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Research Article
Stability of the Quality and Antioxidant Activity of the Dried Bitter Gourd During Long Term Storage Period

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Abstract

Background and Objective: Microwave assisted convective drying is a good alternative for the post-harvest preservation of the bitter gourd in which quality of the product is better retained. The objective of the present study was to investigate the effect of drying methods and storage period on ascorbic acid content, total phenolic content, vitamin A content, DPPH radical scavenging activity, total color change and rehydration ratio of the bitter gourd. **Materials and methods:** Bitter gourds were dried by convective drying (40, 50 and 60°C) and microwave assisted convective drying (40, 50 and 60°C and 320, 400 and 480 W) methods. The dried samples were packed in LDPE pouches and stored at room temperature for 6 months for further analysis. **Results:** The ascorbic acid and total phenolic content were higher in microwave assisted convective dried bitter gourd but decreased during storage in all the dried samples. However, DPPH radical scavenging activity and total color change increased during storage. Both Vitamin A and rehydration ratio showed a continuous decrease with increasing duration of storage in both the drying methods. **Conclusion:** Drying of bitter gourd by microwave assisted convective drying limited the loss of quality attributes and retained the quality characteristics of the bitter gourd.

Key words: Drying, bitter gourd, ascorbic acid, vitamin A, storage period

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Fruits and vegetables are abundant sources of important dietary nutrients such as vitamins, minerals and crude fiber. Fresh fruits and vegetables contain more than 80% water and are susceptible to microbial deterioration due to its high moisture content[1]. In order to overcome this problem, food industries have started paying more interest towards the drying of these perishable commodities.

Drying is most widely used food preservation method which removes the moisture from the food product, reduces the risk of microbial spoilage, suppresses the rates of other deteriorative reactions and thereby increasing the shelf of the food product. It also reduces the mass and volume of the product and thus improves the efficiency of product transportation and storage.

Hot air drying is most common method used for the production of dried fruits and vegetables. But it causes the serious damage to the color, flavour and nutrients of the product and decline in rehydration power and bulk density of the dried product due to the long drying time or higher temperatures needed in conventional drying[2]. The use of microwaves for drying food has gained popularity in the recent years because of the higher drying rates. The microwave energy is absorbed by the food material which is then converted into thermal energy and thus facilitating the heating of food from inside to the outside surface of the food material while in conventional drying heat is transferred from outside to the inside of the solids[3]. However, microwave drying has a drawback of non-uniform heating due to the inhomogeneous distribution in a microwave cavity, food quality and texture damage due to tremendous rapid mass transfer by microwave power[4]. In order to overcome limitations of both conventional drying and microwave drying, one strategy is to combine microwaves with hot air drying such as microwave assisted convective/ hot air drying.

Bitter gourd is an important vegetable from the family Cucurbitaceous and is mostly found in tropical and sub-tropical areas of Asia, tropical Africa, middle east and America. Bitter gourd is a good source of antioxidant and its regular use prevents hypertension and eye complications. It improves the resistance of body against various infections. It is also helpful for blood cleansing and for diabetes. The dried bitter gourd chips, dried bitter gourd powder and bitter gourd pickles are some of the value added products obtained from the bitter gourd. Fresh produce of bitter gourd contains high amount of moisture and hence vegetable may deteriorate within few days after harvest. Drying is a good alternative for the post-harvest preservation of the bitter gourd in which water activity is lowered, microbial spoilage is inhibited and thus shelf life of the product is prolonged.

Microwave assisted convective drying has been successfully used in various food products such as potato[3], garlic[5], carrot[6] and mushrooms[7]. Despite the enormous uses of bitter gourd, no research has been reported on microwave assisted convective drying of bitter gourd. The research gap related to the lack of literature on the effect of microwave assisted convective drying on the quality attributes of bitter gourd during storage led to carry out the present study. Furthermore, the originality of the research comes from the application of microwave assisted convective drying technique to acquire acceptable quality of dried bitter gourd. The objective of the present study was to investigate the effect of drying methods (convective drying and microwave assisted convective drying) and storage period on ascorbic acid content, total phenolic content, vitamin A content, DPPH radical scavenging activity, total color change and rehydration ratio of the bitter gourd.

