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Effect of pre-treatment and drying temperature on quality of dehydrated cauliflower (*Brassica oleracea* var. *botrytis*)

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Abstract

Cauliflower curd were pre-treated with hot water blanching + 0.125% KMS, with/without microwave blanching for 5 minutes and were dehydrated at three levels of temperature *viz.,* 65, 60 and 55 °C at different treatment combinations. Considering the dehydration characters and quality after dehydration and storage it was found that T_2 (hot water blanching + 0.125% KMS + microwave blanching + drying at 65 °C) was the best treatment followed by T_4 (hot water blanching + 0.125% KMS + microwave blanching + drying at 60 °C) and T_5 (hot water blanching + 0.125% KMS + drying at 55 °C). In T_2, time taken for complete dehydration (445 minutes) and moisture content (3.62%) was least. Further, the moisture content after 6 month of storage was also less (9.63%), drying rate (135.74%) and dehydration ratio (10.70) was medium after dehydration. Ascorbic acid retention was maximum during storage in the treatment. Sensory evaluation also supported the superiority of this treatment.

Key words: Cauliflower, pretreatment, drying temperature, quality, dehydration.

Introduction

India is the second largest producer of cauliflower (*Brassica oleracea* var. *botrytis*) in the world with a total annual production of 4.8 million metric tonnes amounting to 30% of the total world production (Anon., 2003). Cauliflower contains considerable amount of protein, carbohydrate, fat, vitamin B, vitamin C and is fairly rich in minerals like phosphorus, potassium, sodium, iron, magnesium etc. (Chatterjee, 1993).

The edible portion of cauliflower constitutes approximately 67.3% of the vegetable (Abhay *et al.*, 2006). Fresh cauliflower is delicate in handling and highly perishable in nature. In peak season, due to market glut cauliflower are sold at a very low price resulting in heavy losses to the growers. In India, it has been estimated that postharvest losses of cauliflower is to the extent of about 28.6 to 35.1 per cent (Pal *et al.*, 2002). Fresh cauliflower cannot be stored for longer period due to its poor shelf life, but good compact heads can be cold stored for 3-4 weeks at 0 °C with 85-90% relative humidity (Madhavi and Ghosh, 1998). Only limited quantity is processed and preserved in different form for future consumption. By drying the fresh cauliflower, it is quickly transformed into a dried stable material, volume and weight about 10 times less than the original fresh material. It is simple, low cost and economical method of preservation. Dehydrated cauliflower is used as an important ingredient in several food preparations including instant soups, kheer, instant mix and to make stuff in prontha (semi friedcake) (Abhay *et al.*, 2006). The demand of dried cauliflower is ever increasing because its export is in progress. Household drying of cauliflower is an age-old common practice in villages. However it develops rancid smell because of prolonged drying under shade.

Osmotic dehydration of cauliflower as influenced by temperature, salt concentration, ratio of brine to material and time was studied by Vijayanand *et al.* (1995). Dehydration of cauliflower by hot air has not been tested extensively as in other vegetables (Von Loesecke, 1998). The meager information available regarding dehydration of cauliflower indicated the problem of retention of texture, colour, flavour and rehydration characteristics of rehydrated product (Srivastava and Sulebele, 1975; Raina *et al.*, 1982 and Abhay *et al.*, 2006).

It has been reported that blanching along with pretreatment with sodium hydroxide, calcium hydroxide, sodium sulphate, potassium metabisulphite has been effective in maintaining the physical and chemical characters of dehydrated product of different vegetables (Srivastava and Sulebele, 1975; Bawa and Saini, 1986; Mulay *et al.*, 1994; Rouf *et al.*, 2003). Further, temperature of dehydration is a critical factor for good quality dehydrated product (Abhay *et al.*, 2006). The high temperature and considerable oxidation of ascorbic acid associated with hot air drying is reported to cause a brown colour (Ranganna and Setty, 1968).

