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Effect of Cabinet Air Drying Temperature on Dehydration and Rehydration Quality of Selected Vegetables

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ABSTRACT

An attempt was made to standardize cabinet drying temperature for cabbage shreds, carrot slices and okra pieces by subjecting them to four drying air temperatures viz. 40^{0}C, 50^{0}C, 60^{0}C and 70^{0}C. The dried samples were analysed for physical parameters, moisture depletion pattern and moisture uptake pattern. The rehydrated samples were evaluated for their sensory quality by a panel of semi-trained judges. On the basis of dehydration and rehydration characteristics of dried treatments, results revealed that drying temperature of 40^{0}C, 50^{0}C and 60^{0}C was found optimum for drying of cabbage shreds, okra pieces and carrot slices respectively. These dried products showed better rehydration properties in terms of rehydration coefficient, reconstitution time and rehydration ratio. Their rehydrated products exhibited natural colour having full appearance and tender texture when compared to fresh samples and scored 'good' overall acceptability by the judges for their rehydration as well as cooked quality.

Key words: *Cabbage, Carrot, Okra, Cabinet drying, Physical parameters, Organoleptic quality.*

INTRODUCTION

Vegetables are seasonal and highly perishable in nature because of their high moisture content, soft texture and enzymatic changes etc. As a result, degradation in their quality starts immediately after the harvest. Hence, they are sold at throwaway prices in the peak season resulting in heavy losses to the growers[16]. To overcome the post-harvest losses, the processing of vegetables into durable products during peak surplus production and seasonal super abundance can go a long way in reducing these losses. To make the availability of vegetables throughout the year, they are processed preserved in various forms. Of the various methods of processing/preservation, drying is the cheapest and commonly used method that has been practised since ancient times. It offers the advantages of increased shelf life, palatability, reduction in cost of packaging and convenience during transport and handling.

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Of the various drying methods, sun drying is the oldest and cheapest method but is dependent upon a consistently warm, dry climate during harvest season. Though sun-drying is common, but it is difficult and very slow in some areas because of the active monsoon during the harvesting season. Hence, sun-drying is not an ideal practice in such humid areas. The longer period required in sun-drying results in production of inferior quality products unacceptable to consumer. The colour of the product often turns brown, the texture becomes tough and the natural flavour is lost during the eight to ten days period of drying ending in poor quality product. Apart from this, dust and flies often contaminate the product[17].

Normally, vegetables are dried in hot air drier where the heat transfer mechanism is by way of convection either with natural air circulation or forced air circulation[19]. The temperature and humidity inside cabinet drier can be controlled thus, producing uniform product of better quality[10]. Cabinet drying method is more efficient than open drying as far as the retention of nutrients and reconstitution ratio is concerned[9,8].

With this backdrop, the present investigation was undertaken with an objective to assess the suitable temperature (which will retain best quality) for cabinet drying of each selected vegetable by a) subjecting the vegetables to different cabinet air drying temperature and b) analyzing the dehydration and rehydration quality of dried vegetables.

MATERIAL AND METHODS

Three vegetables *viz.* cabbage, carrot and okra were procured from the local market at optimum maturity period. Initially, the electrically heated cabinet air drier (Indian Equipment Corporation) was set at a desired temperature (air-velocity 2.0 m/s) for a period of 0.5 hour to stabilize the drying conditions. The cut vegetables were then spread in monolayers (spreading density- 4.46, 5.27 and 4.02 kg/m^2 for cabbage shreds, carrot slices and okra pieces) on aluminum trays and then drying was carried out at desired temperatures upto a specified moisture level.

Standardization of drying temperature for cabinet drying

To assess the best suitable temperature for cabinet drying of each vegetable, fresh samples were subjected to four drying air temperatures, *viz.*, 40^0C (D_4), 50^0C (D_5), 60^0C (D_6) and 70^0C (D_7).

Physical parameters

The dried samples were analyzed for their moisture content by oven drying method[1], dehydration ratio[18], reconstitution time[7], bulk density[4] and drying time. Rehydration ratio, coefficient of rehydration and rehydration percentage were computed as per method suggested by Ranganna[12].

Moisture Depletion Pattern (Drying curves)

During the drying period, the loss in weight of the sample was measured at an interval of 5 min for the first half hour, 10 min interval for next half hour, 15 min interval for next one hour and 30 min for rest of the drying period. The drawn samples were then analyzed for their moisture content. Drying curves were drawn by plotting moisture content (%) against time of drying (h) to study the moisture depletion pattern.

Moisture Uptake Pattern (Rehydration curves)

In two sets, containing an equal number of beakers, 5g of dried sample was taken, to which 100ml of hot (80^0C) and cold (at room temperature) tap water was added, respectively. After a varied time intervals of 0.083, 0.16, 0.25, 0.33, 0.42, 0.50, 0.58, 0.75, 0.92, 1.09, 1.33, 1.59, 1.83, 2.33 and 2.83 hours, the rehydrated samples were taken out from the beaker and allowed to drain for 2 minutes. The drained samples were blotted free of excess surface moisture by keeping them on filter paper for some time. The wiped samples were then analyzed for their moisture content. The moisture uptake pattern of the rehydrated samples was studied by drawing their values as graphic curves.

