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Study for Determination of Suitable Pre treatment Combination and Dehydration Temperature for Broccoli Florets

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ABSTRACT

High moisture content of broccoli limits its post harvest longevity. So in order to make it available for a longer period the vegetable is needed to be preserved. For this, the present study was undertaken where dehydration was chosen as a mode of preservation and the experiment was aimed to establish suitable pre drying treatment combination and dehydration temperature for broccoli florets. Hot water blanching and chemicals like calcium chloride, citric acid, sodium metabisulfite and potassium metabisulfite were used for pre drying treatments. Three different temperatures of 50^{0}C, 55^{0}C and 60^{0}C were employed for dehydration. The dehydrated broccoli florets were pre packed and stored at ambient condition. Storage studies for different physical and biochemical parameters were carried at proper intervals of storage. The work revealed that the pre drying treatment combination of initial immersion of 0.2 % of calcium chloride followed by 4 minutes of hot water blanching and final immersion of 0.1 % of sodium metabisulfite followed by dehydration at 55^{0}C was most effective in maintaining the various physical and biochemical attributes throughout the storage period.

Introduction

The vegetable broccoli possesses very important group of chemicals which helps in prevention of a number of diseases. According to Gullett *et al.*, (2010) sulforaphane and some other phytochemicals present in broccoli like indole-3-carbinol and brassinin are very much useful against cancer.

Apart from having anti cancerous properties broccoli is one of the very few vegetable that is also very effective against diabetes. The work carried out by Platel and Srinivasan,

(1997) showed broccoli have beneficial influence against diabetes in humans as well as in experimental animals. Though broccoli contains numerous functional properties, but the high moisture content present in the vegetable restricts its post harvest life to a limited period. So in order to increase the post harvest utility, it is needed to preserve the vegetable for a longer period of time. For this dehydration can be done where broccoli, by reducing its moisture content can be successfully preserved for an extended span. Dehydration helps in reducing the moisture content to a great extent as a result of which the total volume gets minimized reducing the transformational cost, the chances of microbial contamination becomes less and ultimately the shelf life is prolonged (Kordylas, 1990).

Prior to dehydration of vegetables, various pretreatments are needed which helps in yielding final products of sound quality (Kingsly *et al.,* 2007). Enzymes like peroxidase and lipoxygenase which are present in fresh vegetables causes undesirable chemical reactions that leads to change of colour from green to brown (Vamos-Vigyzao, 1995; McEvily *et al.,* 1992).

So in order to overcome the issue apart for giving pretreatments blanching is also required to be done before dehydration as it helps in inactivation the enzymatic action as a result of which the colour and taste of the commodity is improved.

Furthermore this process of blanching helps in alleviating the internal elastic properties which facilitates the dehydration procedure (Kunzek *et al.,* 1999; Munyaka *et al.,* 2010; Waldron *et al.,* 2003). Therefore the present study was carried to establish a pretreatment combination for successful dehydration and also to determine a suitable temperature in which the broccoli florets can be properly dehydrated.

Materials and Methods

The study was taken during the year 2015-2016 in the Department of Post Harvest Technology of Horticultural Crops, Faculty of Horticulture, Bidhan Chandra Krishi Viswavidyalaya, Nadia West Bengal. Broccoli variety Galaxy (F_1 hybrid) was collected from a farmer field located at Nadia and North 24 Parganas districts of West Bengal. In the laboratory the broccoli heads after proper washing was cut into small florets and subjected to the different treatment combination as follows (immersion in chemical solution for 10 minutes + hot water blanching for 4 minutes + immersion in chemical solution for 10 minutes). The way of application of the treatments and some chemicals used in the study are similar to the works of Das and Dhua (2019) and Ngangom *et al.,* (2019).

T_1 – Citric acid 0.2% + 4 min blanching + water,

T_2 – Citric acid 0.2% + 4 min blanching + potassium metabisulphite 0.1%,

T_3 – Citric acid 0.2% + 4 min blanching + Sodium metabisulfite 0.1%,

T_4 Calcium chloride 0.2% + 4 min blanching + water,

T_5 – Calcium chloride 0.2% + 4 min blanching + potassium metabisulphite 0.1%,

T_6 – Calcium chloride 0.2% + 4 min blanching + Sodium metabisulfite 0.1%,

T_7 – water + 4 min blanching + water

Design of experiment

Two Factorial Completely Randomized Design (Sheoran *et al.,* 1998).

Replication- 3

After that, drying was undertaken at the temperatures of 50^{0}C, 55^{0}C and 60^{0}C. Thereafter dehydrated florets were pre packed and stored in ambient situation. Analysis of different attributes viz. matter content dry weight basis (Shipley and Vu, 2002), moisture content of dehydrated produce (A.O.A.C, 2000), rehydration ratio (A.O.A.C, 2000), total chlorophyll (Ranganna, 2003), total phenols (Singleton *et al.*, 1999), flavanoids (Zhishen *et al.*, 1999), antioxidant activity (Brand-Williams *et al.*, 1995) and fungal estimation (Allen, 1953) were carried on 0, 30, 45 and 60 days of storage.

Results and Discussion

All the treatments under the three temperatures viz. 50^{0}C, 55^{0}C and 60^{0}C showed maximum decrease in the moisture content (dry wt. basis) during the initial periods of dehydration (Fig. 1, 2 and 3). But later on the reduction of content among the treatments stabilized with ongoing time period during dehydration. For 50^{0}C a time span of 720 minutes was required to stabilize the moisture content (dry wt. basis) for all the treatments and after which no further decrease in the value was observed. For the temperature of 55^{0}C the time period required for all the treatments for stabilization was observed at 570 minutes. The temperature of 60^{0}C required a lesser time of 510 minutes to bring down the moisture content (dry wt. basis) for all the treatments.