Thus, considering the above facts, the present investigation was undertaken to standardize the pretreatment with different temperature of dehydration and to study the quality of dehydrated product.

Materials and methods

The cauliflower curd cut pieces (2 × 2 cm) were divided into six lots and subjected to different combinations of pre-treatments *viz.*, hot water blanching (97°C for 1 min) + soaking in 0.125% potassium metabisulphite (KMS) solution for 10 minutes and hot water blanching (97°C for 1 min) + soaking in 0.125% potassium metabisulphite (KMS) solution for 10 minutes and were then dehydrated in hot air cabinet drier at three different temperatures *i.e.*, 65, 60 and 55°C. The drying was carried out at an air velocity of 4.7 mm/sec. The trays were weighed on digital balance at regular interval (5-10 minutes interval during first 4 hours then at an interval of 25 to 30 minutes) until the product attained more or less constant weight. Dried sample was collected from the tray, cooled to room temperature and each treatment was sealed in zip lock (self sealing, 200 gauge) polyethylene bags, which facilitated storage study at different month interval upto 6 months. All the polyethylene bags were stored in air tight plastic container having sachet of silica gel. The moisture content and ascorbic acid of the sample was estimated in three replications before and after dehydration and also during storage using standard procedure (Ranganna, 1991).

Sensory evaluation was conducted by a panel of judges for colour, flavour, texture, odour and overall acceptability using 9 point hedonic scale with rating of 1 for extremely disliked and 9 for extremely excellent (Dasgupta *et al.*, 1999). Statistical analysis was done according to factorial completely randomized design using standard statistical procedure.

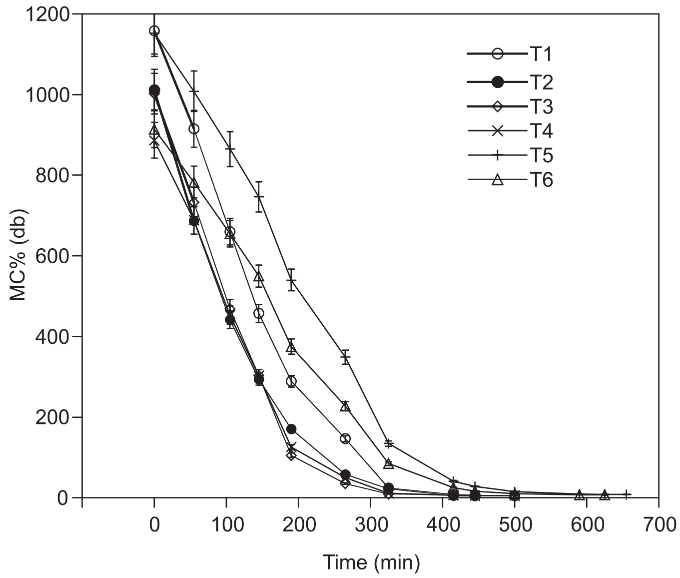

Fig. 1. Moisture content at different time intervals in treatments

Results and discussion

Relationship between the moisture content (% db) vs time of different treatments has been shown in Fig. 1. The initial moisture content was high in all the treatments and it varied from 1158.44% in T_1 (hot water blanching + 0.125 KMS + drying at 65°C) to 913.71% in T_6 (hot water blanching + 0.125% KMS + microwave blanching + drying at 55°C) (Table 2). Moisture content decreased rapidly during the first hour of drying in all the treatments indicating easy escape of moisture during the early period of drying due to high moisture content at the initial stage of drying. It is believed that in the early stages of drying the material behaves as though the surface was saturated with water. Dehydration curve indicated that the time required to achieve desired final moisture (5 to 8%) is influenced predominantly by the temperature of dehydration. Higher temperature of dehydration at 65°C yielded a faster drying (495 minutes in T_1 and 445 minutes in T_2) than the lower temperature of 60 °C (510 minutes in T_3 and 505 minutes in T_4) and 55°C (655 minutes in T_5 and 625 minutes in T_6). Hence, at a temperature level of 65 °C, the drying time ranged from 445-495 min, 505-510 minutes for temperature level of 60 °C and 655-625 minutes for temperature level of 55 °C. The driving force for the mass transfer at the surface increases markedly with temperature, since mass loss due to evaporation at the surface is the function of partial vapour pressure difference between the surface and the convective air which increases the moisture diffusivity at higher temperature, contributing to faster drying at higher temperature (Tulsidas *et al.*, 1995).