MATERIALS AND METHODS

Sample preparation: Fresh bitter gourds were procured from local market of Aligarh, India and kept at 5-6°C. Selection of the vegetables was based on the visual evaluation of similar size and uniform surface colour. The vegetables were sorted, cleaned and washed under running tap water in order to remove any adhering dirt. The sorted bitter gourds were then cut into 3 mm slices using a stainless steel knife. The moisture content of the bitter gourd was determined using an oven[8] at 70°C over 16 h. The initial moisture content of the bitter gourd was 91-92% (w.b).

Microwave assisted convective drying: The drying was performed in a microwave assisted convective dryer at the Department of Post-Harvest Engineering and Technology, AMU, Aligarh, India. The drying set up was same for both convective drying (CD) and microwave assisted convective drying (MACD). The oven magnetron was turned OFF in order to perform only convective drying while for microwave assisted convective drying it was turned ON during the whole experiment. The operation of domestic microwave oven (Kenstar, KE 20 CMGJ-MJK, India) used in this study was programmable with the help of menu keys. It was also provided with grilling operation and air convection but these options were not used in this study. The microwave power may be selected from maximum of 800 W (100%) to a minimum of 80 W (10%) with a variation of 80 W (10%) by setting the power option. Approximately, 300 g of the sample was used in every experimental study. The sample was placed centrally on a turntable fitted on the base of the oven cavity in order to achieve the even absorption of microwave energy. Drying was performed according to the pre-set levels of microwave power (320, 400 and 480 W and the temperature (40, 50 and 60°C). Weight loss was measured by periodic weighing using a digital balance. It was assumed that equilibrium moisture content has been reached when the sample weight approached constant values. The dried samples were packed in LDPE pouches and stored at room temperature for 6 months. Samples were drawn for analysis at 0, 1, 2, 3, 4, 5 and 6 months of storage.

Determination of quality parameters

Ascorbic acid: The ascorbic acid of the dried bitter gourd was estimated by titrimetric method as described by AOAC[8] method. Briefly, 5 mL of standard ascorbic acid solution was added to 5 mL of HPO_3 and then titrated with dye solution to pink end point which persisted for at least 15 sec. The dye factor (mg of ascorbic acid per mL of the dye) was calculated as: 0.5/titre. Five grams of bitter gourd sample was taken and blended with 3% HPO_3 solution and then filtered. The volume was made upto 100 mL with 3% HPO_3. An aliquot of 3 mL HPO_3 was taken and titrated with standard dye to an end point (pink). Ascorbic acid of dried bitter gourd was calculated by using the formula given below:

$$\text{Ascorbic acid (mg/100 g)} = \frac{\text{Titre}\times\text{Dye factor}\times\text{Volume made up}\times 100}{\text{Aliquot of extract taken for estimation}\times\text{Weight of sample taken for estimation}}$$

Total phenolic content: The amount of total phenolic was determined using Folin Ciocalteu reagent following the method described by Mrad *et al.*[9]. In brief, 5 g of homogenized sample was extracted with 4.5 mL of 80% aqueous methanol on a mechanical shaker. The homogenate was then centrifuged at 10,000 rpm for 15 min and the supernatant was then collected, further filtered through Whatman No. 1 filter paper. The clear extract was analyzed for the determination of phenolic content. Total phenolic content was expressed as gallic acid equivalent (mg GAE/100 g DM) using standard curve prepared at different concentrations.