Organoleptic quality

Coded rehydrated samples (soaked overnight) and cooked samples (rehydrated and cooked with 2% salt solution without spices) of cabbage, okra and carrot were served for organoleptic evaluation to a taste panel of 10 semi-trained judges for various sensory attributes *viz.* appearance, colour, texture and overall acceptability. Panelists were asked to compare the quality attributes with a reference i.e. fresh vegetable in raw as well as cooked form of equal sizes as that of rehydrated sample. For each quality attribute evaluated, the direction (i.e. quality change) and magnitude of the difference from the references, if detected were determined.

RESULTS AND DISCUSSION

Moisture depletion pattern

Drying of vegetables to an optimum moisture level is an essential step for good keeping quality. The depletion in moisture content with increase in drying time at different selected temperatures is illustrated in form of drying curves in Figure 1 for cabbage shreds, carrot slices and okra pieces. As evident from the figures, the drying curves followed a declining tend at selected drying air temperatures. The moisture content decreased very rapidly in 1st one hour of drying period and thereafter the moisture removal rate steadily became constant till the completion of the process. The total drying time decreased significantly with increase in drying temperature due to greater rate of moisture evaporation.

After 1 hour drying of cabbage shreds, there was 66 per cent moisture in D_4 as against 57 per cent in D_5, 52 in D_6 and 47 per cent in D_7. D_4, D_5, D_6 and D_7 respectively, took 7.3, 5.8, 4.3 and 2.8 hours for drying to reach a constant weight corresponding to 8 per cent moisture content. The moisture content of okra pieces was reduced from 89 to 6 per cent in less than 3.3 hours in D_7 samples as compared to more than 4.22 hours for D_6, 5.8 for D_5 and 6.8 hours for D_4 samples. Carrot slices took time of 4.8 hours (D_7), 5.8 hours (D_6), 7.3 hours (D_5) and 8.33 hours (D_4) to bring down the initial moisture content of 88 to 8 per cent when subjected to 70, 60, 50 and 40^{0}C temperatures. Arora and Bharti (2005) also observed that as the drying temperature increased, the drying potential also increased.

Moisture uptake pattern

The dried vegetable product before cooking needs to be rehydrated properly. After rehydration, it is expected to come closer to the fresh vegetable particularly in terms of organoleptic quality *viz.*, colour, appearance and texture. An effort was therefore made to investigate the effect of drying temperature upon moisture uptake pattern of selected vegetables in hot and cold water (Figure 2&3).

The effective moisture gain increased with increase in drying temperature from 40^{0}C to 70^{0}C. Rehydration in hot water took less time to rehydrate than the samples rehydrated in cold water. The rehydration curves took a steep rise in their moisture content in just 5-10 minutes before coming to a lengthy constant period.

For cabbage shreds, D_7 absorbed maximum moisture content of 91 and 93 in comparison to D_6 that absorbed 90 and 93, D_5 90 and 92 and D_4 88 and 90 per cent in hot and cold water, respectively after 2.8 hours of rehydration. In carrot slices, D_7 treatment regained 81 and 71 per cent moisture in hot and cold water, respectively after 2.8 hours of rehydration. D_6, D_5 and D_4 were far behind by 2, 3 and 5 per cent in hot water and 1, 4 and 5 per cent in cold water, respectively. In hot water rehydration of okra pieces, D_7, D_6 and D_5 regained 89, 88 and 88 per cent moisture content in comparison to D_4 that could regain only 84 per cent at the end of 2.8 hours of rehydration. Unlike cabbage and okra, the rate of moisture absorption by carrot slices showed a gradual increase rather than a steep rise during the initial period of rehydration.

Srivastava and Nath[15] observed that rehydration of dried cauliflower in boiling water took only 27 minutes as compared to 4.5 hours in cold water. Pande *et al.*[11] noticed that rise in moisture absorption in warm water over cold water was about 13-15 per cent for methi and 6.7 per cent for coriander in both 5 and 30 min duration. The results indicated that samples rehydrated in cold water gave acceptable results while those rehydrated in warm water recorded much better results.

Dehydration and Rehydration characteristics

As evident from Table 1, higher the drying temperature, lesser was the drying time taken for complete dehydration. The total time for drying decreased from 8.12 hours to 2.98 hours on an average with the increase in air temperature from 40-70^{0}C. At all the drying temperatures, D_4 took more time owing to low temperature and slow moisture transfer. So, higher the drying temperature, lesser was the drying time. The total drying time decreased with increase in drying air temperature because of increase in drying rate at higher temperatures. Statistical analysis revealed a significant effect of drying temperature over drying time. The total drying time decreased significantly with increase in drying temperature. Similarly, significant influence of temperature was reported by Arora and Bharti[2]. Total drying temperature was found to decrease significantly with increase in drying temperature. Gupta and Nath[6] noticed that the time required for the reduction of moisture from 93-96 to 5.8 per cent took 8.25 to 8.50 hrs at 70^{0}C and 5.25 to 5.50 hrs at 80^{0}C.