Table 1. Initial moisture content in different treatments of dehydrated cauliflower, before dehydration and their final moisture content after dehydration and storage

Treatment	Initial moisture content before dehydration (% wb)	Final moisture content after dehydration (% wb)	Final moisture content after 6 months of storage (% wb)
T_1	92.23	4.08	9.59
T_2	91.17	3.62	9.63
T_3	90.92	5.26	9.80
T_4	90.13	5.02	10.55
T_5	91.81	7.48	12.49
T_6	91.26	6.24	13.19
LSD (P=0.05)	1.15	0.13	4.40
LSD (P=0.01)	1.61	0.18	N.S.

Table 2. Initial moisture (% db) final moisture content (% db), moisture reduction (%) drying time and drying rate in different treatments of dehydrated cauliflower

Treatment	Moisture		Moisture reduction (%)	Drying time (min.)	Total drying time in h	Overall drying rate (%/h)
	Initial (% db)	Final (% db)				
T_1	1158.44	5.56	1152.88	495	8.15	139.74
T_2	1012.23	5.47	1006.76	445	7.25	135.74
T_3	1002.15	5.62	996.53	505	8.25	118.39
T_4	886.85	4.96	881.89	500	8.20	105.82
T_5	1151.82	8.02	1143.80	655	10.55	104.77
T_6	913.71	6.64	907.07	625	10.25	87.07

Drying rate versus average moisture content indicated that in general, with decrease in the average moisture content drying rate decreased in all the treatments (Fig. 2). In T_2 (hot water + 0.125% KMS + microwave blanching + drying at 65 °C), the decrease in drying rate with the average moisture content indicated that

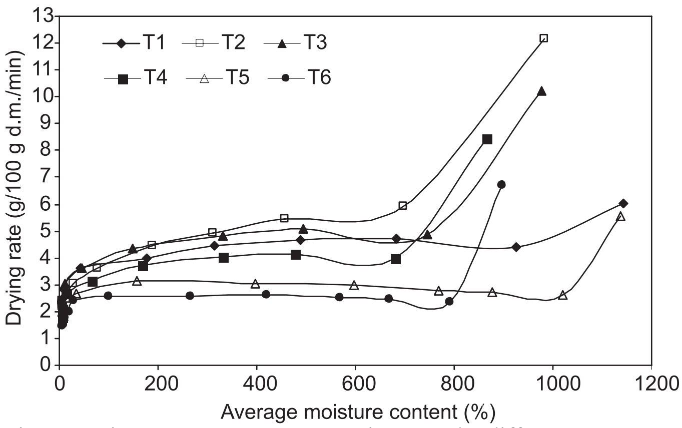

Fig. 2. Drying rate versus average moisture under different treatments

whole drying took place in falling rate period *i.e.*, a declined trend and no constant rate period of drying was observed. In T_1 (hot water + 0.125% KMS + drying at 65°C), T_3 (hot water blanching + 0.125% KMS + drying at 60°C) and T_4 (hot water blanching + 0.125% KMS + microwave blanching + drying at 60°C) drying rate increased slightly and thereafter showed the declining trend. But in T_5 (hot water blanching + 0.125% KMS + drying at 55°C) and T_6 (hot water blanching + 0.125% KMS + microwave blanching + drying at 55°C) drying rate increased slightly and thereafter almost a constant rate of drying was observed which was followed by decreasing trend. The characteristics features of cauliflower curd and pretreatment effect (like KMS and microwave) might be attributed to the differences in the drying rate with average moisture content in treatments (T_1 to T_6). It has been reported earlier (Madamba *et al*., 1996) that almost all the drying of biological products takes place in the decline rate period. *i.e*., with decrease in average moisture content drying rate decreased continuously.