Vitamin A content: Beta carotene was estimated according to the method of Zhuang *et al.*[10]. Five grams of sample was weighed and then crushed in acetone and petroleum ether mixture. This process was repeated many times and supernatant was collected into a separating funnel and petroleum ether (10-15 mL) was added to it. The upper layer formed was collected and the volume was made upto 100 mL with petroleum ether. Beta carotene was determined by measuring the absorbance at 450 nm with spectrophotometer.

$$\text{Beta carotene } (\mu\text{g/100 g}) = \frac{\text{O.D}\times 13.9\times 104\times 100}{\text{Weight of sample}\times 560\times 1000}$$

$$\text{Vitamin A (I.U.)} = \text{Beta carotene } (\mu\text{g/100 g})/0.6$$

DPPH radical scavenging activity: The antioxidant activity of the bitter gourd was determined using DPPH[11]. Two milliliters of methanol solution of DPPH (0.004%) was mixed with 20 µL of extracts. The mixture was allowed to stand at room temperature for 30 min and then absorbance was measured at 517 nm. Control was prepared containing the same volume without any extract. The antioxidant activity of sample was expressed as inhibition (%) of the DPPH radical and was calculated by using following equation:

$$\text{AA (\%)} = \frac{A_{control} - A_{sample})}{A_{control}}\times 100$$

Total color change: The color of the dried bitter gourd was measured by a Hunter Lab colorimeter (Mini san XE plus, USA). The color was expressed in CIE L* (lightness), a* (redness/greenness) and b* (yellowness/blueness). The total colour change was determined by using the following equation[12]:

$$E = [(L-L_0)^2+(a-a_0)^2+(b-b_0)^2]^{1/2}$$

where, L_0, a_0 and b_0 are the initial color values of bitter gourd and L, a, b are the color values of dried bitter gourd.

Rehydration ratio: The rehydration ratio estimation was done according to the procedure of Gupta *et al.*[13]. Five grams of dried sample was taken in container and 55 mL of water was added to it and gently boiled for 30 min. After boiling, water was drained and the weight of sample was recorded. The rehydration ratio was calculated as the ratio of weight of sample after rehydration to the weight of dried sample.

RESULTS AND DISCUSSION

Ascorbic acid content: Ascorbic acid is considered as the quality indicator in dried food products due to its heat sensitivity. The drying method had an important effect on the retention of ascorbic acid of the bitter gourd. The initial ascorbic acid content was found more in microwave assisted convective dried bitter gourd as compared to the convective dried one. In both MACD and CD, loss of total ascorbic content is more at lower temperatures as compared to higher temperatures. Moreover, ascorbic acid increased with increase in temperature and microwave power during the drying. This could be due to the faster drying and the reduction of drying time due to the higher temperature and microwave power used during the microwave assisted convective drying which resulted in better retention of total ascorbic content. Vega-Gálvez *et al.*[1] also reported similar findings. The effect of drying method and storage period on the total ascorbic content of bitter gourd could be visualized on Fig. 1a-d. There was minor continuous degradation of ascorbic acid with increasing period of storage in both microwave assisted convective drying and convective drying. The highest ascorbic acid content (45.67 mg/100 g) was retained in a sample dried at 60°C and 480 W microwave power during microwave assisted convective drying.

Total phenolic content: The phenolic compounds of processed plant food products are closely associated with its nutritional quality. The drying method affected the retention of total phenolic content of the bitter gourd. The initial total phenolic content was higher in microwave assisted convective dried bitter gourd samples. The total phenolic content degradation was found more at lower temperatures in both microwave assisted convective drying and convective drying than at higher temperatures. A probable reason for this could be the degradation of total phenolic content due to the longer drying time at lower temperatures[9]. Changes in the total phenolic content of dried bitter gourd during storage are shown in Fig. 2a-d. It could be seen that there is a continuous reduction of total phenolic content in both microwave assisted convective dried and convective dried samples during storage. However, retention of total phenolic content was found more in microwave assisted convective dried samples.

