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Implications of the drying techniques for an effective preservation of broccoli

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Abstract
The present investigation was carried out to study the implications of the drying techniques for an effective preservation of broccoli. Blanching treatments such as potassium metabisulphite 0.1 per cent, sodium bicarbonate 0.1per cent in water at 100ºC for 180 seconds and steam blanching for 300 seconds were found suitable for blanching treatments in broccoli. Among the blanching treatments potassium metabisulphite was found to have better retention of moisture, rehydration ratio, acidity, ascorbic acid, total phenols and antioxidant activity during storage of dried broccoli. Sodium bicarbonate was found to have better retention of total chlorophyll and color attributes during storage of 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 dried by different drying techniques but there was significant ($p \leq 0.05$) increase in moisture content. The freeze drying method was found best to retain physicochemical, phytochemical constituents and antioxidant activity during 6 months of storage followed by cabinet drying (50ºC), solar drying, sun drying and fan drying.

Keywords: implications, preservation, broccoli, blanching, antioxidant activity, storage

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. Currently India ranks second in the combined production of broccoli and cauliflower with annual production of 59, 88, 500 tonnes (FAO 2012) [9]. Broccoli, one of the major agricultural products widely considered to contain high level of phytochemicals including glucosinolates and flavonoids. Glucosinolates, a secondary metabolite product, was found in Brassica vegetables including broccoli. These compounds have gained renewed interest in recent years due to the chemoprotective properties of their major hydrolysis products, isothiocyanates. The main isothiocyanate in broccoli is sulforaphane, which together with selenium can regulate the expression and activity of thioredoxin reductase in humans (Campbell *et al*. 2007) [5]. These phytochemicals and nutrients have gained renewed interest in preventing cancer, cardiovascular diseases and stimulate the immune system (Terry *et al*. 2001) [40].

Broccoli florets have a shorter shelf-life as a result of high rates of respiration and metabolism, during which many chemical reactions occur (Brennan and Shewflet 1989) [4]. Some of these reactions, if not controlled, can lead to rapid senescence and undesirable quality loss, expressed as surface dehydration, loss of green color and stem firmness, opening of florets, development of undesirable odors, and soft rots (Forney *et al*. 1993) [11] 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, UV-C treatments (Lemoine *et al*. 2007) [18], heat treatments like hot water (Tian *et al*. 1996) [41] and appropriate refrigerated storage (Gillies and Toivonen 1995) [14]. These treatments have been observed to effectively reduce yellowing of stored fresh broccoli while some other scientists used dehydration technique for preservation of broccoli (Shahab and Jayas 1987) [33].

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. Thus, dehydration techniques were used to maintain quality criteria like color, nutritional composition, shape or texture. Therefore, there is need to standardize the techniques for drying of broccoli and to study the effect of drying techniques on physicochemical, phytochemical constituents and antioxidant activity of 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 analysed for the peroxidase enzyme activity test. Broccoli was blanched with different concentrations of salts such as potassium metabisulphite (0.1%, 0.2%, 0.3%) and sodium bicarbonate (0.1%, 0.2%, 0.3%) in hot water at 100° C for 180 seconds and optimized on the basis of color test.

Drying of broccoli using different drying methods

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 drying methods.

Drying of Broccoli

The cabinet dryer was used for drying with the capacity of twelve trays. The broccoli was spread evenly in a single layer on trays. The trays were placed inside the cabinet dryer maintained at 50 ºC and dried till they attained similar amount of moisture content. Freeze drying process took 72 hours to dry the broccoli. Freeze drying is a process whereby water or other solvent is removed from frozen material by converting the frozen water directly into vapor without the intermediate formation of liquid water. The fan drying method was used for drying of broccoli. The broccoli was spread evenly in a single layer on trays. The trays were placed in open room under fan for 1 month. The sun drying method was used for drying of broccoli. The broccoli was spread evenly in a single layer on trays. The trays were kept under open sun light for 6 hours for 9 days. The solar drying method was used for drying of broccoli. The broccoli was spread evenly in a single layer on trays of solar drier. The solar drier was kept in sunlight facing direct rays of sun for 6 hrs for 3 days.

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.

Analysis of the drying data and drying models

Data was analysed at regular intervals of dried broccoli

Moisture ratio

Moisture ratio was calculated at different drying times

MR= M-Me/Mo-Me

Where,

M= Moisture content of sample at any time (%, db), Me= Equilbrium moisture content (%, db),

Mo= Initial moisture content (%, db)

Implication of drying model

The semi-theoretical and empirical model used to describe the drying kinetics of sample. Drying curves were fitted to the experimental data using moisture ratio equations. MR is the moisture ratio defined as M/Mo: M is the moisture content at time t and Mo is the initial moisture content, dry basis. However, moisture ratio (MR) was simplified to M/Mo instead of (M-Me/Mo-Me) as used by many authors (Pokharkar and Parsad 2002)

Model name	Model	Reference
Newton	MR= exp(-kt)	Page (1949)

Adequacy of fit of empirical model

Modeling the drying behavior of different agricultural products often requires the statistical methods of regression and correlation analysis. Linear and nonlinear regression models are important tools to find the relationship between different variables, especially for which no established empirical relationship exists. Regression analysis was conducted to fit the mathematical models by the statistical package for social sciences (SPSS version 11.5). The determination coefficient (R2) and plots of residuals were the primary criterions for selecting the best equation to define the drying curves. In addition to R2, the goodness of fit was determined by various statistical parameters such as reduced chi- square(χ2), mean bias error (MBE), root mean square error (RMSE) and mean deviation modulus (P) and were defined by the equations 1.1 to 1.5 (Gomez and Gomez, 1983).

$$R^2 = \frac{\sum_{i=1}^{n}\left(MR_i - MR_{pre,i}\right)\cdot\sum_{i=1}^{n}\left(MR_i - MR_{exp,i}\right)}{\sqrt{\left[\sum_{i=1}^{n}\left(MR_i - MR_{pre,i}\right)^2\right]\cdot\left[\sum_{i=1}^{n}\left(MR_i - MR_{exp,i}\right)^2\right]}} \quad (1.1)$$

$$\chi^2 = \frac{\sum_{i=1}^{n}\left(MR_{exp,i} - MR_{pre,i}\right)^2}{N-n} \quad (1.2)$$

$$MBE = \frac{1}{N}\sum_{i=1}^{N}\left(MR_i - MR_{pre,i}\right) \quad (1.3)$$

$$RMSE = \left[\frac{1}{N}\sum_{i=1}^{N}\left(MR_i - MR_{pre,i}\right)^2\right]^{\frac{1}{2}} \quad (1.4)$$

$$P(\%) = \frac{100}{N}\sum_{i=1}^{N}\left|\frac{\text{Experimetnal value - Predicted value}}{\text{Experimental value}}\right| \quad (1.5)$$

Where,

$MR_{exp,\ i}$ and $MR_{pre,\ i}$ are experimental and predicted dimensionless moisture ratios, respectively, N is number of observations and z is number of constants.