Moisture content before dehydration varied from 90.13% (T_4 *i.e.* hot water blanching + 0.125% KMS + microwave blanching + drying at 60°C) to 92.23% (T_1 *i.e.* hot water blanching + 0.125% KMS + drying at 65°C) and after dehydration moisture content ranged from 3.62% in T_2 (hot water blanching + 0.125% KMS + microwave blanching + drying at 65°C) to 7.48% in T_5 (hot water blanching + 0.125% KMS + drying at 55°C). The moisture content (before and after dehydration on wet basis) in almost all the treatment was within the range of earlier findings (Kaur and Singh, 1981; Raina *et al.*, 1982; Bawa and Saini, 1986 and Maldonado *et al.*, 2003).

The high final moisture content of T_5 (hot water blanching + 0.125% KMS + drying at 55°C) and T_6 (hot water blanching + 0.125% KMS + microwave blanching + drying at 55°C) (7.48% and 6.24, respectively) was due to comparatively low drying temperature which was also demonstrated by Abhay *et al.* (2006). After six months of storage, moisture content was lower in T_1 and T_2 compared to other treatments, however, there was no significant difference between the treatments for the dehydrated cauliflower (Table 1).

The total moisture reduction (% db) in different treatments and their respective drying time is shown in Table 3. The total moisture reduction was observed to be highest (1152.88%) in T_1 (hot water blanching + 0.125% KMS + drying at 65°C) followed by 1143.80% in T_5 (hot water blanching + 0.125% KMS + drying at 55°C), 1006.76% in T_2 (hot water blanching + 0.125% KMS + microwave blanching + drying at 65°C), 996.53% in T_3 (hot water blanching + 0.125% KMS + drying at 60°C), 907.07% in T_6 (hot water blanching + 0.125% KMS + microwave blanching + drying at 55°C) and 881.89% in T_4 (hot water blanching + 0.125% KMS + microwave blanching +drying at 60°C).

The drying time taken for the dehydration was maximum in T_5 (655 min) to remove 1143.80% moisture from the initial moisture content of 1151.82% whereas drying time taken was least in T_2 (445 min) to remove 1006.76% moisture from the initial moisture content of 1012.23% (Table 3). Thus, drying time for T_2 was minimum *i.e.* 445 minutes followed by 495 minutes in T_1, 500 minutes in T_4, 505 minutes in T_3, 625 minutes in T_6 and 655 minutes in T_5. The difference in drying time can be attributed to differences in dehydration temperature of 65°C (for T_1 and T_2), 60°C (for T_3 and T_4) and 55°C (T_4 and T_5). Drying time decreased with increased temperature of drying. Higher temperature causes the increase in the product temperature and higher vapour pressure gradient resulting in the increased moisture diffusivity and accelerated drying (Sarvacos and Rouzeos, 1986). The treatments T_1, T_3 and T_5 received common pretreatment (hot water blanching + 0.125% KMS) and only the temperature of dehydration varied (65, 60 and 55°C temperature, respectively) as indicated earlier. Thus, the drying time increased in the order of T_1 (495 min), T_3 (505 min) and T_5 (655 min) bearing the inverse relationship with temperature in these treatments. Similar behaviour was exhibited by the treatments T_2, T_4 and T_6 which received same pretreatments (hot water blanching + 0.125% KMS + microwave blanching) but different drying temperatures as T_2 (445 min, at 65°C), T_4 (500 minutes at 60°C) and T_6 (625 minutes at 55°C). It is interesting to note that drying time varied in different pretreated cauliflower samples dehydrated at common temperatures *i.e.* T_1, T_2 at 65°C, T_3, T_4 at 60°C and T_5, T_6 at 55°C, indicating that although the moisture content slightly varied initially, pretreatment with microwave blanching influenced the drying time. T_2, T_4 and T_6 took lesser drying time compared to T_1, T_3 and T_5 (without microwave blanching). Overall drying rate (%/hr) was least in T_6 (87.07%) followed by T_5 (104.77%), T_4 (105.82%), T_3 (118.35%), T_2 (135.74%) and T_1 (139.74%) in that increasing order. It showed that drying rate increased with increased temperature of drying from 55°C (T_6 and T_5) to 65°C (T_1 and T_2).