The dehydration ratio was significantly affected by drying temperature. The samples dried at 70^{0}C exhibited higher drying ratio, whereas those dried at 40^{0}C had lower dehydration ratio. During cabbage drying, ratio of 12.34 was observed for D_7 which was maximum as compared to other treatments. Similar results were found in case of carrot and okra. Dehydration ratio of D_7 was found as 9.98 (carrot) and 9.70 (okra) as a maximum value followed by $D_{6,}$ D_5 and D_4. Gupta and Nath[6] also observed a significant effect of temperature on dehydration ratio. Drying ratio of cabinet air dried mushrooms at 80^{0}C was 15.8 which was higher than drying at 70^{0}C (14.8).

Results indicated that D_7 treatment showed maximum rehydration ratio of 5.32, 2.08 and 3.53 and D_4 exhibited minimum to the value of 4.41, 1.27 and 2.76 for cabbage, carrot and okra, respectively. All the treatments showed significant relationship. The higher rehydration ratio of samples dried at 70^{0}C may be due to change in cellulose crystallinity at higher temperature.

Reconstitution time exhibited a decrease with increase in drying temperature. In cabbage shreds, maximum time for reconstitution was taken by D_4 (1.10 min) and minimum by D_7 (0.96 min). Same results were calculated for okra and carrot treatments. D_4 carrot took 5.17 min and D_7 took 4.15 min, whereas D_4 and D_7 okra reconstituted within 1.20 min and 1.04 min respectively. Carrot took more time for reconstitution as compared to cabbage and okra. This may be due to high sugars on the surface of cell wall[14] and the slightly shrunken and leathery texture of the slices that restricted the absorption of moisture. In addition, the elasticity of cell wall and swelling power of starch which are important for good rehydration are reduced during heat treatment.

The rehydration percentage increased significantly with increase in drying temperature. When compared the rehydration percentage in rehydrated samples dried under different drying temperature, the results indicated that drying at 70^{0}C (D_7) of cabbage, carrot and okra resulted in better rehydration percentage (80.67, 60.00 and 73.00), respectively, over other temperatures. The minimum rehydration percentage was seen in 40^{0}C dried sample (D_4) as 71.3 percent, 50.67 percent and 61.33 per cent, respectively.

Rehydration coefficient decreased with increase in drying temperature. Higher values of rehydration coefficient were observed in D_4 treatment of cabbage, carrot and okra that respectively showed coefficient of 0.27, 0.31 and 0.36 and lowest in D_7 as 0.16, 0.18 and 0.19, respectively. Pande *et al.*[11] noticed that rehydration coefficient of dried methi and coriander decreased from 0.99 to 0.97 and from 0.99 to 0.96 respectively with gradual increase in temperature from 40^{0}C to 60^{0}C.

Per cent yield, bulk density and moisture content

Table 2 represents the per cent yield (%), bulk density ((kg/m^3) and moisture content (%) of the dehydrated vegetables. The percent yield increased with increase in temperature. When cabbage, carrot and okra were dried at 40, 50, 60 to 70^{0}C, higher percent yield was observed in D_7 being 40.01, 31.34 and 34.19, respectively. Similar trend was noticed by Rashmi *et al.*[13] in pineapple rings.

An increase in drying air temperature resulted in subsequent decrease in bulk density of selected vegetables. The bulk density of dried cabbage was found maximum (0.14) in D_4 and minimum (0.08) in D_7. The dried carrot and okra followed the same trend as D_4 had 0.44 and 0.18 and D_7 acquiring minimum value of 0.34 and 0.10 kg/m^3 respectively. The statistical results showed a significant relationship among all the treatments. Banga and Bawa[3] calculated maximum bulk density in dehydrated carrot dried at 50^{0}C in comparison to those dried at 60 and 70^{0}C.

The moisture content decreased with increase in drying temperature. Cabbage, carrot and okra dried at 40^{0}C (D_4) had higher moisture content as 7.90, 9.19 and 8.84 per cent, respectively, while D_7 retained a low per cent of moisture content as 6.98, 7.34 and 7.73 respectively. Gupta and Nath[6], Pande *et al.*[11], Deshpande and Tamhane[5] and Rashmi *et al.*[13] did studies on drying characterisitcs and reported that higher moisture losses occur at high temperature.

Organoleptic quality

Rehydrated quality

The quality required in a finished product is determined by its end use. For use, the dried product has to been rehydrated properly before cooking. Rehydrated D_4cabbage shreds scored highest because of its natural colour with nearly full appearance, tender texture and 'good' overall acceptability whereas cabbage dried at 70^{0}C was adjudged as 'average'. In carrot, treatment D_6 exhibited natural orange colour with full rehydration appearance but, still had tough texture and thus was accepted as 'good' for sensory analysis. D_4 and D_5 okra pieces exhibited natural colour but D_5 was fully rehydrated having tender texture and was evaluated for its 'excellent' acceptability as compared to other treatments.

Cooked quality

The colour, flavour and texture of (D_4) cabbage shreds scored maximum points of 8.00, 8.50 and 7.30, respectively, whereas D_7 cabbage showed poor score of 6.12, 6.80 and 5.70(Table 4). Carrot dried at 60^{0}C (D_6) scored maximum points for colour (8.00), flavour (8.12) and texture (8.00) and minimum points were given for D_4 carrot dried at 40^{0}C. D_5 okra showed highest point for colour (7.87), flavour (7.87) and texture (7.87) and lowest points were recorded in D_7 as 5.8 for colour. D_4 scored lower points for texture (6.6) and flavour (6.12).