During the period of storage the moisture content for all the treatments dehydrated at different temperatures viz. 50^{0}C 55^{0}C and 60^{0}C increased (Table 1). Treatments dehydrated at 50^{0}C showed maximum increase in the moisture levels throughout the period of storage. Treatments dehydrated at 55^{0}C and 60^{0}C maintained a steady rate of moisture gain during the storage period, with lowest levels of moisture content was recorded for the treatments dehydrated at 60^{0}C at the end of the storage. Among the different treatments the broccoli florets in which initial immersion with 0.2 % of calcium chloride followed by 4 minutes of hot water blanching and final immersion with 0.1 % of sodium metabisulfite was done, showed the least uptake of moisture.

The maximum rehydration ratio of 7.25 at the 0 days of storage was seen for treatments dehydrated at 50^{0}C followed by 5.68 for treatments dehydrated at 55^{0}C and 4.94 for treatments dehydrated at 60^{0}C respectively (Table 2). The rehydration ratio throughout the storage period for different treatments dehydrated at each temperature decreased. At the end of 60 days of storage treatments dehydrated at 50^{0}C recorder the maximum rehydration ratio of 6.23 in broccoli florets where initial immersion with 0.2 % of calcium chloride, 4 minutes of hot water blanching and final immersion with 0.1 % of sodium metabisulfite was done.

After 30 days of storage treatments dehydrated at 50^{0}C showed the maximum concentration of total chlorophyll followed by treatments which were dehydrated at 55^{0}C and 60^{0}C respectively (Table 3). However at 45 days of storage, treatments dehydrated at 55^{0}C showed similar concentrations of total chlorophyll reatinment as compared to treatments dehydrated at 50^{0}C whereas concentration for chlorophyll for different treatments dehydrated at 60^{0}C was at the lower side. At the end of storage at 60 days, considerable loss in the total chlorophyll content was seen for all the treatments dehydrated at 50^{0}C and 60^{0}C. Treatments dehydrated at temperature of 55^{0}C recorded the maximum concentration of chlorophyll at 60 days of storage. Treatment of broccoli florets where initial immersion with 0.2 % of calcium chloride, 4 minutes of hot water blanching and final immersion with 0.1 % of sodium metabisulfite which were dehydrated at a temperature of 55^0C maintained a significant higher level of total chlorophyll concentration throughout the storage period

Biochemical parameters like phenols, flavanoids and antioxidant levels (% inhibition of DPPH) were highest for all treatments at 0 days of storage for dehydration temperature of 50^0C followed by dehydration temperature of 55^0C and dehydration temperature of 60^0C (Table 4, 5, 6). But later during the storage period the concentration of phenols, flavanoids and antioxidant levels (% inhibition of DPPH) decreased for all the treatments dehydrated at temperature of 50^0C and 60^0C. Treatments dehydrated at 55^0C showed the maximum possession of phenols, flavanoids and antioxidant levels throughout the period of storage. Dehydrated at the temperature 55^0C/B_2 after 60 days of storage, the broccoli florets were initial immersion with 0.2 % of calcium chloride, 4 minutes of hot water blanching and final immersion with 0.1 % of sodium metabisulfite showed the maximum levels of phenols, flavanoids and antioxidant activity

The fungal count for both unicellular and filamentous type were lowest at the initial day of storage for treatments dehydrated at 60^0C (unicellular fungi: 1.33 x 10^2 cfu/g, filamentous fungi: 0.66 x 10^2 cfu/g) followed by treatments dehydrated at 55^0C and 50^0C (Table 7 and 8).

The microbial population for the treatments dehydrated at temperature of 50^0C, 55^0C and 60^0C increased during the storage period. Treatments dehydrated at the temperature of 50^0C showed the highest levels of fungal population. However treatments dehydrated at temperature of 55^0C and 60^0C maintained a lower rate of fungal infestation throughout the storage period of 60 days. At the end of the experiment broccoli florets where initial immersion with 0.2 % of calcium chloride, 4 minutes of hot water blanching and final immersion with 0.1 % of sodium metabisulfite was done and dehydration was carried at a temperature of 60^0C showed the lowest fungal population of 2 x 10^2 cfu/g (unicellular type) and 0.67 x 10^2 cfu/g (filamentous type) respectively.

For fresh vegetable various enzymes like lipoxygenase and peroxidase are responsible for development of brown colour due to enzymatic reaction and also results in the occurrence of unpleasant odour (Vamos-Vigyzao, 1995; McEvily *et al.,* 1992).

These problems are lessened by the help of dehydration as it helps in reduction of free water content which in turn reduces the microbial affinity and ultimately increases the post harvest life (Hatamipour *et al.,* 2007). Before dehydration the broccoli florets were blanched with hot water which facilitates the drying and ensures proper shrinkage (Kunzek *et al.,* 1999; Munyaka *et al.,* 2010; Waldron *et al.,* 2003) and various pre drying treatments were given.

Previous studies have reported that treating the cut tissues of the vegetable helps in reducing the rate of respiration and escalates the healing process (Picchioni, 1994) and also the tissue firmness is elevated (Rosen and Kader, 1989; Izumi and Watada, 1994).

In the experiment the effectiveness of chemicals like calcium chloride and sodium meta bisulphite as pre drying treatments were observed. The findings were at par to that of Owureku *et al.,* (2014) were tomato fruits pretreated with sodium metabisulfite were uniformly dehydrated with least degradation of chlorophyll and maximum rehydration ration than the other treatments.