The pretreatments followed by dehydration at 3 levels of temperature affected the dehydration ratio and it ranged from 9.37 in T_4 (hot water blanching + 0.125 KMS + microwave blanching + drying at 60°C) to 12.09% in T_1 (hot water blanching + 0.125% KMS + drying at 65°) (Table 2). Rehydration ratio after dehydration on the other hand ranged from 4.60 (T_4) to 6.72 (T_5). Similar trend of dehydration ratio to the present findings has also been reported by Srivastava and Sulebele (1975) and Raina *et al.* (1982). Dehydration ratio as reported by Bawa and Saini (1986), Mishra and Agarwal (2005) was however higher than our findings, which might be due to varietal differences. Additional microwave blanching treatments (T_2, T_4 and T_6) lowered the dehydration ratio in contrast to treatments without microwave blanching (T_1, T_3 and T_5). The high dehydration ratio of T_1 (12.09) at 65°C compared to lower dehydration temperature treatments at 60 and 55°C is contrary to the reports of Maskan (2000) and Rouf *et al.* (2003) in banana and cabbage. Further among treatments without microwave blanching (T_1, T_3 and T_5) drying ratio of T_1 at 65°C was highest *i.e.* 12.09 followed by T_5 (11.58) at 55°C and T_3 (10.43) at 60°C. This result is not consistent with Abhay *et al.* (2006) who reported that dehydration ratio increased with decreased temperature of drying.

Rehydration ratio was high in treatments not receiving microwave blanching *i.e.* T_1, T_3 and T_5 (Table 2). Among these treatments rehydration ratio was maximum in T_5 (6.72) followed by T_3 (5.21) and T_1 (5.03) indicating that rehydration ratio decreased with increase in temperature of drying. However, among the treatments receiving microwave blanching rehydration ratio was highest in T_2 (5.02) with drying temperature of 65°C. In others microwave blanching treatments *i.e.* T_4 (drying temperature of 60°C) and T_6 (drying temperature of 55°C) the rehydration ratio was 4.6 and 4.7 which were more or less similar. Rehydration ratio gradually decreased throughout the period of storage upto six months. Highest reduction in the capacity to rehydrate was observed in T_5 (30.13) where the rehydration ratio dropped sharply from 5.21 (initially) to 3.64 after six months which was followed by T_2 (5.02 to 3.63), T_4 (4.60 to 3.58), T_5 (6.72 to 5.34), T_6 (4.7 to 4.04), and T_1 (5.03 to 4.37).

Rehydration coefficient increased with decrease in dehydration temperature (Table 4). After dehydration, treatments without

Table 3. Dehydration ratio in different treatments of dehydrated cauliflower and their rehydrated ratio after dehydration and during storage

Treatment	Drying ratio	Rehydration ratio (storage period in months)				Reduction (%) (storage period in months)		
		0	2	4	6	2	4	6
T_1	12.09	5.03	4.93	4.60	4.37	1.98	8.54	13.12
T_2	10.70	5.02	4.96	4.26	3.63	1.19	15.13	27.68
T_3	10.43	5.21	4.60	3.82	3.64	11.70	26.67	30.13
T_4	9.37	4.60	4.41	3.90	3.58	4.13	15.21	22.17
T_5	11.58	6.72	6.07	5.38	5.34	9.67	19.94	20.53
T_6	9.50	4.70	4.53	4.20	4.04	3.61	10.63	14.04