Table 1: Effect of cabinet air drying temperatures on dehydration and rehydration characteristics of vegetables

a. Drying time

	D_4	D_5	D_6	D_7	Mean
Cabbage	5.30	4.37	3.38	2.32	3.84
Carrot	11.87	7.53	5.25	4.27	7.23
Okra	7.20	5.35	3.58	2.35	4.62
Mean	8.12	5.75	4.07	2.98	5.23
CD ($P \leq 0.05$)					
Between vegetable = 0.21, Between temperature = 0.25, V x T = 0.43					

b. Dehydration ratio

	D_4	D_5	D_6	D_7	Mean
Cabbage	9.20	9.36	11.63	12.34	10.63
Carrot	5.35	6.61	7.63	9.98	7.39
Okra	7.26	8.55	9.63	9.70	8.78
Mean	7.27	8.17	9.63	10.67	8.93
CD ($P \leq 0.05$)					
Between vegetable = 0.11, Between temperature = 0.13, V x T = 0.23					

c. Reconstitution time (min)

	D_4	D_5	D_6	D_7	Mean
Cabbage	1.10	1.05	0.98	0.96	1.09
Carrot	5.17	4.50	4.17	4.15	4.50
Okra	1.20	1.13	1.10	1.04	1.12
Mean	2.45	2.23	2.08	2.05	2.23
CD ($P \leq 0.05$)					
Between vegetable = 0.11, Between temperature = 0.13, V x T = 0.23					

d. Rehydration ratio

	D_4	D_5	D_6	D_7	Mean
Cabbage	5.07	4.41	4.68	5.32	4.87
Carrot	1.27	1.62	1.89	2.08	1.71
Okra	2.76	3.35	3.47	3.53	3.28
Mean	3.03	3.13	3.35	3.65	3.28
CD ($P \leq 0.05$)					
Between vegetable = 0.10, Between temperature = 0.11, V x T = 0.20					

e. Rehydration percentage

	D_4	D_5	D_6	D_7	Mean
Cabbage	71.33	74.00	79.07	80.67	76.42
Carrot	50.67	53.00	56.00	60.00	54.92
Okra	61.33	65.00	69.00	73.00	67.08
Mean	61.11	64.00	68.22	71.22	66.14
CD ($P \leq 0.05$)					
Between vegetable = 0.99, Between temperature = 1.14, V x T = 1.98					

f. Rehydration coefficient

	D_4	D_5	D_6	D_7	Mean
Cabbage	0.27	0.22	0.20	0.16	0.21
Carrot	0.31	0.25	0.21	0.18	0.24
Okra	0.36	0.30	0.25	0.19	0.28
Mean	0.31	0.26	0.22	0.18	0.24
CD ($P \leq 0.05$)					
Between vegetable = 0.01, Between temperature = 0.01, V x T = 0.02					

Table 2: Effect of cabinet air drying temperatures on per cent yield (%), bulk density (kg/m^3) and moisture content (%) of vegetables

a. Per cent yield

	D_4	D_5	D_6	D_7	Mean
Cabbage	36.64	38.71	39.61	40.01	38.74
Carrot	26.05	26.71	29.87	31.34	28.51
Okra	32.01	30.84	33.55	34.19	32.65
Mean	31.57	31.11	34.44	35.18	33.30
CD ($P \leq 0.05$)					
Between vegetable = 0.33, Between temperature = 0.39, V x T = 0.67					

b. Bulk density

	D_4	D_5	D_6	D_7	Mean
Cabbage	0.14	0.12	0.09	0.08	0.11
Carrot	0.44	0.40	0.37	0.34	0.39
Okra	0.18	0.15	0.12	0.10	0.14
Mean	0.25	0.22	0.19	0.17	0.21
CD ($P \leq 0.05$)					
Between vegetable = 0.21, Between temperature = 0.25, V x T = 0.43					

c. Moisture content

	D_4	D_5	D_6	D_7	Mean
Cabbage	7.90	7.58	7.50	6.98	7.49
Carrot	9.19	9.07	8.22	7.34	8.46
Okra	8.84	8.69	8.19	7.13	8.13
Mean	8.64	8.45	7.92	7.35	8.03
CD ($P \leq 0.05$)					
Between vegetable = 0.21, Between temperature = 0.25, V x T = 0.43					

Table 3: Effect of cabinet drying air temperatures on rehydration quality of vegetables

a. Cabbage shreds

	D_4	D_5	D_6	D_7	CD ($P \leq 0.05$)
Colour	1.37	2.00	3.00	3.00	0.77
Appearance	2.12	2.12	3.50	3.37	0.60
Texture	2.00	2.12	2.87	3.25	0.64
Acceptability	2.50	2.62	4.25	4.12	0.48

b. Carrot slices

	D_4	D_5	D_6	D_7	CD ($P \leq 0.05$)
Colour	2.12	2.25	1.25	2.00	0.59
Appearance	2.25	2.12	1.37	2.50	0.48
Texture	3.62	3.37	2.25	5.37	0.51
Acceptability	3.00	3.12	2.25	4.00	0.73

c. Okra pieces

	D_4	D_5	D_6	D_7	CD ($P \leq 0.05$)
Colour	1.12	1.12	1.37	1.37	0.45
Appearance	2.12	1.12	1.37	1.50	0.76
Texture	1.50	1.12	1.25	1.37	0.48
Acceptability	2.87	1.87	3.75	3.87	0.39