Analytical Methods

Moisture and titratable acidity was determined according to AOAC (2000) method. Rehydration ratio was calculated using the method of Sra *et al*. (2011) [38]. 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 Ranganna (1997) [29] 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 Swain and Hillis (1959) [39]. Total chlorophyll of broccoli sample was determined by using the colourimetric method of Singh (1977). Antioxidant activity was estimated using the method of Shimada *et al*. (1992) [35].
Results collected were analyzed statistically with the help of factorial design in completely randomized design using the software CPCS-1 (Singh 1991).

Results and Discussion

Physicochemical, phytochemical constituents and antioxidant activity of raw broccoli

Moisture content in fresh broccoli was found to be 86.5 per cent as shown in Table 1. Earlier, Redman (2009) [30] also reported 88 per cent moisture content in fresh broccoli. Later on, according to Koh *et al*. (2009) [17] discovered that the moisture content in fresh broccoli ranged between 83.87per cent and 90.27 per cent. 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**.** Patras *et al*. (2011) [27] reported that the L value for fresh broccoli was 29.5. The acidity in fresh broccoli was found as 0.42per cent. Nadia and Moez (2011) [23] observed 0.49 per cent of titratable acidity in fresh broccoli.
During the analysis of fresh broccoli 99.2 mg/100g ascorbic acid was found in present study Similarly, Nath *et al*. (2011) [24] 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 by Albrecht *et al*. (1990) [2]; Vallejo *et al*. (2002) [42]. Later on, Koh *et al*. (2009) [17] reported that 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. Patras *et al*. (2011) [27] observed the total phenolic content of 446 mg GAE/100 g in fresh broccoli. Similarly, Chu *et al*. (2002) [8] showed that fresh broccoli had a total phenol content of 101.63 mg GAE/100 g. Koh *et al*. (2009) [17] reported that the value of phenol content ranged within 48.15 to 157.77 mg GAE/100 g in raw broccoli. Total chlorophyll in fresh broccoli was found to be 19.23 mg/100 g. Funamoto *et al*. (2003) [23] observed 26 mg/100g of total chlorophyll in fresh broccoli. The fresh broccoli contained 37 per cent antioxidant activity presented in Table 1. Lisiewska and Gebczynski (2006) [20] observed 40.3±0.7per cent antioxidant activity in fresh broccoli.

Table 1: Physicochemical and phytochemical constituents of fresh broccoli

Parameters		Fresh Broccoli
Moisture (%)		86.5
Acidity (%)		0.47
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 different drying methods on physicochemical, phytochemical constituents and antioxidant activity of dried broccoli

Effect of different drying methods on physicochemical, phytochemical constituents and antioxidant activity of dried broccoli is tabulated in Table 2. As evident from Table 7, the moisture content was highest (10.68) in fan dried broccoli followed by sun dried broccoli (7.29), solar dried broccoli (7.23), cabinet dried broccoli (6.98) and the lowest (4.63) was recorded in freeze dried broccoli. Fig 1, explains the effect of various blanching treatments on weight loss in relation to time in cabinet dried broccoli at 50° C. At the end of 8 h of drying there was 79.42 per cent reduction in control sample followed by 79.55per cent in steam blanched sample, 80.65per cent in sodium bicarbonate blanched sample and 80.66per cent in KMS blanched sample. The rate of dehydration in fan dried broccoli was shown in Fig 2 where drying was carried out for 30 days. At the end of 30 days of drying highest weight reduction occurred in KMS blanched sample (76.61per cent) and lowest in control sample (75.72per cent). Similarly in sun drying after 9 days of drying weight reduced by 79.01per cent in control sample followed by 79.24per cent in steam blanched sample, 80.21per cent in sodium bicarbonate blanched sample and 80.24 per cent in KMS blanched sample. In solar drying at the end of 3 days of drying there was 79.27per cent reduction in control sample followed by 79.31per cent reduction in steam blanched sample, 80.28per cent reduction in sodium bicarbonate blanched sample and 80.29 per cent reduction in KMS blanched sample.
Rehydration ratio was found highest in freeze dried broccoli (6.31) and lowest in fan dried broccoli (5.67) as shown in Table 2. Acidity was found maximum in freeze dried broccoli (2.35 per cent) which was significantly ($p \leq 0.05$) higher than the cabinet dried sample (2.34 per cent), solar dried sample (1.86 per-cent) and sun dried sample (1.52 per-cent). Minimum acidity was found in fan dried broccoli (1.03 per cent) due to less concentration of total phenol content.
Highest retention of ascorbic acid was observed in freeze dried broccoli (438 mg/100g) which was significantly ($p \leq 0.05$) more than the cabinet dried sample followed by solar and sun dried sample Lowest ascorbic acid retention was found in fan dried broccoli (136 mg/100g) due to oxidation of ascorbic acid in the presence of air and light. Freeze dried samples retained more of ascorbic acid as compared to hot air dried samples, as freeze drying is a low temperature processing technique carried under vacuum conditions. Earlier, similar was reported by Leoni (2002) [19].

