technology, 28: 39- 46.
[26] Lisiewska Z., Gebczynski P. (2006): Comparison of the level of selected antioxidative compounds in frozen broccoli produced using traditional and modified methods. Innovative Food Science and Emerging Technology, 7: 239-245.
[27] Mozumder N.H.M.R., Rahman M.A., Kamal M.S., Mustafa A.K.M., Rahman M.S. (2012): Effects of pre-drying chemical treatments on quality of cabinet dried tomato powder. Journal of Environmental Science and Natural Resources, 5: 253-265.
[28] Speck P.F., Escher J., Solms J. (1977): Effect of salt pre-treatment on quality and storage stability of air dried vegetables. Lebensmittel Wissenschaft and Technology, 10:308-313.
[29] Baloch A.K., Buckle K.A., Edwards R. A., (1987): Effect of sulphur dioxide and blanching on the stability of carotenoids of dehydrated carrot. Journal of the Science of Food and Agriculture, 40: 179-187.

[30] Mazza G. (1983): Dehydration of carrots: Effects of pre-drying treatments on moisture transport and product quality. International Journal of Food Science and Technology, 18: 113-123.
[31] LEE S.K., KADER A.A. (2000): Preharvest and postharvest factors influencing vitamin C content of horticultural crops. Postharvest Biology and Technology, 20: 207-220.
[32] Gliszczynska S.A., Ciska E., Pawlak L.K., Chmielewski J., Borkowski T., Tyrakowska B. (2006): Changes in the content of health-promoting compounds and antioxidant activity of broccoli after domestic processing. Food Additives and Contaminants, 23: 1088-1098.
[33] Miglio C., Chiavaro E., Visconti A., Fogliano V., Pellegrini N. (2008): Effects of different cooking methods on nutritional and physicochemical characteristics of selected vegetables. Journal of Agricultural and Food Chemistry, 56: 139–147.
[34] Atkinson F.E., Strachan C.C., (1962): Sulphur dioxide preservation of fruits. Summerland Research Station, Department of Agriculture, Canada, pp SP 28.
[35] Gould G.W., Russel N.J.C. (1991): Food preservation. Pp.368. AVI Publ, New York.
[36] Cartea M.E., Francisco M., Soengas P., Velasco P. (2011): Phenolic compounds in Brassica vegetables. Molecules, 16: 251-280.
[37] Danesi F., Bordoni A. (2008): Effect of home freezing and Italian style of cooking on antioxidant activity of edible vegetables. Journal of Food Science, 73: 109-112.
[38] Duddone S., Vitrac X., Coutiere P., Woillez M., Merillon J. M. (2009): Comparative study on antioxidant properties and total phenolic content of 30 plant extracts of industrial interest using DPPH, ABTS, FRAP, SOD and ORAC assays. Journal of Agricultural and Food Chemistry, 57:1768-1774.
[39] Wen T.N., Prasad K.N., Yang B., Ismail A. (2010): Bioactive substance contents and antioxidant capacity of raw and blanched vegetables. Innovative Food Science and Emerging Technology, 11: 464-469.
[40] Patil V.R., Kulkarni D.N., Kulkarni K., Ingle U.M. (1978): Effect of blanching factors on quality and durability of sun dried and dehydrated fenugreek (methi). Indian Food Packer, 32: 43-49.
[41] Chaudhary A.T. (1979): Retention of chlorophyll and ascorbic acid in dried fenugreek (Trigonella foenom graecum). Indian Food Packer, 33: 35-51.
[42] Sagar V.R., Khurdiya D.S., Maini S.B. (2000). Quality of ripe mango powder as affected by storage temperature and period. Journal of Food Science &Technology, 37:165-168.
[43] Shrivastava R.P., Kumar S. (2007): Fruit and vegetable preservation: Principles and practices. International Book Distributing Co, Lucknow.
[44] Serrano M., Martinez R.D., Guillen F., Castillo S., Valero D. (2006): Maintenance of broccoli quality and functional properties during cold storage as affected by modified atmosphere packaging. Postharvest Biology and Technology, 39: 61-68.
[45] Oladele O.O., Aborisade A.T. (2009): Influence of different drying methods and storage on the quality of Indian Spinach (Basella rubra L.). American Journal of Food Technology, 4: 66-70.
[46] Vinson J.A., Su X., Zubik L., Bose P. (2001): Phenol antioxidant quantity and quality in foods. Journal of Agricultural and Food Chemistry, 49: 5315–5321.
[47] Akagic B.A., Spaho N., Orucevic S., Drkenda P., Kurtovic M., Gasi F., Kopjar M., Pilizota (2011): Influence of cultivar, storage time and processing on the phenol content of cloudy apple juice. Journal of Food Science and Technology, 3: 1-8.
[48] Gardner P.T., White T.A.C., Mcphail D.B., Duthie G.G.(2000): The relative contributions of vitamin C, carotenoids and phenolics to the antioxidant potential of fruit juices. Food Chemistry, 68: 471-474.
[49] Klimczak I., Matecka M., Szlachta M., Swiglo A.G. (2007): Effect of storage on the content of polyphenols, vitamin C and the antioxidant activity of orange juices. Journal of Food Composition and Analysis, 20: 313-322.

Publication History
Received 21st Jan 2018
Revised 08th Mar 2018
Accepted 15th Mar 2018
Online 30th Mar 2018