Table 4: Effect of cabinet drying air temperatures on cooked quality of vegetables

a. Cabbage shreds

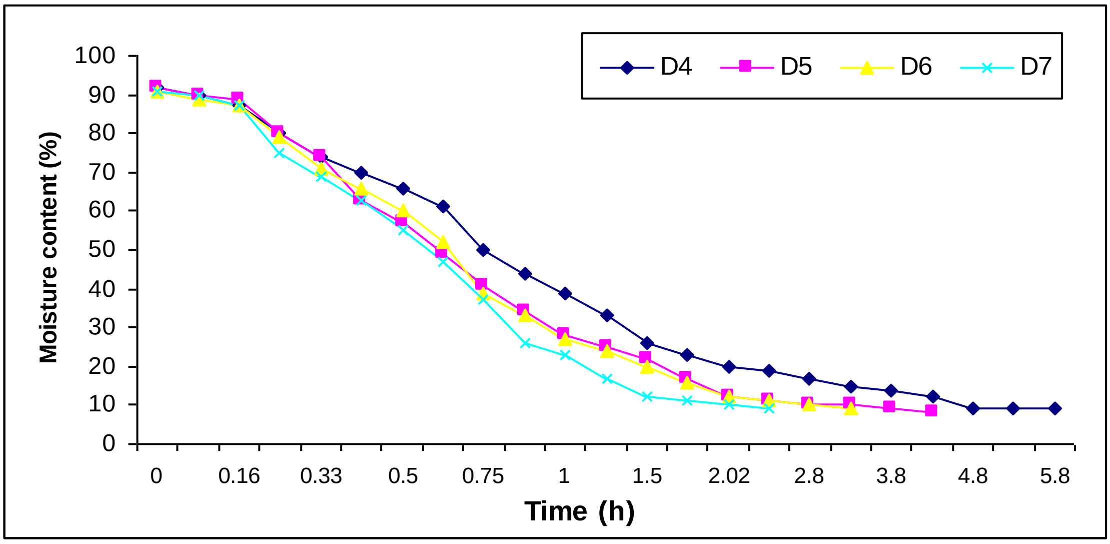
	D_4	D_5	D_6	D_7	CD ($P\leq 0.05$)
Colour	8.00	7.50	6.00	6.12	0.69
Flavour	8.50	8.00	6.60	6.80	0.74
Texture	7.30	6.70	5.80	8.70	0.76

b. Carrot slices

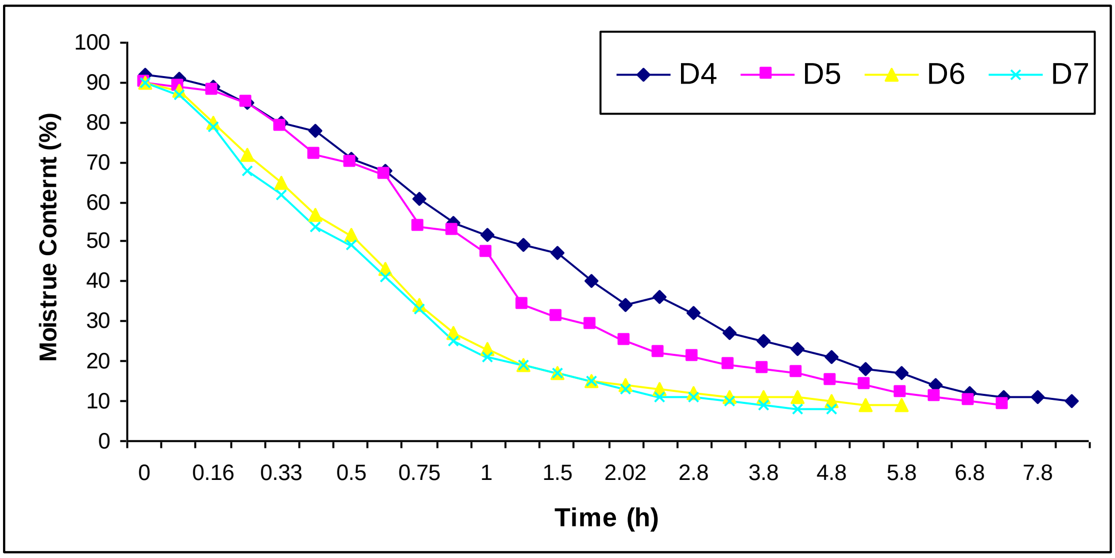
	D_4	D_5	D_6	D_7	CD ($P\leq 0.05$)
Colour	5.87	6.62	8.00	7.75	0.73
Flavour	4.12	6.12	8.12	7.62	0.83
Texture	5.37	6.50	8.00	7.25	0.75