Table 2: Effect of different drying methods on physicochemical, phytochemical constituents and antioxidant activity of dried broccoli

Drying methods	Moisture (%)	Re-hydration ratio	Color			Acidity (%)	Ascorbic acid (mg/ 100g)	Total Phenol (mg/ 100g)	Total Chloro-phyll (mg/ 100g)	Anti-oxidant activity (%)
			L	a	b					
Freeze drying	4.63	6.31	39.56	-1.21	-0.61	2.35	438	548	20.18	45.55
Cabinet drying(50°C)	6.98	5.90	37.14	-1.04	-0.56	2.34	424	506	14.98	39.47
Solar drying	7.23	5.89	37.29	-0.96	-0.37	1.86	238	365	11.55	28.46
Sun drying	7.29	5.88	50.48	-0.08	1.21	1.52	143	322	7.85	25.11
Fan drying	10.68	5.67	44.82	0.69	2.31	1.03	136	236	3.28	18.43
CD (p≤0.05)	0.40	0.15	0.83	0.32	0.33	0.13	20.59	11.21	3.39	5.21

Effect of different drying techniques on rate of dehydration of broccoli

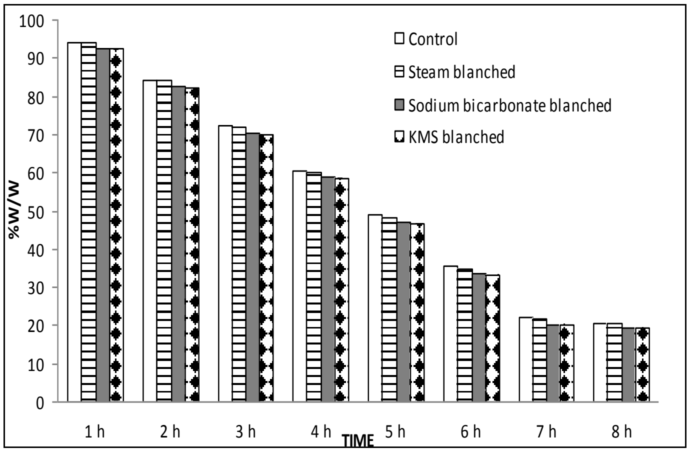

Fig 1: Rate of drying of broccoli in cabinet drying at 50°C

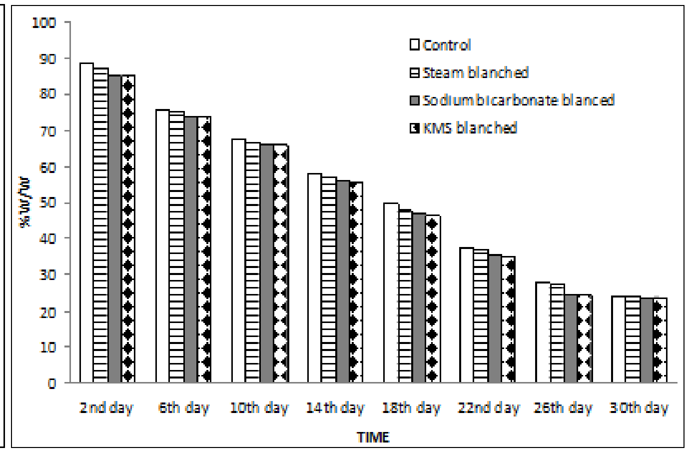

Fig 2: Rate of drying of broccoli in fan drying

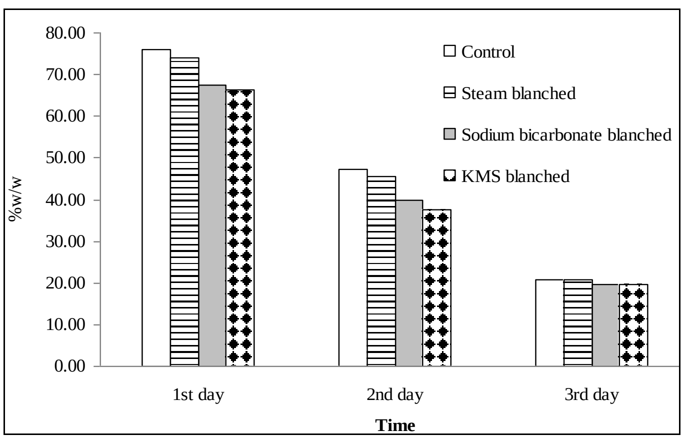

Fig 3: Rate of drying of broccoli in sun drying

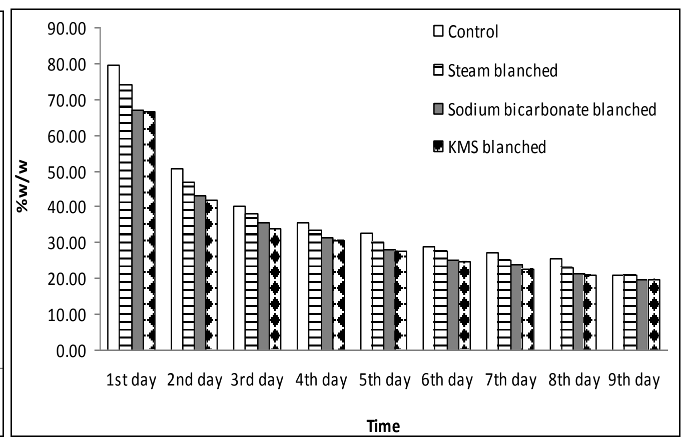

Fig 4: Rate of drying of broccoli in solar drying

Vitamin C is destroyed mainly due to oxidation reactions and heat applied in the presence of air. Later on, Chang *et al*. (2006) [6] found that low temperature processing brought about minor effect on the loss of ascorbic acid as compared to high temperature treatment which leads to tremendous decrease in ascorbic acid. Total phenols were found to be highest in freeze dried broccoli (548.62 mg GAE/100g) and lowest in fan dried broccoli (236.51 mg GAE/100g) due to less phenol concentration in vegetable tissue because of open air drying and more losses occur in fan dried sample. Maximum antioxidant activity was recorded in freeze dried broccoli (45.55 per cent) due to high phenolic content and other bioactive compounds. Freeze dried broccoli showed the maximum total chlorophyll content (20.18 mg/100g) and lowest in fan dried broccoli (3.28 mg/100g). Similar trend was observed in color attributes (a value) in which greenness was significantly (p≤0.05) higher in freeze dried sample (-1.21) and lower in fan dried sample (0.69).

Validation of drying model

In order to evaluate the performance of newton model, the values of statistical parameters for all the experiment runs were compared and model coefficients for newton model was calculated by using non-linear regression techniques of SPSS version 11.5. Newton model was fitted to experimental data using –Plot.