Table.1 Moisture content (%) of dehydrated broccoli florets during the storage intervals

0 DAS	$50^0C/B_1$	$55^0C/B_2$	$60^0C/B_3$	Mean A
A_1-A_7	7.14	5.66	5.00	-
Mean B	-	-	-	
30 DAS	B_1	B_2	B_3	**Mean A**
T_1/A_1	7.66	6.22	5.39	6.42
T_2/A_2	7.66	6.16	5.38	6.40
T_3/A_3	7.26	5.92	5.28	6.15
T_4/A_4	7.91	6.52	5.62	6.68
T_5/A_5	7.45	5.96	5.35	6.25
T_6/A_6	7.24	5.87	5.23	6.11
T_7/A_7	7.98	6.58	5.65	6.73
Mean B	7.60	6.18	5.41	
	Factors	**C.D.**	**SE(d)**	**SE(m)**
	Factor(A)	0.013	0.006	0.005
	Factor(B)	0.009	0.004	0.003
	Factor (AxB)	0.023	0.011	0.008
45 DAS	$50^0C/B_1$	$55^0C/B_2$	$60^0C/B_3$	**Mean A**
T_1/A_1	8.38	6.46	6.41	7.08
T_2/A_2	8.32	6.39	6.28	7.00
T_3/A_3	8.22	6.22	5.98	6.81
T_4/A_4	8.97	6.52	6.45	7.31
T_5/A_5	8.25	6.35	6.23	6.95
T_6/A_6	8.14	6.16	5.92	6.74
T_7/A_7	9.20	6.78	6.45	7.47
Mean B	8.50	6.41	6.25	
	Factors	**C.D.**	**SE(d)**	**SE(m)**
	Factor(A)	0.020	0.010	0.007
	Factor(B)	0.013	0.007	0.005
	Factor (AxB)	0.035	0.017	0.012
60 DAS	$50^0C/B_1$	$55^0C/B_2$	$60^0C/B_3$	**Mean A**
T_1/A_1	12.23	7.69	7.15	9.02
T_2/A_2	11.63	7.45	6.75	8.61
T_3/A_3	8.32	6.72	6.32	7.12
T_4/A_4	12.90	8.23	7.24	9.46
T_5/A_5	11.13	6.97	6.44	8.18
T_6/A_6	8.26	6.64	6.28	7.06
T_7/A_7	13.29	8.34	7.29	9.64
Mean B	11.11	7.43	6.78	
	Factors	**C.D.**	**SE(d)**	**SE(m)**
	Factor(A)	0.035	0.018	0.012
	Factor(B)	0.023	0.011	0.008
	Factor (AxB)	0.061	0.030	0.021

A(1-7): Treatments {**A1**(T_1) – Citric acid 0.2% + 4 min blanching + water, **A2** (T_2) – Citric acid 0.2% + 4 min blanching + $K_2S_2O_5$ 0.1%, **A3** (T_3) – Citric acid 0.2% + 4 min blanching + $Na_2S_2O_5$ 0.1%, **A4** (T_4)– $CaCl_2$ 0.2% + 4 min blanching + water, **A5** (T_5) – $CaCl_2$ 0.2% + 4 min blanching + $K_2S_2O_5$ 0.1%, **A6** (T_6) – $CaCl_2$ 0.2% + 4 min blanching + $Na_2S_2O_5$ 0.1%, **A7** (T_7) – water + 4 min blanching + water}, B(1-3): Temperatures (**B1**- 50^0C, **B2**- 55^0C, **B3**- 60^0C)

Table.2 Rehydration ratio of dehydrated broccoli florets during the storage intervals

0 DAS	$50^0C/B_1$	$55^0C/B_2$	$60^0C/B_3$	Mean A
A_1-A_7	7.25	5.68	4.94	-
Mean B	-	-	-	
30 DAS	B_1	B_2	B_3	**Mean A**
T_1/A_1	6.88	5.34	4.64	5.62
T_2/A_2	6.92	5.52	4.81	5.75
T_3/A_3	6.96	5.54	4.85	5.78
T_4/A_4	6.56	5.32	4.53	5.47
T_5/A_5	6.96	5.52	4.81	5.77
T_6/A_6	7.05	5.62	4.87	5.85
T_7/A_7	6.56	5.26	5.26	5.69
Mean B	6.84	5.45	4.83	
	Factors	**C.D.**	**SE(d)**	**SE(m)**
	Factor(A)	0.013	0.006	0.005
	Factor(B)	0.009	0.004	0.003
	Factor (AxB)	0.023	0.011	0.008
45 DAS	$50^0C/B_1$	$55^0C/B_2$	$60^0C/B_3$	**Mean A**
T_1/A_1	5.97	5.16	4.14	5.09
T_2/A_2	6.13	5.22	4.27	5.21
T_3/A_3	6.91	5.33	4.33	5.52
T_4/A_4	5.94	4.96	3.98	4.96
T_5/A_5	6.62	5.41	4.31	5.44
T_6/A_6	6.83	5.46	4.38	5.56
T_7/A_7	5.91	4.95	3.93	4.93
Mean B	6.33	5.21	4.19	
	Factors	**C.D.**	**SE(d)**	**SE(m)**
	Factor(A)	0.039	0.019	0.014
	Factor(B)	0.026	0.013	0.009
	Factor (AxB)	0.068	0.034	0.024
60 DAS	$50^0C/B_1$	$55^0C/B_2$	$60^0C/B_3$	**Mean A**
T_1/A_1	5.35	4.33	3.79	4.49
T_2/A_2	5.71	4.64	3.86	4.74
T_3/A_3	6.03	4.81	4.18	5.01
T_4/A_4	5.13	4.31	3.66	4.37
T_5/A_5	5.74	4.81	4.02	4.86
T_6/A_6	6.23	4.84	4.18	5.08
T_7/A_7	5.05	4.31	3.64	4.33
Mean B	5.61	4.58	3.90	
	Factors	**C.D.**	**SE(d)**	**SE(m)**
	Factor(A)	0.014	0.007	0.005
	Factor(B)	0.009	0.004	0.003
	Factor (AxB)	0.024	0.012	0.008