Table 4. Rehydration characteristics of different treatment of cauliflower during storage

Treatments	0 months		2 months		4 months		6 months	
	R.R.	CO R.	R.R.	CO R.	R.R.	CO R.	R.R.	CO R.
T_1	1 : 503	0.486	1 : 4.93	0.476	1 : 4.60	0.445	1 : 4.37	0.423
T_2	1 : 502	0.486	1 : 4.96	0.475	1 : 4.26	0.408	1 : 3.63	0.352
T_3	1 : 521	0.528	1 : 4.60	0.525	1 : 3.82	0.440	1 : 3.64	0.359
T_4	1 : 4.6	0.516	1 : 4.41	0.495	1 : 3.90	0.438	1 : 3.58	0.402
T_5	1 : 6.72	0.699	1 : 6.07	0.684	1 : 5.38	0.612	1 : 5.34	0.55
T_6	1 : 4.70	0.529	1 : 4.53	0.507	1 : 4.20	0.470	1 : 4.04	0.484

R.R. = Rehydration ratio, COR = Coefficient of rehydration

Table 5. Ascorbic acid content (mg/100 gm) in different treatments of raw and dehydrated cauliflower after dehydration and during storage period (MFB)

Treatment	Initial	Ascorbic acid content (mg/100 g) (MFB) (months of storage)			
		0	2	4	6
T_1	502	36.09	15.07	12.11	10.79
T_2	404	24.82	17.62	14.31	6.53
T_3	440	55.36	14.28	11.51	7.91
T_4	358	59.27	11.32	9.72	6.55
T_5	441	96.04	19.29	15.61	12.78
T_6	357	67.70	10.65	8.54	8.32
LSD (P=0.05)	114	14.71	4.97	4.21	3.66
LSD (P=0.01)	N.S.	20.62	6.97	5.90	5.13

Table 6. Losses and retention of ascorbic acid content of dehydrated cauliflower after dehydration and during storage (MFB)

Treatment	Loss (%) (months of storage)			Retention (%) (months of storage)		
	2	4	6	2	4	6
T_1	58.24	66.4	70.10	41.76	33.56	29.90
T_2	29.00	42.34	73.69	71.00	57.66	26.31
T_3	74.20	79.20	85.71	25.80	20.80	14.29
T_4	80.90	83.60	88.94	19.10	16.40	11.06
T_5	79.91	83.74	86.69	20.09	16.26	13.31
T_6	84.26	87.38	87.71	15.74	12.62	12.29

Table 7. Sensory quality evaluation after dehydration and after storage period of six months of dehydrated cauliflower

Treatments	Storage period (in months)							
	Colour		Flavour		Texture		Over all acceptability	
	0	6	0	6	0	6	0	6
T_1	8	6	8	5	8	6	8	6
T_2	9	7	9	7	9	6	9	7
T_3	9	6	9	6	9	7	9	6
T_4	9	7	9	7	9	7	9	7
T_5	8	6	9	6	9	6	8	6
T_6	7	5	8	6	8	7	8	6

microwave blanching (T_1, T_3 and T_5) exhibited lowest coefficient of rehydration values in T_1 (0.486) at 65°C of drying followed by T_3 (0.528) at 60 °C and T_5 (0.699) at 55°C in that increasing order (Table 4). The trend was similar in microwave blanched treatments (T_2, T_4, T_6). At same temperature of drying the rehydration coefficient of microwave blanched treatments was equal or lesser than untreated. In storage, coefficient of rehydration decreased gradually and on 6th month rehydration coefficient remained high in T_5 (0.55) followed by T_6 (0.454), T_1 (0.423), T_4 (0.402), T_3 (0.359) and T_2 (0.352).