For cabinet, solar, sun and fan drying

The model showed the R^2 value >0.89 for cabinet dried broccoli. The highest R^2 value was observed in case of KMS blanched sample i.e. 0.903 and least in control sample i.e. 0.895. The least χ2 value was observed in KMS blanched sample i.e. 0.00767. K value was observed highest in case of KMS blanched sample (0.165) followed by sodium bicarbonate blanched sample (0.164), steam blanched sample (0.158) and least in control sample (0.156). P% was observed highest in case of KMS blanched sample i.e. 21.97% as shown in Table 3. The highest MBE and RMSE value i.e. 0.0148 and 0.00725 was observed in case of control sample and least MBE and RMSE value i.e. 0.00125 and 0.00671 was observed in KMS blanched sample. Similarly, the model showed the R^2 value >0.88 for solar dried broccoli. K value was observed highest in case of KMS blanched sample (0.495) followed by sodium bicarbonate blanched sample (0.48), steam blanched sample (0.423) and least in control sample (0.41). P% was observed highest in case of control sample i.e. 22.21% as shown in Table 3. The highest MBE and RMSE value i.e. 0.0076 and 0.0062 was observed in case of control sample. The model showed the R^2 value >0.59 for sun dried broccoli. K value was observed highest in case of KMS blanched sample (0.295) followed by sodium bicarbonate blanched sample (0.285), steam blanched sample (0.258) and least in control sample (0.236). P% was observed highest in case of KMS blanched sample i.e. 30.35% as shown in Table. Similarly, The model showed the R^2 value >0.96 for fan dried broccoli. The highest R^2 value was observed in case of KMS blanched sample i.e. 0.967 and least in control sample i.e. 0.964. The highest χ2 value was observed in KMS blanched sample i.e. 0.00198. K value was observed highest in case of KMS blanched sample (0.169) followed by sodium bicarbonate blanched sample (0.168), steam blanched sample (0.162) and least in control sample (0.158). P% was observed highest in case of control sample i.e. 10.002 % as shown in Table 3. The highest MBE and RMSE value i.e.0.005 and 0.00174 was observed in case of control sample.

Table 3: Implication of Newton model in various drying methods

Parameters	T1	T2	T3	T4	AVG
1. K	0.156	0.158	0.164	0.165	0.1608
R^2	0.895	0.896	0.902	0.903	0.899
MBE	0.0148	0.0145	0.0126	0.0125	0.0136
RMSE	0.00725	0.00726	0.00676	0.00671	0.00700
χ2	0.00828	0.0083	0.00772	0.00767	0.00799
P %	21.052	21.333	21.963	21.971	21.579
2. K	0.41	0.423	0.48	0.495	0.452
R2	0.881	0.901	0.956	0.964	0.926
MBE	0.0076	0.0061	0.002	0.0018	0.0044
RMSE	0.0062	0.0048	0.0017	0.0014	0.00353
χ2	0.0094	0.0073	0.0026	0.0021	0.00535
P%	22.215	19.712	12.192	10.098	16.0543
3. K	0.236	0.258	0.285	0.295	0.269
R2	0.817	0.75	0.616	0.593	0.694
MBE	0.0032	0.0049	0.0076	0.0097	0.0064
RMSE	0.0054	0.0063	0.0077	0.008	0.0069
χ2	0.00603	0.00707	0.00867	0.00905	0.00771
P %	20.3784	24.1186	28.7397	30.3549	25.8979
4. K	0.158	0.162	0.168	0.169	0.164
R2	0.964	0.969	0.966	0.967	0.966
MBE	0.005	0.004	0.0024	0.0023	0.0034
RMSE	0.00174	0.00145	0.00159	0.00155	0.00158
χ2	0.00198	0.00165	0.00182	0.00177	0.00181
P %	10.0021	9.1529	9.6496	9.5402	9.5862

T1 – Control; T2 – Steam blanked, T3 – Sodium bicarbonate blanked, T4 – KMS blanched
1) Cabinet Drying 2) Solar Drying 3) Sun Drying 4) Fan Drying

Effect of storage on physicochemical, phytochemical constituents and antioxidant activity of dried broccoli

Effect of storage on moisture 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 6.82 per cent at zero month, which increased significantly to 10.38 per cent after 6 months of storage as shown in Table 4. The gain in moisture during storage might be due to hygroscopic nature of dried products and storage environment conditions (temperature and relative humidity). Sagar *et al.* (2004) [31] also found increase in moisture content after four months storage in dehydrated carrot.

Effect of storage on rehydration of dried broccoli

Rehydration ratio of the entire dried broccoli owing to be affected by storage is shown in Table 5. During storage the mean rehydration ratio was 6.02 at 0 month and 5.69 after 6 months of storage. The rehydration ratio declined by 5.48 per cent during 6 months of storage and that might be due to microstructural changes during storage. The loss of rehydration was reported due to changes in macromolecular components, including cellulose, pectin, hemicelluloses and protein, which were adversely affected during pre- treatment, dehydration and storage (Weier and Stocking 1949) [45].

Effect of storage on color of dried broccoli

The color profile of dried broccoli affected by storage is given in Table 6 (a, b, c). There was significant increase and decrease in the L value i.e lightness during six months of storage under different drying methods. L value in freeze, cabinet and solar drying increased after 180 days of storage to 41.6, 40.02 and 40.25 respectively. This was due to the reason that on storage the green color of the product degrades with time because of the degradation of the chlorophyll and pigments like carotenoids on storage of the product at room temperature. The lightness decreased in sun and fan drying was might be due to the formation of brown color by non enzymatic browning. Similar, was reported by Mohammadi *et al*. (2008) [22] in kiwifruit slices during drying and storage.

There was significant ($p \leq 0.05$) decrease in the a value observed during storage as shown in Table 6 (b). During storage, the a values vary from -1.47 (at 0 month) to 1.22 (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. Mishra *et al*. (2009) [21] observed more greenness a value in freeze drying and less in sun drying. Significant ($p \leq 0.05$) increase in the b value was also observed during storage, which varies from -0.17 (at 0 month) to 3.31(after 6 months). The mean b values of freeze dried broccoli was found to be significantly lower in case of freeze drying (0.37) followed by cabinet (0.63), solar (1.11), sun (2.20) and fan drying (3.22) as shown in Table 6(c).

Effect of storage on titra table acidity of dried broccoli

Table 7 represents the effect of storage on the titra table 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 1.83per cent, which declined by 4.1 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 (Sra *et al*. 2011) [38]. Acidity decreased from 2.37 to 2.31per cent in KMS treated freeze dried samples followed by cabinet (2.36- 2.28 per cent), solar (1.92-1.84 per cent), sun (1.57-1.52 per cent) and fan drying (1.08-0.98 per cent) after storage of six months. The reduction in the acidity during storage might be due to disappearance of SO_2 and intake of the moisture from environment (Sagar *et al*. 2000) [30].