A(1-7): Treatments {**A1**(T_1) – Citric acid 0.2% + 4 min blanching + water, **A2** (T_2) – Citric acid 0.2% + 4 min blanching + $K_2S_2O_5$ 0.1%, **A3** (T_3) – Citric acid 0.2% + 4 min blanching + $Na_2S_2O_5$ 0.1%, **A4** (T_4)– $CaCl_2$ 0.2% + 4 min blanching + water, **A5** (T_5) – $CaCl_2$ 0.2% + 4 min blanching + $K_2S_2O_5$ 0.1%, **A6** (T_6) – $CaCl_2$ 0.2% + 4 min blanching + $Na_2S_2O_5$ 0.1%, **A7** (T_7) – water + 4 min blanching + water}, B(1-3): Temperatures (**B1**- 50^0C, **B2**- 55^0C, **B3**- 60^0C)

Table.3 Total chlorophyll (mg/g) of dehydrated broccoli florets during the storage intervals

0 DAS	$50^0C/B_1$	$55^0C/B_2$	$60^0C/B_3$	Mean A
A_1-A_7	9.70	9.13	8.26	-
Mean B	-	-	-	
30 DAS	B_1	B_2	B_3	**Mean A**
T_1/A_1	7.07	4.63	4.47	5.39
T_2/A_2	7.40	6.07	5.17	6.21
T_3/A_3	8.57	7.27	6.73	7.52
T_4/A_4	6.43	4.27	3.60	4.77
T_5/A_5	8.07	6.50	5.83	6.80
T_6/A_6	8.87	7.50	7.03	7.80
T_7/A_7	6.17	3.40	3.07	4.21
Mean B	7.51	5.66	5.13	
	Factors	**C.D.**	**SE(d)**	**SE(m)**
	Factor(A)	0.129	0.064	0.045
	Factor(B)	0.084	0.042	0.029
	Factor AxB	0.223	0.11	0.078
45 DAS	$50^0C/B_1$	$55^0C/B_2$	$60^0C/B_3$	**Mean A**
T_1/A_1	4.40	3.67	3.47	3.84
T_2/A_2	6.10	4.33	4.03	4.82
T_3/A_3	7.77	6.10	5.30	6.39
T_4/A_4	3.83	3.27	2.80	3.30
T_5/A_5	6.83	5.67	5.03	5.84
T_6/A_6	8.30	6.80	6.10	7.07
T_7/A_7	3.13	3.00	2.20	2.78
Mean B	5.77	4.69	4.13	
	Factors	**C.D.**	**SE(d)**	**SE(m)**
	Factor(A)	0.158	0.078	0.055
	Factor(B)	0.104	0.051	0.036
	Factor AxB	0.274	0.135	0.096
60 DAS	$50^0C/B_1$	$55^0C/B_2$	$60^0C/B_3$	**Mean A**
T_1/A_1	2.70	2.43	2.73	2.62
T_2/A_2	3.40	3.20	3.17	3.26
T_3/A_3	5.43	5.77	5.07	5.42
T_4/A_4	2.13	2.93	1.80	2.29
T_5/A_5	4.50	4.73	4.17	4.47
T_6/A_6	6.13	6.27	5.63	6.01
T_7/A_7	1.63	1.83	1.13	1.53
Mean B	3.71	3.88	3.39	
	Factors	**C.D.**	**SE(d)**	**SE(m)**
	Factor(A)	0.132	0.065	0.046
	Factor(B)	0.087	0.043	0.03
	Factor AxB	0.229	0.113	0.08

A(1-7): Treatments {**A1**(T_1) – Citric acid 0.2% + 4 min blanching + water, **A2** (T_2) – Citric acid 0.2% + 4 min blanching + $K_2S_2O_5$ 0.1%, **A3** (T_3) – Citric acid 0.2% + 4 min blanching + $Na_2S_2O_5$ 0.1%, **A4** (T_4)– $CaCl_2$ 0.2% + 4 min blanching + water, **A5** (T_5) – $CaCl_2$ 0.2% + 4 min blanching + $K_2S_2O_5$ 0.1%, **A6** (T_6) – $CaCl_2$ 0.2% + 4 min blanching + $Na_2S_2O_5$ 0.1%, **A7** (T_7) – water + 4 min blanching + water}, B(1-3): Temperatures (**B1**- 50^0C, **B2**- 55^0C, **B3**- 60^0C)

Table.4 Total content of phenols (mg GAE/g) of dehydrated broccoli florets during the storage intervals

0 DAS	$50^0C/B_1$	$55^0C/B_2$	$60^0C/B_3$	Mean A
A_1-A_7	5.83	5.24	4.73	-
Mean B	-	-	-	
30 days	B_1	B_2	B_3	Mean A
T_1/A_1	4.92	4.08	3.34	4.11
T_2/A_2	5.05	4.23	3.64	4.31
T_3/A_3	5.36	4.74	4.14	4.75
T_4/A_4	4.85	4.01	3.08	3.98
T_5/A_5	5.25	4.55	3.77	4.52
T_6/A_6	5.55	4.84	4.45	4.95
T_7/A_7	4.63	3.82	2.85	3.76
Mean B	5.09	4.32	3.61	
	Factors	C.D.	SE(d)	SE(m)
	Factor(A)	0.024	0.012	0.008
	Factor(B)	0.015	0.008	0.005
	Factor(A X B)	0.041	0.02	0.014
45 days	$50^0C/B_1$	$55^0C/B_2$	$60^0C/B_3$	Mean A
T_1/A_1	3.05	2.96	2.65	2.88
T_2/A_2	3.57	3.52	3.26	3.45
T_3/A_3	4.35	4.08	3.76	4.06
T_4/A_4	2.65	2.52	2.24	2.47
T_5/A_5	3.92	3.82	3.61	3.78
T_6/A_6	4.73	4.66	4.16	4.52
T_7/A_7	2.22	2.05	1.85	2.04
Mean B	3.50	3.37	3.07	
	Factors	C.D.	SE(d)	SE(m)
	Factor(A)	0.026	0.013	0.009
	Factor(B)	0.017	0.008	0.006
	Factor(A X B)	0.045	0.022	0.016
60 days	$50^0C/B_1$	$55^0C/B_2$	$60^0C/B_3$	Mean A
T_1/A_1	1.55	2.15	1.42	1.71
T_2/A_2	1.77	2.32	1.59	1.89
T_3/A_3	2.16	3.07	1.82	2.35
T_4/A_4	1.25	1.76	1.04	1.35
T_5/A_5	1.95	2.55	1.65	2.05
T_6/A_6	2.59	3.35	2.41	2.78
T_7/A_7	0.96	1.44	0.84	1.08
Mean B	1.75	2.38	1.54	
	Factors	C.D.	SE(d)	SE(m)
	Factor(A)	0.026	0.013	0.009
	Factor(B)	0.017	0.008	0.006
	Factor(A X B)	0.045	0.022	0.016