Pretreatment with chemicals like KMS has been reported to increase rehydration ratio and coefficient of rehydration (Srivastava and Sulebele, 1975; Mishra and Agrawal, 2005). However rehydration ratio and coefficient of rehydration decreases with increase in temperature of dehydration (Abhay *et al.*, 2006). Dehydrated product sometimes did not recover their structural properties after rehydration as a result of structural damage during drying and the hysteresis phenomenon that takes place during rehydration (Magdalini and Zacharias, 2001).

The ascorbic acid content for each treatment varied significantly at both 5 and 1% level (Table 5). In treatments without microwave blanching *i.e.* in T_1 (drying temperature 65°C), T_3 (drying temperature 60°C) and T_5 (drying temperature 55°C) ascorbic acid content was recorded 36.09 mg/100 g, 55.36 mg/100 g and 96.04 mg/100 g, respectively indicating that ascorbic acid content increased with decrease in drying temperature. Ascorbic acid content deteriorated rapidly and after 6th month, it remained highest in T_5 (12.78 mg/100 g) followed by T_1 (10.79 mg/100 g), T_6 (8.32 mg/100 g), T_3 (7.91 mg/100 g), T_4 (6.55 mg/100 g) and T_2 (6.53 mg/100 g). Although ascorbic acid content after dehydration was low in T_1 and T_2 after 6 months storage, loss of ascorbic acid was low (70.10 and 73.69% respectively) and retention of ascorbic acid was maximum (29.90 and 26.31%, respectively). Rate of loss of ascorbic acid decreased and retention of ascorbic acid increased with increase of dehydration temperature during storage (Table 6).

Bawa and Saini (1986) and Kadam *et al.* (2005) also recorded similar range of ascorbic acid in dehydrated cauliflower. Losses of vitamins during processing occur either due to oxidation or by dissolving into water (Vail *et al.*, 1978). Loss of ascorbic acid to the extent of 63.2% has been reported by Raina *et al.* (1982) which is slightly lower than present finding probably due to different blanching time (Kadam *et al.*, 2005) and pretreatemnt (Mulay *et al.*, 1994).

Sensory evaluation of rehydrated product indicated that T_2 (hot water blanching + 0.125% KMS + microwave blanching + drying at 65 °C), T_3 (hot water blanching + 0.125% KMS + drying at 60 °C), T_5 (hot water blanching + 0.125% KMS + drying at 55 °C) and T_4 (hot water blanching + 0.125% KMS + microwave blanching + drying at 60 °C) recorded high score for colour (8-9), flavour (8-9), texture (8-9) and overall acceptability (8-9). In storage, the sensory qualities decreased rapidly, the overall acceptability of T_3, T_4 and T_5 decreased to 5, 5 and 6, respectively. However, the colour and flavour and overall acceptability of T_2 could be retained even after six months to acceptable score of 7. Previous reports (Srivastava and Sulebele, 1975; Kaur and Singh, 1981; Raina *et al.*, 1982; Bewa and Saini, 1986; and Abhay *et al.*, 2006) also indicated that chemical like potassium metabisulphite was effective in improving quality in respect of colour, flavour, texture and overall acceptability.

Thus considering the dehydration characters and quality after dehydration and storage it can be concluded that T_2 (hot water blanching + 0.125% KMS + microwave blanching + drying at 65°C) was the best treatment followed by T_4 (hot water blanching + 0.125% KMS + microwave blanching + drying at 60°C) and T_5 (hot water blanching + 0.125% KMS + drying at 55°C). In T_2, time taken for complete dehydration (445 minutes) and moisture content (3.62%) after dehydration was least. Further the moisture content after six month of storage was also less (9.63%), drying rate (135.74%/h) and dehydration ratio (10.70) was medium after dehydration. Ascorbic acid retention was maximum during storage in the treatment (T_2). Sensory evaluation also supported the superiority of this treatment.

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