Vitamin A: The vitamin A content of the bitter gourd immediately after drying varied from 24.58-48.54 IU. The vitamin A was found higher in microwave assisted convective dried bitter gourd as comparison to convective one. The

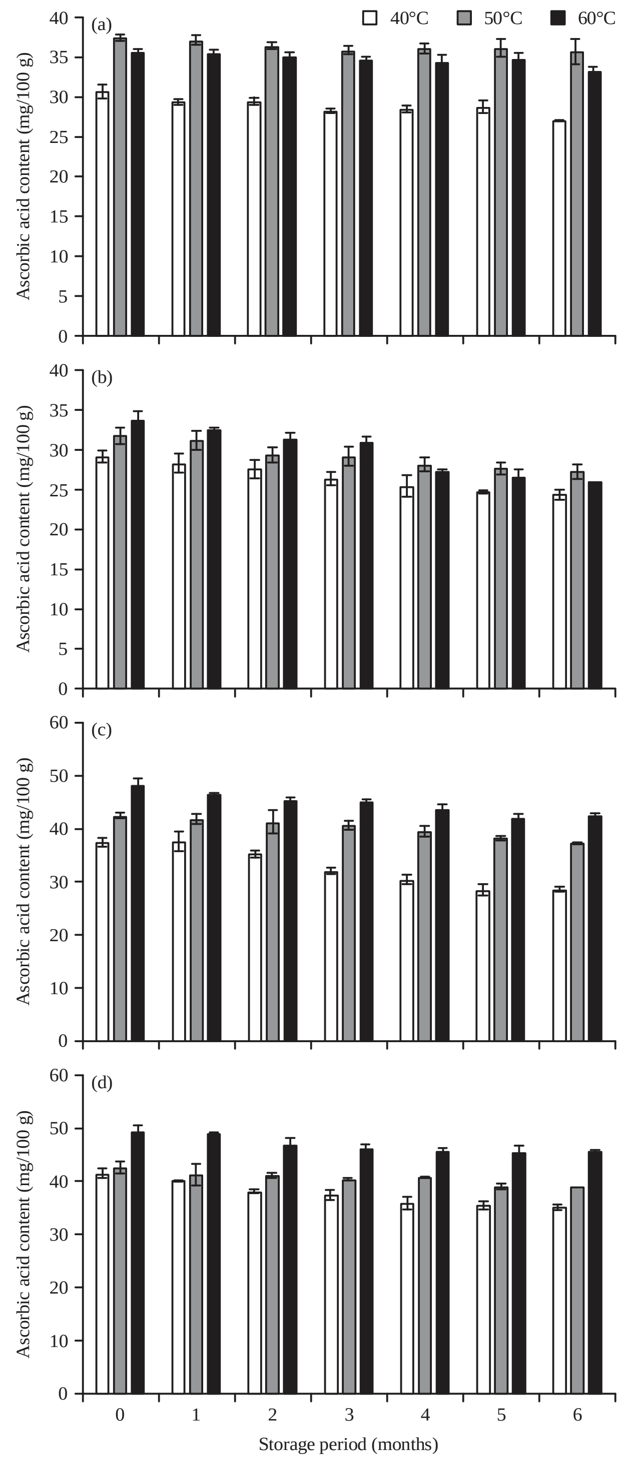

Fig. 1(a-d): Effect of drying methods and storage period on ascorbic acid of the bitter gourd (a) CD, (b) 320 W, (c) 400 W and (d) 480 W

vitamin A content increased with increase in temperature and microwave power and higher vitamin A was found in a sample dried at 60°C and 480 W microwave power. This could be due