A(1-7): Treatments {**A1**(T_1) – Citric acid 0.2% + 4 min blanching + water, **A2** (T_2) – Citric acid 0.2% + 4 min blanching + $K_2S_2O_5$ 0.1%, **A3** (T_3) – Citric acid 0.2% + 4 min blanching + $Na_2S_2O_5$ 0.1%, **A4** (T_4)– $CaCl_2$ 0.2% + 4 min blanching + water, **A5** (T_5) – $CaCl_2$ 0.2% + 4 min blanching + $K_2S_2O_5$ 0.1%, **A6** (T_6) – $CaCl_2$ 0.2% + 4 min blanching + $Na_2S_2O_5$ 0.1%, **A7** (T_7) – water + 4 min blanching + water}, B(1-3): Temperatures (**B1**- 50^0C, **B2**- 55^0C, **B3**- 60^0C)

Table.5 Total flavanoid content (mg CE/g) of dehydrated broccoli florets during the storage intervals

0 DAS	$50^0C/B_1$	$55^0C/B_2$	$60^0C/B_3$	Mean A
A_1-A_7	1.26	1.13	1.02	-
Mean B	-	-	-	
30 DAS	B_1	B_2	B_3	**Mean A**
T_1/A_1	0.82	0.63	0.58	0.68
T_2/A_2	0.88	0.72	0.67	0.76
T_3/A_3	1.01	0.83	0.81	0.88
T_4/A_4	0.74	0.57	0.51	0.61
T_5/A_5	0.94	0.77	0.72	0.81
T_6/A_6	1.08	0.91	0.84	0.95
T_7/A_7	0.64	0.51	0.45	0.53
Mean B	0.87	0.71	0.66	
	Factors	**C.D.**	**SE(d)**	**SE(m)**
	Factor(A)	0.010	0.005	0.003
	Factor(B)	0.006	0.003	0.002
	Factor (AxB)	0.017	0.008	0.006
45 DAS	$50^0C/B_1$	$55^0C/B_2$	$60^0C/B_3$	**Mean A**
T_1/A_1	0.64	0.57	0.52	0.57
T_2/A_2	0.72	0.66	0.61	0.66
T_3/A_3	0.84	0.79	0.69	0.77
T_4/A_4	0.55	0.51	0.45	0.50
T_5/A_5	0.78	0.71	0.65	0.71
T_6/A_6	0.93	0.84	0.75	0.84
T_7/A_7	0.44	0.38	0.32	0.38
Mean B	0.70	0.64	0.57	
	Factors	**C.D.**	**SE(d)**	**SE(m)**
	Factor(A)	0.011	0.006	0.004
	Factor(B)	0.007	0.004	0.003
	Factor (AxB)	0.020	0.010	0.007
60 DAS	$50^0C/B_1$	$55^0C/B_2$	$60^0C/B_3$	**Mean A**
T_1/A_1	0.19	0.30	0.16	0.22
T_2/A_2	0.28	0.35	0.24	0.29
T_3/A_3	0.38	0.48	0.33	0.40
T_4/A_4	0.15	0.26	0.09	0.17
T_5/A_5	0.32	0.42	0.27	0.34
T_6/A_6	0.48	0.53	0.44	0.48
T_7/A_7	0.11	0.15	0.06	0.11
Mean B	0.27	0.36	0.23	
	Factors	**C.D.**	**SE(d)**	**SE(m)**
	Factor(A)	0.009	0.004	0.003
	Factor(B)	0.006	0.003	0.002
	Factor (AxB)	0.016	0.008	0.005

A(1-7): Treatments {**A1**(T_1) – Citric acid 0.2% + 4 min blanching + water, **A2** (T_2) – Citric acid 0.2% + 4 min blanching + $K_2S_2O_5$ 0.1%, **A3** (T_3) – Citric acid 0.2% + 4 min blanching + $Na_2S_2O_5$ 0.1%, **A4** (T_4)– $CaCl_2$ 0.2% + 4 min blanching + water, **A5** (T_5) – $CaCl_2$ 0.2% + 4 min blanching + $K_2S_2O_5$ 0.1%, **A6** (T_6) – $CaCl_2$ 0.2% + 4 min blanching + $Na_2S_2O_5$ 0.1%, **A7** (T_7) – water + 4 min blanching + water}, B(1-3): Temperatures (**B1**- 50^0C, **B2**- 55^0C, **B3**- 60^0C)

Table.6 Antioxidant activity (percent inhibition of DPPH) of dehydrated broccoli florets during the storage intervals