c. Okra pieces

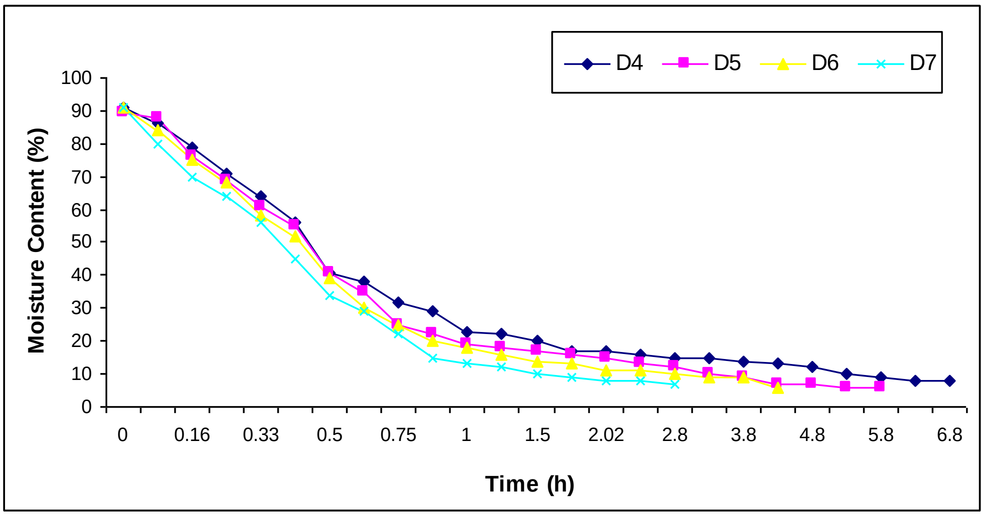
	D_4	D_5	D_6	D_7	CD ($P\leq 0.05$)
Colour	7.00	7.87	6.20	5.87	1.01
Flavour	6.12	7.87	6.37	6.37	1.01
Texture	6.62	7.87	7.37	7.25	1.26



Cabbage shreds



Carrot slices



Okra pieces

Figure 1: Effect of cabinet air drying temperatures on moisture depletion pattern