Effect of storage on ascorbic acid of dried broccoli

The effect of storage on the ascorbic acid retention in dried broccoli is presented in Table 8. Farnworth *et al*. (2001) [10] noted that decline in ascorbic acid content during storage might be due to its degradation into other substances in the presence of light and oxygen. During storage, there was a significant ($p \leq 0.05$) reduction of the mean ascorbic acid content by 51.06per cent of the initial ascorbic acid content after 6 months of storage. The maximum overall mean among all the drying techniques was observed in freeze drying (376.36 mg/100g) and minimum in fan drying (96.72 mg/100g). Verma and Gupta (2004) [43] and Singh *et al*. (2006) reported that solar drier proved better for retention of ascorbic acid than sun drying in dried aonla fruit. Mishra *et al*. (2009) [21] observed the highest ascorbic acid content in freeze dried amla powder while the lowest in sun dried amla powder.

Effect of storage on total phenols 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 9. There was significant ($p \leq 0.05$) reduction of total phenols during storage. Highest phenol content was found in freeze drying followed by cabinet drying, sun drying and solar drying during the initial period of storage in the control sample. The observations of our study were similar to Vinson *et al*. (2001) [44]; Akagic *et al*. (2011) [1], who also reported that total phenols decreased due to the presence of enzymes which results in oxidation of the phenols. The highest phenol content was observed in control samples of all drying methods at intial storage period but at the end of 3 month storage least phenol content was calculated in control among all the samples. During the six months of storage period the overall mean of total phenols was found highest in freeze drying followed by cabinet, solar, sun and fan drying. Similar was reported by Mishra *et al*. (2009) [21] that highest phenol content was found in freeze dried amla powder while the lowest in sun dried amla powder. Significant ($p \leq 0.05$) decrease in the mean phenolic content i.e. 59.15per cent of the initial phenolic content was observed after 6 months of storage.

Effect of storage on total chlorophyll content of dried broccoli

Table 10 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 freeze drying in sodium bicarbonate treated samples followed by cabinet drying, solar drying, sun drying and fan drying. Similar findings were reported by Sharma *et al*. (2011) [34] that freeze drying was more efficient in preserving the chlorophyll content of dried broccoli sprouts. Patil *et al*. (1978) [26] reported improvement in chlorophyll retention with magnesium oxide, potassium metabisulphite and sodium bicarbonate blanching, while improved chlorophyll retention with sulphite treatment was reported by Chaudhary (1979) [7]. The mean of chlorophyll content at beginning of storage was 25.68, which declined by 24.18 per cent after 6 months of storage. Oladele and Aborisade (2009) [25] from their experiments conducted found that total chlorophyll decreased with both drying and storage but the decrease was negligible.

Effect of storage on antioxidant activity of dried broccoli

Effect of storage on antioxidant activity of dried broccoli sample as observed during 6 months of storage is presented in Table 11. There was significant ($p \leq 0.05$) reduction of antioxidant activity during storage. The highest antioxidant activity was observed in control samples of all drying methods at initial storage period but at the end of 3 month 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. Gardner *et al*. (2000) [13] also reported that polyphenols are strongly correlated with the antioxidant activity. A significantly (p<0.05) highest antioxidant activity was calculated in freeze dried broccoli and least in fan drying because freeze drying was carried out in vacuum at very low temperature due to this reason the oxidation of phytochemicals does not occurred. Significant (p≤0.05) decrease in the mean antioxidant activity i.e. 59.84% 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 (Klimczak *et al*. 2007) [16].

Table 4: Effect of storage on moisture content (%) of dried broccoli

Storage Months	Cabinet drying 50ºC				Solar drying				Sun drying				Fan drying				Freeze drying				Mean
	Control	Steam	KMS	Na HCO_3	Control	Steam	KMS	Na HCO_3	Control	Steam	KMS	Na HCO_3	Control	Steam	KMS	Na HCO_3	Control	Steam	KMS	Na H CO_3	
0	6.98	6.95	5.84	5.85	7.23	7.19	6.21	6.22	7.29	7.27	6.28	6.29	10.68	10.63	10.09	10.10	4.63	4.57	3.01	3.03	6.82
1	7.20	7.15	6.09	6.10	7.49	7.44	6.49	6.52	7.54	7.52	6.54	6.55	10.93	10.88	10.34	10.35	4.86	4.82	3.26	3.28	7.07
2	7.59	7.52	6.43	6.45	7.82	7.78	6.81	6.83	7.89	7.86	6.88	6.89	11.27	11.22	10.68	10.69	5.20	5.16	3.67	3.69	7.41
3	7.93	7.89	6.82	6.82	8.23	8.19	7.23	7.24	8.29	8.27	7.32	7.34	11.68	11.63	11.09	11.09	6.66	6.61	5.12	5.14	8.02
4	8.47	8.43	7.27	7.28	8.71	8.67	7.70	7.72	8.78	8.76	7.75	7.76	12.16	12.11	11.57	11.58	8.22	8.20	6.70	6.71	8.73
5	8.94	8.87	7.81	7.82	9.24	9.20	8.21	8.22	9.31	9.28	8.30	8.31	12.69	12.64	12.12	12.13	10.40	10.37	8.87	8.89	9.58
6	9.22	9.18	8.13	8.15	9.58	9.54	8.54	8.55	9.64	9.61	8.65	8.67	13.06	12.98	12.44	12.45	13.08	13.04	11.54	11.56	10.38
Overall mean	7.47				7.81				7.89				11.47				6.80				

CD (≤0.05)

Drying method (D)	0.020	D×T	0.040	D×T×S	NS
Treatment (T)	0.018	D×S	0.052		
Storage (S)	0.023	T×S	NS		