0 DAS	**$50^0C/B_1$**	**$55^0C/B_2$**	**$60^0C/B_3$**	**Mean A**
A_1-A_7	38.46	33.50	32.46	-
Mean B	-	-	-	
30 DAS	**B_1**	**B_2**	**B_3**	**Mean A**
T_1/A_1	27.83	24.47	23.17	25.16
T_2/A_2	29.20	26.20	23.80	26.40
T_3/A_3	32.37	31.10	27.37	30.28
T_4/A_4	27.10	22.57	20.57	23.41
T_5/A_5	30.60	26.70	24.50	27.27
T_6/A_6	35.30	31.73	28.50	31.84
T_7/A_7	23.20	21.37	19.50	21.36
Mean B	29.37	26.31	23.91	
	Factors	**C.D.**	**SE(d)**	**SE(m)**
	Factor(A)	0.204	0.101	0.071
	Factor(B)	0.134	0.066	0.047
	Factor AxB	0.354	0.175	0.123
45 DAS	**$50^0C/B_1$**	**$55^0C/B_2$**	**$60^0C/B_3$**	**Mean A**
T_1/A_1	24.07	22.90	18.10	21.69
T_2/A_2	24.80	24.70	18.80	22.77
T_3/A_3	26.63	25.33	20.63	24.20
T_4/A_4	23.37	22.17	16.20	20.58
T_5/A_5	25.70	24.57	19.20	23.16
T_6/A_6	31.23	30.30	25.53	29.02
T_7/A_7	20.13	18.57	13.67	17.46
Mean B	25.13	24.08	18.88	
	Factors	**C.D.**	**SE(d)**	**SE(m)**
	Factor(A)	0.156	0.077	0.054
	Factor(B)	0.102	0.05	0.036
	Factor AxB	0.27	0.133	0.094
60 DAS	**$50^0C/B_1$**	**$55^0C/B_2$**	**$60^0C/B_3$**	**Mean A**
T_1/A_1	17.33	17.63	10.20	15.06
T_2/A_2	18.17	21.17	10.80	16.71
T_3/A_3	19.27	22.57	14.63	18.82
T_4/A_4	15.30	16.47	8.50	13.42
T_5/A_5	18.70	21.83	11.43	17.32
T_6/A_6	23.73	24.00	18.53	22.09
T_7/A_7	11.23	11.90	6.53	9.89
Mean B	17.68	19.37	11.52	
	Factors	**C.D.**	**SE(d)**	**SE(m)**
	Factor(A)	0.203	0.1	0.071
	Factor(B)	0.133	0.066	0.046
	Factor AxB	0.351	0.173	0.123

A(1-7): Treatments {**A1**(T_1) – Citric acid 0.2% + 4 min blanching + water, **A2** (T_2) – Citric acid 0.2% + 4 min blanching + $K_2S_2O_5$ 0.1%, **A3** (T_3) – Citric acid 0.2% + 4 min blanching + $Na_2S_2O_5$ 0.1%, **A4** (T_4)– $CaCl_2$ 0.2% + 4 min blanching + water, **A5** (T_5) – $CaCl_2$ 0.2% + 4 min blanching + $K_2S_2O_5$ 0.1%, **A6** (T_6) – $CaCl_2$ 0.2% + 4 min blanching + $Na_2S_2O_5$ 0.1%, **A7** (T_7) – water + 4 min blanching + water}, B(1-3): Temperatures (**B1**- 50^0C, **B2**- 55^0C, **B3**- 60^0C)

Table.7 Populations of unicellular fungi (x 10^2 cfu/g) on dehydrated broccoli florets during the storage intervals

0 DAS	**$50^0C/B_1$**	**$55^0C/B_2$**	**$60^0C/B_3$**	**Mean A**
A1-A7	2.00	2.00	1.33	-
Mean B	-	-	-	
30 days	**B1**	**B2**	**B3**	**Mean A**
T_1/A_1	3.00	2.00	2.00	2.33
T_2/A_2	2.67	1.67	1.67	2.00
T_3/A_3	2.00	2.00	1.67	1.89
T_4/A_4	3.00	2.67	2.33	2.67
T_5/A_5	2.00	1.67	1.67	1.78
T_6/A_6	2.00	2.00	1.67	1.89
T_7/A_7	3.67	3.00	2.67	3.11
Mean B	2.62	2.14	1.95	
	Factors	**C.D.**	**SE(d)**	**SE(m)**
	Factor(A)	0.399	0.197	0.139
	Factor(B)	0.261	0.129	0.091
	Factor(A X B)	N/A	0.341	0.241
45 days	**$50^0C/B_1$**	**$55^0C/B_2$**	**$60^0C/B_3$**	**Mean A**
T_1/A_1	3.67	2.67	2.67	3.00
T_2/A_2	3.67	2.33	2.33	2.78
T_3/A_3	2.67	2.00	2.00	2.22
T_4/A_4	3.67	3.00	2.67	3.11
T_5/A_5	3.00	2.33	2.00	2.44
T_6/A_6	1.67	1.67	1.67	1.67
T_7/A_7	4.00	3.67	3.00	3.56
Mean B	3.19	2.52	2.33	
	Factors	**C.D.**	**SE(d)**	**SE(m)**
	Factor(A)	0.45	0.222	0.157
	Factor(B)	0.295	0.145	0.103
	Factor(A X B)	N/A	0.385	0.272
60 days	**$50^0C/B_1$**	**$55^0C/B_2$**	**$60^0C/B_3$**	**Mean A**
T_1/A_1	6.33	3.67	3.00	4.33
T_2/A_2	4.67	3.00	2.33	3.33
T_3/A_3	3.00	2.67	2.00	2.56
T_4/A_4	7.00	4.33	3.33	4.89
T_5/A_5	3.67	2.67	2.33	2.89
T_6/A_6	2.67	2.00	2.00	2.22
T_7/A_7	8.67	5.67	4.00	6.11
Mean B	5.14	3.43	2.71	
	Factors	**C.D.**	**SE(d)**	**SE(m)**
	Factor(A)	0.434	0.214	0.151
	Factor(B)	0.284	0.140	0.099
	Factor(A X B)	0.751	0.371	0.262