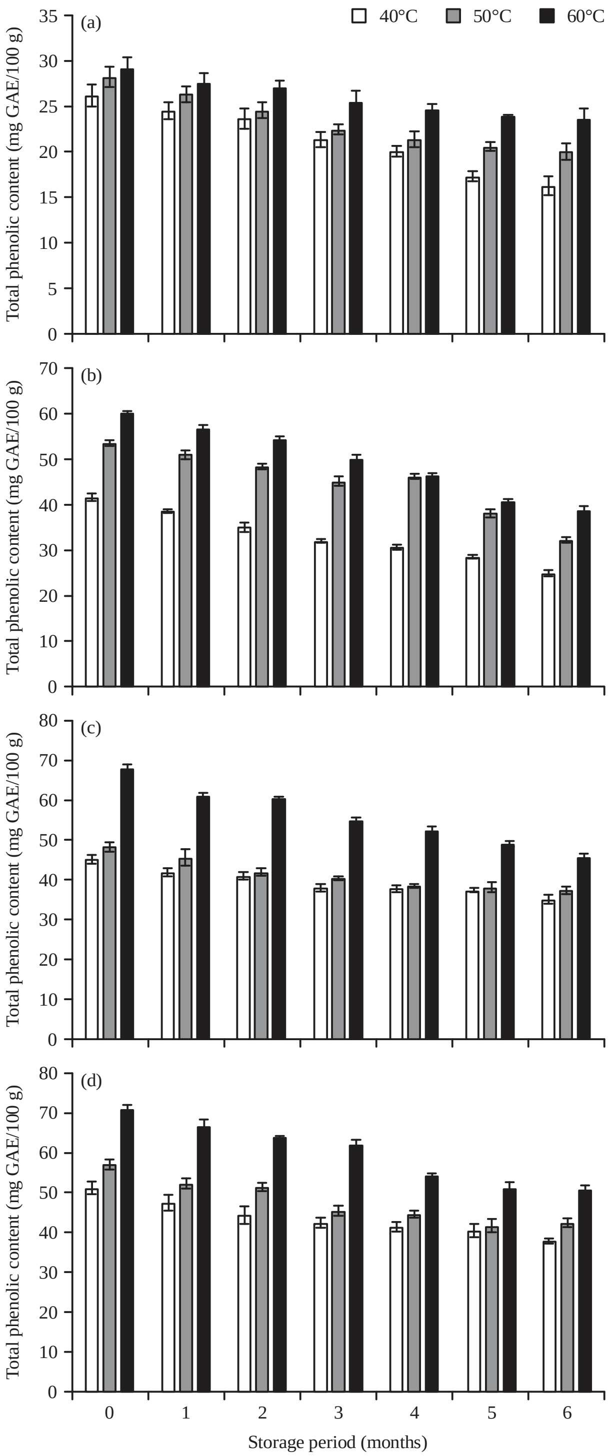

Fig. 2(a-d): Effect of drying methods and storage period on total phenolic content of the bitter gourd (a) CD, (b) 320 W, (c) 400 W and (d) 480 W

to the reduction of drying time at higher temperature and the application of microwave power. Cui *et al.*[14] also observed in their study that application of microwave power resulted in better retention of beta carotene during drying. The change in vitamin A content during the storage is shown in Table 1. There is a little decrease in vitamin A content with increase in storage period in both drying methods. However, retention of vitamin A content was found higher in a microwave assisted convective dried sample.

DPPH radical scavenging activity: The DPPH radical scavenging activity was used to determine the antioxidant activity of bitter gourd. The highest value of DPPH radical scavenging activity (30%) was found in a microwave assisted convective dried sample at a temperature and microwave power of 60°C and 480 W, respectively and the lowest value of 10% was found in a sample dried by convective drying at 40°C. The higher temperatures and microwave power associated with more retention of antioxidant activity of bitter gourd may be due to the reduction of heat exposure during drying. The effect of drying method and storage period on the DPPH radical scavenging activity could be observed on Fig. 3a-d. There is a minor increase in antioxidant activity during the storage and it may be attributed to the occurrence of maillard reactions. Nevertheless, a higher increase of DPPH radical scavenging was found in a bitter gourd (dried at 60°C and 480 W microwave) during last month of storage (6 month), corresponding with more complex phases of maillard reactions. These results are in consistence with that of Moreno *et al.*[15], where they reported that the sub-stantial increase of antioxidant activity is due to the development of maillard reaction during the storage.