Table 5: Effect of storage on rehydration of dried broccoli

Storage months	Cabinet drying 50ºC				Solar drying				Sun drying				Fan drying				Freeze drying				Mean
	Control	Steam	KMS	Na HCO_3	Control	Steam	KMS	Na HCO_3	Control	Steam	KMS	Na HCO_3	Control	Steam	KMS	Na HCO_3	Control	Steam	KMS	Na HCO_3	
0	5.90	5.91	5.99	5.99	5.89	5.89	5.952	5.95	5.88	5.89	5.93	5.93	5.67	5.68	5.73	5.72	6.31	6.32	6.95	6.94	6.02
1	5.89	5.89	5.98	5.98	5.86	5.863	5.94	5.94	5.85	5.85	5.93	5.92	5.65	5.66	5.72	5.72	6.25	6.24	6.91	6.90	6.00
2	5.88	5.88	5.95	5.95	5.84	5.85	5.92	5.92	5.83	5.84	5.91	5.90	5.63	5.64	5.69	5.68	6.09	6.10	6.80	6.79	5.95
3	5.87	5.87	5.94	5.93	5.82	5.84	5.9	5.89	5.80	5.83	5.89	5.88	5.61	5.63	5.65	5.65	5.92	5.93	6.11	6.10	5.85
4	5.83	5.84	5.91	5.89	5.75	5.78	5.89	5.87	5.74	5.76	5.87	5.86	5.61	5.62	5.65	5.64	5.85	5.86	5.94	5.93	5.80
5	5.83	5.83	5.88	5.88	5.73	5.74	5.86	5.85	5.71	5.72	5.85	5.84	5.60	5.62	5.64	5.64	5.65	5.66	5.83	5.81	5.76
6	5.81	5.82	5.86	5.86	5.72	5.73	5.84	5.83	5.70	5.71	5.82	5.81	5.59	5.60	5.63	5.63	5.42	5.42	5.55	5.53	5.69
Overall mean	5.90				5.85				5.84				5.65				6.11				

CD (≤0.05)

Drying method (D)	0.029	D×T	0.059	D×T×S	0.156
Treatment (T)	0.026	D×S	0.078		
Storage (S)	0.035	T×S	NS		

Table 6(a): Effect of storage on the color (L value) of dried broccoli

Storage months	Cabinet drying 50ºC				Solar drying				Sun drying				Fan drying				Freeze drying				Mean
	Control	Steam	KMS	Na HCO_3	Control	Steam	KMS	Na HCO_3	Control	Steam	KMS	Na HCO_3	Control	Steam	KMS	Na HCO_3	Control	Steam	KMS	Na HCO_3	
0	37.14	38.57	36.85	36.56	37.29	38.64	36.94	36.85	50.48	50.66	43.21	43.06	44.82	46.30	39.67	39.50	39.56	42.51	37.54	37.48	40.74
1	37.48	38.90	37.02	36.63	37.56	39.05	37.16	37.06	51.12	51.67	43.56	43.51	45.37	46.75	40.58	40.53	40.06	42.93	37.92	37.85	41.11
2	37.69	39.12	37.28	36.95	37.87	39.22	37.35	37.30	51.47	51.96	44.06	43.92	45.88	46.95	40.90	40.82	40.44	43.20	38.33	38.26	41.43
3	38.20	39.33	37.64	37.12	38.34	39.45	37.82	37.57	52.11	52.37	44.36	44.22	44.06	45.78	39.51	39.40	40.69	43.48	38.60	38.52	41.42
4	38.57	39.63	37.92	37.59	38.67	39.80	38.05	37.96	49.24	50.71	43.67	43.54	43.67	44.55	39.22	39.16	40.89	43.62	38.89	38.70	41.20
5	39.19	40.11	38.23	37.88	39.31	40.23	38.42	38.35	49.95	50.23	43.3	43.21	43.21	44.34	38.86	38.79	41.27	44.01	39.12	39.07	41.35
6	40.02	40.54	38.41	38.36	40.25	40.73	38.69	38.55	48.34	49.65	42.86	42.8	42.90	43.63	39.70	39.65	41.60	44.25	39.75	39.70	41.52
Overall mean	38.18				38.37				47.11				42.30				40.29				

CD (≤0.05)

Drying method (D)	0.072	D×T	0.144	D×T×S	0.381
Treatment (T)	0.064	D×S	0.190		
Storage (S)	0.085	T×S	0.170		

Table 6(b): Effect of storage on the color (a value) of dried broccoli

Storage months	Cabinet drying 50ºC				Solar drying				Sun drying				Fan drying				Freeze drying				Mean
	Control	Steam	KMS	Na HCO_3	Control	Steam	KMS	Na HCO_3	Control	Steam	KMS	Na HCO_3	Control	Steam	KMS	Na HCO_3	Control	Steam	KMS	Na HCO_3	
0	-1.04	-1.22	-1.52	-1.63	-0.96	-1.12	-1.27	-1.56	-0.08	-0.36	-0.75	-0.92	0.69	-0.19	-0.96	-1.03	-1.21	-2.12	-6.01	-6.23	-1.47

1	-0.53	-1.02	-1.34	-1.48	-0.38	-0.96	-1.14	-1.45	0.19	-0.22	-0.61	-0.84	0.97	-0.01	-0.73	-0.91	-0.64	-2.03	-5.60	-6.05	-1.24
2	-0.36	-0.81	-1.27	-1.36	-0.22	-0.75	-1.03	-1.23	0.44	0.27	-0.49	-0.66	1.63	1.51	0.96	0.88	-0.59	-1.35	-4.67	-5.53	-0.73
3	-0.09	-0.58	-1.10	-1.29	1.09	-0.41	-0.76	-1.11	0.75	0.43	-0.33	-0.52	2.61	1.97	1.12	0.93	-0.38	-0.76	-3.03	-4.38	-0.40
4	0.91	-0.22	-0.85	-1.15	1.27	-0.11	-0.53	-0.99	1.34	0.89	-0.27	-0.38	2.85	2.10	1.45	1.00	-0.02	-0.17	-2.67	-3.71	0.04
5	0.62	0.44	-0.54	-0.72	1.65	0.55	-0.23	-0.52	2.81	1.64	-0.02	-0.21	3.39	2.30	1.81	1.27	0.54	0.39	-1.24	-2.97	0.55
6	1.41	1.34	-0.29	-0.58	2.84	1.87	-0.15	-0.28	3.28	2.57	1.22	0.98	3.82	2.74	2.21	1.76	1.37	0.83	-1.09	-1.44	1.22
Overall mean	-0.58				-0.35				0.36				1.29				-2.17				

CD (≤0.05)
Drying method (D) 0.060 D×T 0.119 D×T×S 0.315
Treatment (T) 0.053 D×S 0.158
Storage (S) 0.070 T×S 0.141