A(1-7): Treatments {**A1**(T_1) – Citric acid 0.2% + 4 min blanching + water, **A2** (T_2) – Citric acid 0.2% + 4 min blanching + $K_2S_2O_5$ 0.1%, **A3** (T_3) – Citric acid 0.2% + 4 min blanching + $Na_2S_2O_5$ 0.1%, **A4** (T_4)– $CaCl_2$ 0.2% + 4 min blanching + water, **A5** (T_5) – $CaCl_2$ 0.2% + 4 min blanching + $K_2S_2O_5$ 0.1%, **A6** (T_6) – $CaCl_2$ 0.2% + 4 min blanching + $Na_2S_2O_5$ 0.1%, **A7** (T_7) – water + 4 min blanching + water}, B(1-3): Temperatures (**B1**- 50^0C, **B2**- 55^0C, **B3**- 60^0C)

Table.8 Populations of filamentous fungi (x 10^2 cfu/g) on dehydrated broccoli florets during the storage intervals

0 DAS	**$50^0C/B_1$**	**$55^0C/B_2$**	**$60^0C/B_3$**	**Mean A**
A1-A7	0.66	0.66	0.66	-
Mean B	-	-	-	
30 days	**B1**	**B2**	**B3**	**Mean A**
T_1/A_1	1.33	1.33	1.00	1.22
T_2/A_2	1.33	1.33	1.00	1.22
T_3/A_3	1.33	1.33	0.67	1.11
T_4/A_4	1.33	1.67	1.33	1.44
T_5/A_5	1.33	1.00	0.67	1.00
T_6/A_6	1.33	1.33	0.67	1.11
T_7/A_7	2.00	1.67	1.67	1.78
Mean B	1.429	1.381	1.00	
	Factors	**C.D.**	**SE(d)**	**SE(m)**
	Factor(A)	N/A	0.245	0.173
	Factor(B)	0.325	0.16	0.113
	Factor(A X B)	N/A	0.424	0.300
45 days	**$50^0C/B_1$**	**$55^0C/B_2$**	**$60^0C/B_3$**	**Mean A**
T_1/A_1	1.67	1.67	1.33	1.56
T_2/A_2	1.67	1.67	1.33	1.56
T_3/A_3	1.33	1.33	1.00	1.22
T_4/A_4	1.67	2.00	1.67	1.78
T_5/A_5	1.67	1.33	1.00	1.33
T_6/A_6	1.33	1.00	0.67	1.00
T_7/A_7	2.33	2.00	1.67	2.00
Mean B	1.67	1.57	1.24	
	Factors	**C.D.**	**SE(d)**	**SE(m)**
	Factor(A)	0.481	0.238	0.168
	Factor(B)	0.315	0.156	0.110
	Factor(A X B)	N/A	0.411	0.291
60 days	**$50^0C/B_1$**	**$55^0C/B_2$**	**$60^0C/B_3$**	**Mean A**
T_1/A_1	2.00	2.00	1.67	1.89
T_2/A_2	2.00	1.67	1.33	1.67
T_3/A_3	1.67	1.67	1.00	1.44
T_4/A_4	2.33	2.33	2.00	2.22
T_5/A_5	2.00	1.67	1.33	1.67
T_6/A_6	1.33	1.00	0.67	1.00
T_7/A_7	2.67	2.67	2.33	2.56
Mean B	2.00	1.86	1.48	
	Factors	**C.D.**	**SE(d)**	**SE(m)**
	Factor(A)	0.450	0.222	0.157
	Factor(B)	0.295	0.145	0.103
	Factor(A X B)	N/A	0.385	0.272

A(1-7): Treatments {**A1**(T_1) – Citric acid 0.2% + 4 min blanching + water, **A2** (T_2) – Citric acid 0.2% + 4 min blanching + $K_2S_2O_5$ 0.1%, **A3** (T_3) – Citric acid 0.2% + 4 min blanching + $Na_2S_2O_5$ 0.1%, **A4** (T_4)– $CaCl_2$ 0.2% + 4 min blanching + water, **A5** (T_5) – $CaCl_2$ 0.2% + 4 min blanching + $K_2S_2O_5$ 0.1%, **A6** (T_6) – $CaCl_2$ 0.2% + 4 min blanching + $Na_2S_2O_5$ 0.1%, **A7** (T_7) – water + 4 min blanching + water}, B(1-3): Temperatures (**B1**- 50^0C, **B2**- 55^0C, **B3**- 60^0C)

Fig.1 Moisture content (dry weight basis) of broccoli florets at variable temperature during the process of dehydration

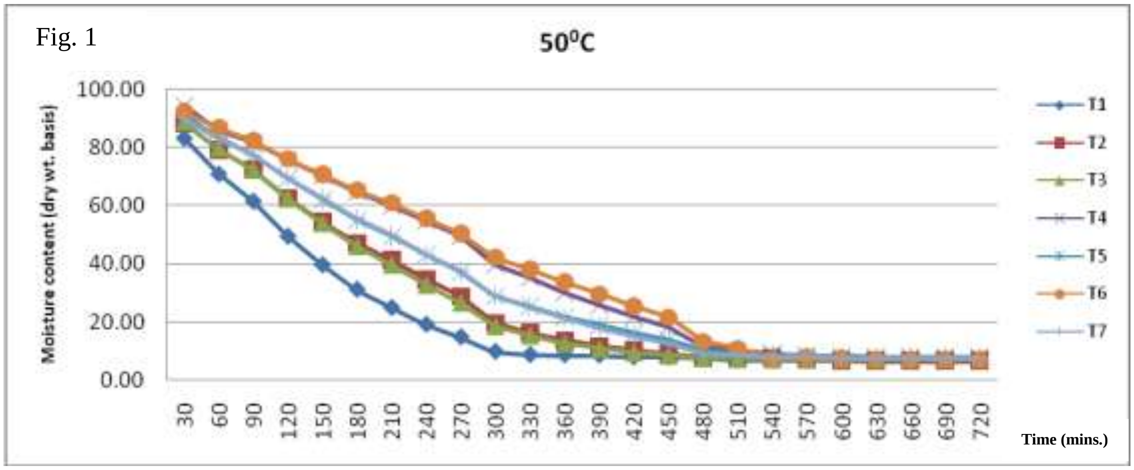


Fig.2 Moisture content (dry weight basis) of broccoli florets at variable temperature during the process of dehydration