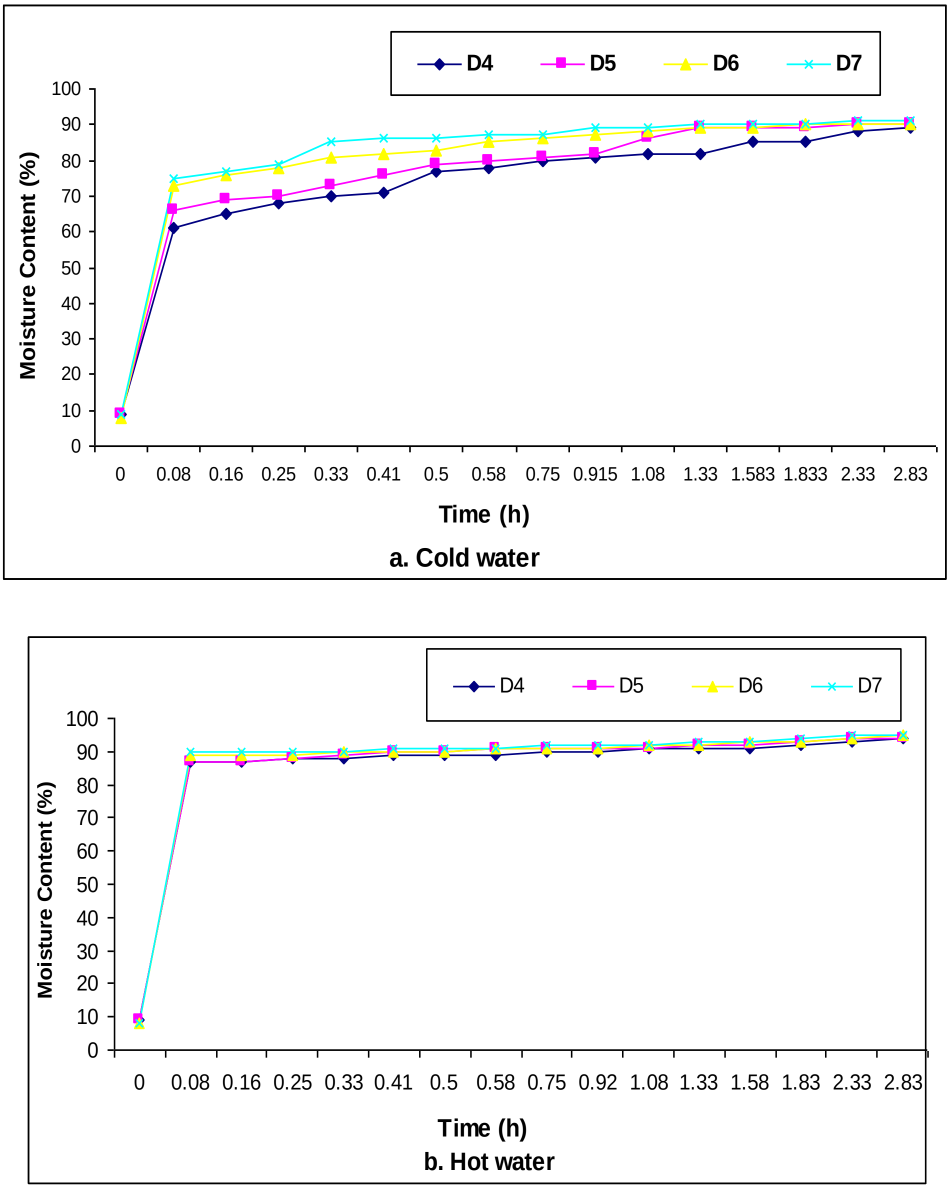


Figure 2: Effect of cabinet air drying temperatures on moisture uptake pattern of cabbage shreds

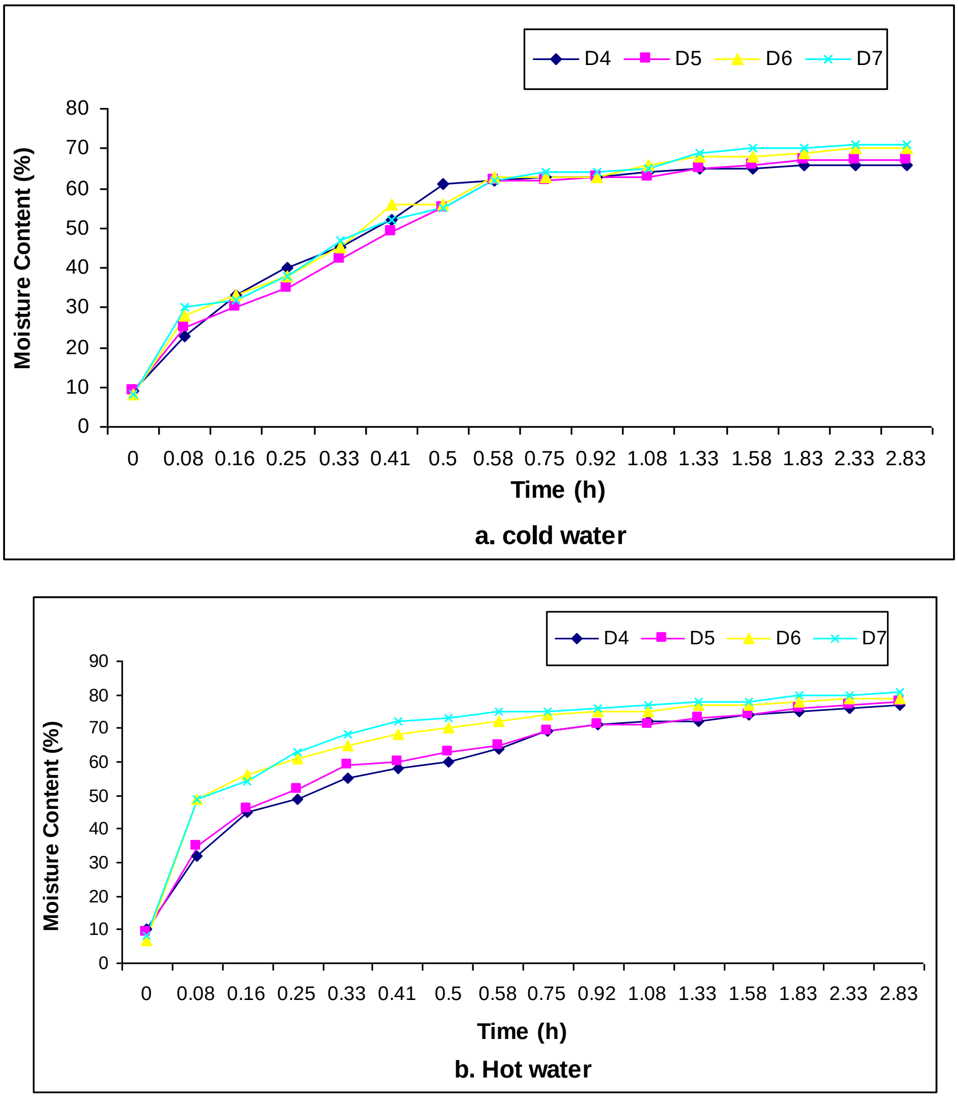
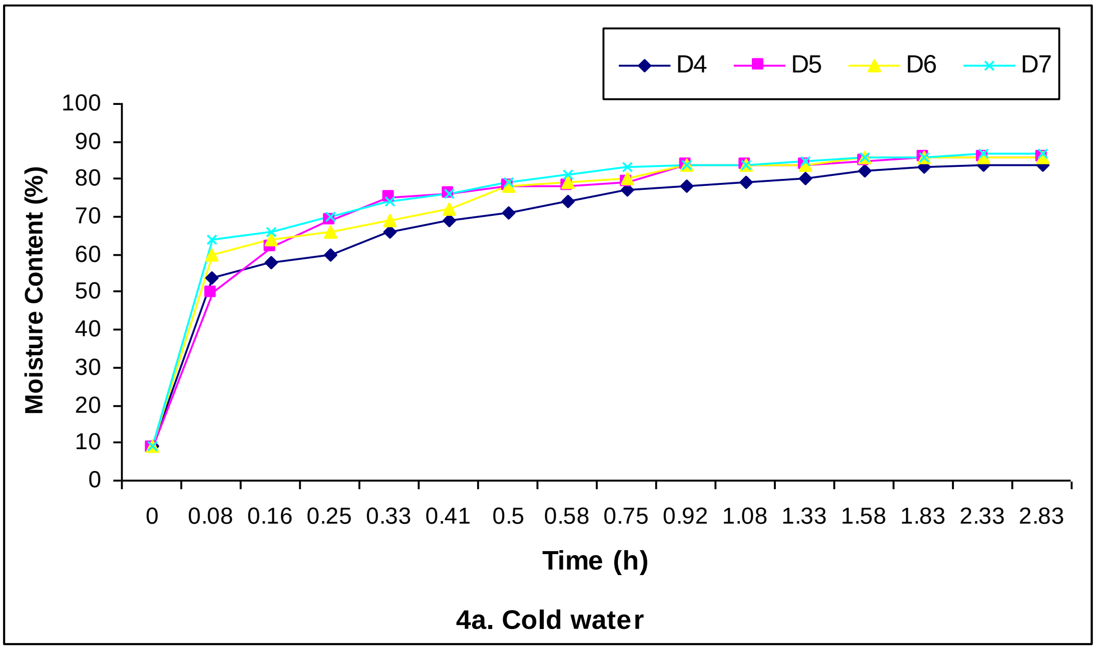