Table 6(c): Effect of storage on the color (b value) of dried broccoli

Storage months	Cabinet drying 50ºC				Solar drying				Sun drying				Fan drying				Freeze drying				Mean
	Control	Steam	KMS	Na HCO_3	Control	Steam	KMS	Na HCO_3	Control	Steam	KMS	Na HCO_3	Control	Steam	KMS	Na HCO_3	Control	Steam	KMS	Na HCO_3	
0	-0.56	-0.83	-1.12	-1.21	-0.37	-0.66	-1.03	-1.12	1.21	0.95	0.41	0.27	2.31	1.23	0.69	0.55	-0.61	-1.07	-1.16	-1.28	-0.17
1	-0.22	-0.41	-0.66	-0.72	-0.12	-0.37	-0.52	-0.61	1.57	1.08	0.62	0.54	3.42	1.66	0.96	0.84	-0.32	-0.51	-0.74	-0.97	0.22
2	0.74	0.66	0.42	0.37	1.09	0.94	0.71	0.55	2.21	1.34	0.83	0.67	4.26	2.16	1.59	1.37	-0.18	-0.34	-0.54	-0.66	0.91
3	1.72	0.85	0.67	0.41	1.81	1.44	1.09	0.94	2.72	1.98	1.64	1.23	4.73	2.71	2.08	1.88	0.98	0.71	0.53	0.27	1.52
4	1.96	1.24	0.79	0.63	2.03	1.85	1.63	1.29	4.23	2.51	2.17	1.88	6.87	3.98	2.81	2.77	1.66	1.15	0.69	0.56	2.13
5	2.36	1.68	1.18	0.75	2.67	2.24	2.05	1.83	5.45	3.33	2.87	2.29	7.44	4.26	3.44	3.16	2.12	1.61	0.91	0.87	2.62
6	2.55	1.91	1.32	1.19	3.32	3.09	2.78	2.51	6.01	4.78	3.66	3.07	8.76	5.64	4.51	4.28	2.38	2.01	1.27	1.13	3.31
Overall mean	0.63				1.11				2.20				3.22				0.37				

CD (≤0.05)
Drying method (D) 0.042 D×T 0.083 D×T×S 0.220
Treatment (T) 0.037 D×S 0.110
Storage (S) 0.049 T×S 0.098

Table 7: Effect of storage on titratable acidity (%) of dried broccoli

Storage months	Cabinet drying 50ºC				Solar drying				Sun drying				Fan drying				Freeze drying				Mean
	Control	Steam	KMS	Na HCO_3	Control	Steam	KMS	Na HCO_3	Control	Steam	KMS	Na HCO_3	Control	Steam	KMS	Na HCO_3	Control	Steam	KMS	Na HCO_3	
0	2.34	2.32	2.36	2.35	1.86	1.83	1.92	1.90	1.52	1.48	1.57	1.55	1.03	0.98	1.08	1.07	2.35	2.33	2.37	2.37	1.83
1	2.32	2.29	2.34	2.33	1.85	1.82	1.90	1.88	1.50	1.47	1.56	1.54	1.02	0.97	1.06	1.04	2.34	2.31	2.36	2.35	1.81
2	2.31	2.29	2.33	2.32	1.83	1.81	1.87	1.85	1.49	1.46	1.55	1.53	1.00	0.96	1.04	1.03	2.34	2.29	2.35	2.34	1.80
3	2.31	2.28	2.33	2.31	1.82	1.80	1.86	1.84	1.48	1.45	1.55	1.53	0.98	0.95	1.03	1.01	2.33	2.29	2.34	2.34	1.79
4	2.30	2.27	2.31	2.30	1.82	1.80	1.86	1.84	1.47	1.45	1.54	1.52	0.98	0.95	1.03	0.99	2.32	2.28	2.34	2.33	1.78
5	2.28	2.26	2.30	2.29	1.8	1.78	1.85	1.83	1.44	1.43	1.53	1.51	0.96	0.94	1.02	0.98	2.31	2.27	2.33	2.32	1.77
6	2.26	2.25	2.28	2.27	1.78	1.76	1.84	1.81	1.42	1.40	1.52	1.50	0.94	0.92	0.98	0.96	2.30	2.27	2.31	2.30	1.75
Overall mean	2.30				1.84				1.50				1.00				2.32				

CD (≤0.05)
Drying method (D) 0.011 D×T 0.023 D×T×S NS
Treatment (T) 0.010 D×S NS
Storage (S) 0.014 T×S NS

Table 8: Effect of storage on ascorbic acid (mg/100g) of dried broccoli

Storage months	Cabinet drying 50ºC				Solar drying				Sun drying				Fan drying				Freeze drying				Mean
	Control	Steam	KMS	Na HCO_3	Control	Steam	KMS	Na HCO_3	Control	Steam	KMS	Na HCO_3	Control	Steam	KMS	Na HCO_3	Control	Steam	KMS	Na HCO_3	
0	424	289	602	587	238	271	415	396	143	101	223	208	136	88	189.3	173	438	302	618	606	322.36
1	386	251	565	550	221	217	391	384	130	89	213	193	126	82	168	154	403	268	583	567	297.05
2	349	214	528	511	201	194	378	360	106	76	191	174	98	65	156	143	364	230	544	536	270.90
3	309	172	487	481	187	153	350	342	88	64	168	150	76	60	130	113	335	185	503	495	242.40
4	271	138	451	444	153	113	323	316	74	58	153	134	63	52	103	92	295	151	469	456	215.45
5	228	104	412	400	139	91	296	283	52	40	139	119	46	36	90	84	252	113	414	402	187.00
6	193	71	371	337	116	58	265	250	46	32	113	98	38	28	61	58	203	89	378	350	157.75
Overall mean	361.61				253.61				120.53				96.72				376.75				

CD (≤0.05)
Drying method (D) 1.55 D×T 3.11 D×T×S 8.22
Treatment (T) 1.39 D×S 4.11
Storage (S) 1.84 T×S 3.68