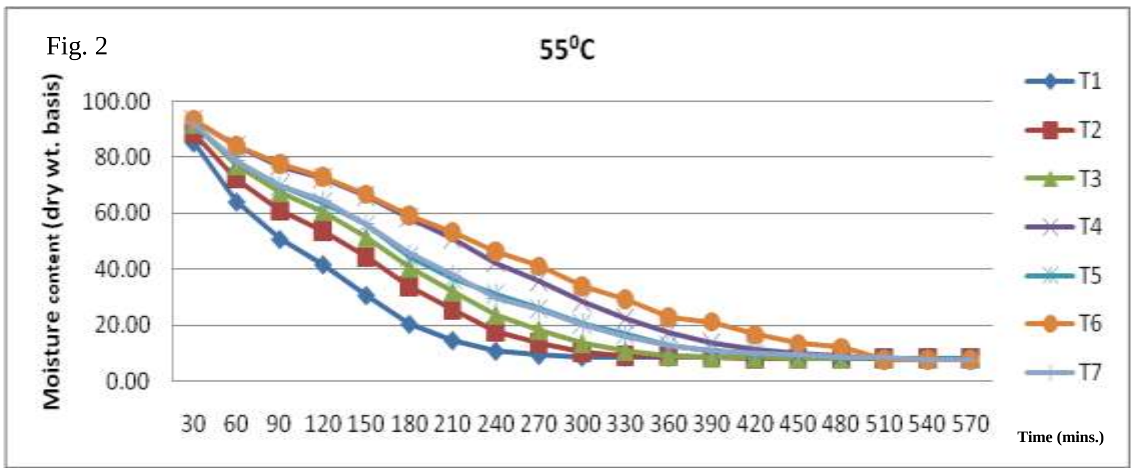
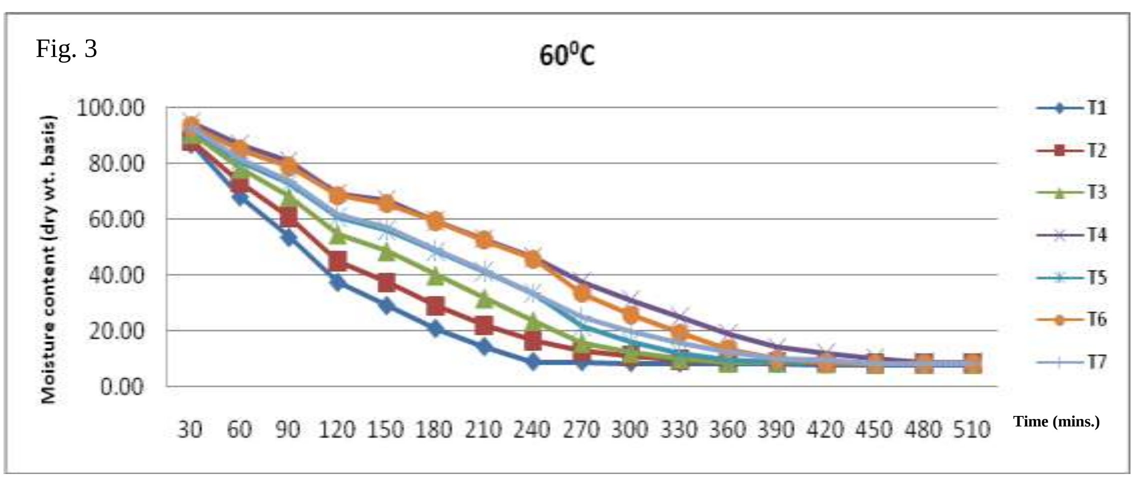


Fig.3 Moisture content (dry weight basis) of broccoli florets at variable temperature during the process of dehydration



Das and Dhua (2019) reported similar observation for dehydrated banana inflorescence on several attributes.

The study showed that at 0 days of storage various physical and chemical attributes for dehydrated broccoli florets were at their maximum for treatments dehydrated at 50^0C followed by treatments dehydrated at 55^0C and treatments dehydrated at 60^0C. However later during the study, concentration of various biochemical parameters decreased for treatments dehydrated at 50^0C and treatments dehydrated at 60^0C respectively. At first 30 days of storage maximum concentration of total chlorophyll, phenols, flavanoids and antioxidants were seen for treatments dehydrated at 50^0C followed by treatments dehydrated at 55^0C and lastly for treatments dehydrated at 60^0C. But at 45 days of storage various attributes for different treatments dehydrated at 50^0C decreased as compared to treatments dehydrated at 55^0C. Similar trend was seen at 60 days of storage. The biochemical parameters and other physical attributes for treatments dehydrated at 60^0C were always low. The fungal populations for treatments dehydrated at 60^0C was lesser than treatments dehydrated at 55^0C and treatments dehydrated at 50^0C but the population count of treatments dehydrated at 55^0C were very much similar to that of the treatments dehydrated at 60^0C. So lastly it was concluded that the temperature of 55^0C for dehydration of broccoli florets and pre drying treatment of initial immersion with 0.2 % of calcium chloride, 4 minutes of hot water blanching and final immersion with 0.1 % of sodium metabisulfite was most effective which helped in retaining the physical and biochemical properties throughout the storage period.

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