Figure3: Effect of cabinet air drying temperatures on moisture uptake pattern of carrot slices



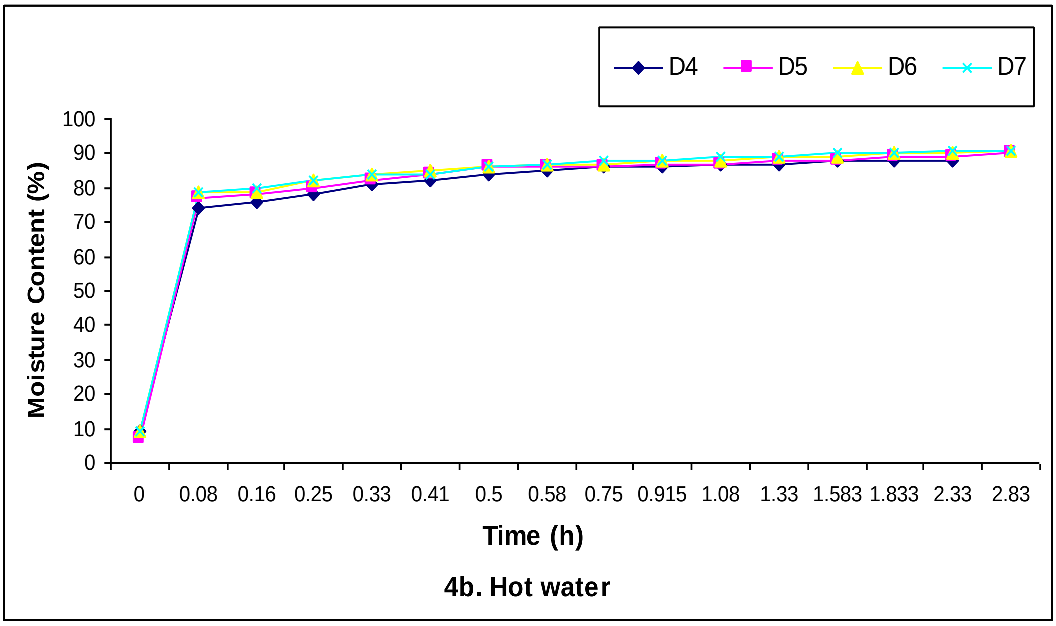


Figure 4: Effect of cabinet air drying temperatures on moisture uptake pattern of okra pieces

CONCLUSION

The best method for a given product is determined by quality requirements. To obtain a dehydrated product of high quality, the drying process should be such that it allows effective retention of colour, texture, flavour, taste and nutritive value comparable to the fresh fruits/vegetables on rehydration. An attempt to standardize the cabinet drying temperature for each vegetable to obtain good quality product revealed that drying temperature of 40^0C (D_4) was found optimum for cabbage. This dried product showed better rehydration properties in terms of higher rehydration coefficient, reconstitution time and rehydration ratio.

The carrot samples showed encouraging results at 60^0C. D_6 treatment had rehydration ratio more than D_5 and D_4. The product on rehydration possessed its characteristic orange colour and was able to reconstitute fully. It had an attractive, shiny appearance without much wrinkling on its slices. The results of rehydration characteristics showed D_5 okra to be of better quality when compared to other. The rehydrated product exhibited dark green natural colour having full appearance and tender texture when compared to fresh sample.

So, on the basis of dehydration and rehydration characteristics of dried treatments, drying temperature of 60^0C was found optimum for drying of carrot slices, 50^0C for okra pieces and 40^0C for drying of cabbage shreds.

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