Table 9: Effect of storage on total phenols (mg GAE/100g) of dried broccoli

Storage months	Cabinet drying 50ºC				Solar drying				Sun drying				Fan drying				Freeze drying				Mean
	Control	Steam	KMS	Na HCO_3	Control	Steam	KMS	Na HCO_3	Control	Steam	KMS	Na HCO_3	Control	Steam	KMS	Na HCO_3	Control	Steam	KMS	Na HCO_3	
0	506.32	481.37	459.35	456.58	365.17	324.00	306.55	284.45	322.08	285.03	269.66	240.15	236.51	193.37	176.57	148.25	548.62	518.06	510.28	501.03	356.67
1	449.85	436.57	428.35	405.68	323.27	307.62	297.64	290.06	280.09	268.17	255.26	251.08	204.05	185.27	148.37	133.99	488.08	473.30	470.04	463.28	328.00
2	403.00	375.21	364.27	357.31	301.06	292.11	286.33	278.61	258.12	246.08	238.11	231.08	195.11	161.28	114.08	106.32	445.00	435.96	427.52	420.30	296.84
3	322.58	321.08	335.14	329.61	218.34	247.65	266.50	258.29	183.06	200.18	218.28	205.66	72.22	88.16	100.82	92.17	372.03	387.32	403.08	391.25	250.67
4	149.35	293.16	304.27	297.07	88.06	233.18	245.88	235.66	74.11	184.24	197.55	190.08	59.08	63.27	84.22	71.85	201.65	360.91	378.02	365.94	203.88
5	125.08	261.05	275.01	270.14	68.25	200.09	219.11	205.05	48.22	164.42	175.09	171.11	41.55	43.07	61.27	54.87	178.90	330.54	343.36	332.08	178.45
6	109.63	220.05	231.04	224.54	47.99	170.09	180.06	174.44	24.19	126.21	136.77	132.54	7.29	28.11	34.18	31.12	147.21	290.46	304.5	293.01	145.68
Overall mean	328.30				239.84				199.16				104.87				385.06				

CD (≤0.05)

Drying method (D)	9.40	D×T	18.81	D×T×S	NS
Treatment (T)	8.41	D×S	24.89		
Storage (S)	11.13	T×S	22.26		

Table 10: Effect of storage on the total chlorophyll content (mg/100g) of dried broccoli

Storage months	Cabinet drying 50ºC				Solar drying				Sun drying				Fan drying				Freeze drying				Mean
	Control	Steam	KMS	Na HCO_3	Control	Steam	KMS	Na HCO_3	Control	Steam	KMS	Na HCO_3	Control	Steam	KMS	Na HCO_3	Control	Steam	KMS	Na HCO_3	
0	14.98	27.36	38.10	41.07	11.55	24.41	34.19	37.26	7.85	19.64	29.16	31.92	3.28	12.59	20.13	24.37	20.18	31.27	40.19	44.08	25.68
1	12.60	26.61	37.82	40.68	10.29	23.62	33.53	36.84	5.36	18.89	28.56	30.86	2.05	12.04	19.51	22.62	18.54	30.89	39.76	43.44	24.72
2	10.28	25.47	37.06	40.13	9.54	22.31	33.02	35.26	3.21	18.03	27.31	28.92	1.52	11.46	19.03	21.09	17.68	30.17	39.09	42.97	23.68
3	8.69	23.19	36.54	39.45	7.98	20.54	32.38	34.12	1.58	17.24	26.32	28.13	0.43	10.78	18.37	20.46	16.31	29.77	38.54	42.31	22.66
4	7.06	22.64	36.12	38.57	6.64	20.01	30.57	33.45	0.85	16.57	25.38	27.54	0.09	10.05	17.56	19.27	14.19	29.10	38.02	41.85	21.78
5	5.36	21.32	35.63	38.05	4.31	19.33	29.35	32.19	0.07	15.12	23.95	26.22	0.008	9.42	16.18	18.35	11.24	28.56	37.41	41.10	20.66
6	3.50	20.35	33.09	37.46	1.62	18.27	28.34	31.51	0.005	14.28	22.08	24.89	0.001	8.06	15.43	17.28	9.37	27.03	35.88	40.65	19.47
Overall mean	27.12				23.66				56.19				12.56				31.41				

CD (≤0.05)

Drying method (D)	0.061	D×T	0.122	D×T×S	0.323
Treatment (T)	0.055	D×S	0.162		
Storage (S)	0.072	T×S	0.145		

Table 11: Effect of storage on antioxidant activity (% activity) of dried broccoli

Storage months	Cabinet drying 50ºC				Solar drying				Sun drying				Fan drying				Freeze drying				Mean
	Control	Steam	KMS	Na HCO_3	Control	Steam	KMS	Na HCO_3	Control	Steam	KMS	Na HCO_3	Control	Steam	KMS	Na HCO_3	Control	Steam	KMS	Na HCO_3	
0	39.47	37.52	36.13	35.57	28.46	25.61	23.84	22.13	25.11	22.22	20.98	18.71	18.43	15.07	13.74	11.68	45.55	42.74	39.78	39.06	28.09
1	35.06	34.05	33.69	22.76	25.18	21.13	23.12	22.53	21.84	20.91	19.88	19.56	15.89	14.43	11.56	10.45	40.51	39.05	36.62	36.09	25.21
2	31.41	29.26	28.65	27.84	23.45	19.58	22.24	21.65	20.12	19.18	18.53	18.00	15.20	12.56	8.89	8.28	36.94	35.97	33.30	32.75	24.22
3	25.03	25.15	26.33	25.68	16.78	17.00	20.70	20.06	14.27	15.06	16.98	16.02	12.49	6.87	7.86	7.18	30.48	30.88	31.96	31.40	19.61
4	11.67	22.86	23.93	23.14	6.86	14.84	19.10	18.03	5.88	14.38	15.37	14.80	4.60	4.93	6.56	5.59	16.74	28.51	29.78	29.45	15.85
5	9.78	20.35	21.63	21.045	5.31	11.49	17.02	15.09	3.76	12.82	13.64	13.33	3.23	3.36	4.79	4.27	14.85	25.87	27.27	26.75	13.79
6	8.76	17.16	18.17	17.49	3.73	9.38	13.99	13.55	1.89	9.87	10.64	10.35	0.57	2.19	2.66	2.46	12.24	22.84	23.97	23.73	11.28
Overall mean	25.34				17.92				15.50				8.47				31.37				

CD (≤0.05)

Drying method (D)	0.129	D×T	0.26	D×T×S	0.68
Treatment (T)	0.115	D×S	0.34		
Storage (S)	0.153	T×S	0.30		

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 and sodium bicarbonate 0.1per cent on the basis of color. 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 dried by different drying techniques but there was significant ($p \leq 0.05$) increase in moisture content. Among the various blanching treatments potassium metabisulphite was found to have better retention of moisture, rehydration ratio, acidity, ascorbic acid, total phenols, and antioxidant activity during storage of dried broccoli. Sodium bicarbonate was found to have better retention of total chlorophyll and color attributes during storage of dried broccoli. Freeze drying method was found best to retain physicochemical, phytochemical constituents and antioxidant activity during 6 months of storage.

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