Total color change: The drying method also affected the surface color of the dried bitter gourd samples. The microwave assisted convective dried samples exhibited lower color change as compared to convective dried samples. The highest color change was found in sample dried at 60°C and lowest color change was found at 40°C and 480 W microwave power. However, the color change in both convective and microwave assisted convective dried samples increased throughout the storage period (Table 2). During the first 3 months of storage, less color change was observed but it slightly enhanced for an extended period of storage. The colour degradation may be related to the occurrence of non-enzymatic browning reaction under storage conditions. Topaz *et al.*[16] also noticed that color change during the extended period of storage and related it to continued non enzymatic browning activity during storage.

Table 1: Effect of drying methods and storage period on vitamin A (I.U.) content of bitter gourd

Drying method	Power (W)	Temperature (°C)	Storage period (months) 0	1	2	3	4	5	6
CD		40	25.29±0.47	24.48±0.28	24.93±0.03	23.13±0.15	23.93±0.04	22.89±0.68	22.40±0.43
		50	24.58±0.90	23.96±0.01	23.95±0.63	23.70±0.60	22.80±0.73	24.77±0.82	22.57±0.86
		60	28.53±0.48	27.34±0.19	27.88±0.75	26.55±0.48	25.24±0.26	22.42±0.45	24.50±0.58
MACD	320	40	34.58±0.51	33.42±0.37	33.40±0.28	32.50±0.42	32.97±0.42	31.51±0.08	31.35±0.56
	320	50	40.46±0.47	39.45±0.20	39.07±0.59	38.81±0.29	38.22±0.29	38.11±0.79	37.46±0.47
	320	60	45.40±0.50	44.60±0.23	44.29±0.23	43.66±0.42	42.40±0.50	41.41±0.41	41.32±0.54
	400	40	38.08±0.37	37.50±0.07	37.41±0.46	36.52±0.08	35.82±0.14	34.79±0.29	34.26±0.36
	400	50	40.34±0.20	38.81±0.48	39.32±1.48	38.79±0.18	38.31±0.32	37.87±0.19	37.51±0.49
	400	60	50.36±0.23	49.55±0.32	49.46±0.199	47.30±0.33	46.91±0.11	46.64±0.39	45.09±0.07
	480	40	36.30±0.41	35.66±0.25	35.33±0.38	34.67±0.26	34.27±0.26	33.54±0.24	33.61±0.24
	480	50	42.30±0.42	41.9±0.13	41.35±0.79	41.33±0.54	40.70±0.30	40.71±0.56	39.42±0.56
	480	60	48.54±0.49	47.77±0.30	46.62±0.44	45.81±0.15	44.51±0.46	44.53±0.46	43.59±0.43

Table 2: Effect of drying methods and storage period on total color change of the bitter gourd

Drying method	Power (W)	Temperature (°C)	Storage period (months) 0	1	2	3	4	5	6
CD		40	19.42±0.05	20.00±0.40	20.78±0.82	20.88±0.53	21.26±0.35	24.42±0.27	25.03±0.58
		50	20.73±0.04	20.37±0.71	21.30±0.32	21.57±0.39	21.83±0.22	24.70±0.22	26.06±0.71
		60	21.86±0.05	21.85±0.83	22.26±0.64	27.71±1.21	28.15±0.52	28.16±0.57	28.52±0.63
MACD	320	40	15.70±0.11	15.74±0.24	16.50±0.27	16.80±0.51	18.49±0.46	19.38±0.39	20.04±0.93
	320	50	18.13±0.12	19.00±0.40	19.252±0.23	19.81±0.17	21.18±0.95	22.65±0.47	23.67±0.22
	320	60	17.24±0.13	18.38±0.31	19.77±0.72	20.57±0.35	22.21±0.48	23.63±0.51	24.49±0.48
	400	40	14.36±0.20	14.61±0.36	15.47±0.45	15.56±0.41	17.43±0.47	18.42±0.51	18.82±0.71
	400	50	16.39±0.43	15.45±0.28	17.61±0.39	18.57±0.44	19.74±0.58	19.36±0.18	20.20±0.24
	400	60	16.49±0.06	17.61±0.39	17.40±0.21	18.64±0.34	20.66±0.97	20.60±0.16	21.34±0.52
	480	40	13.80±0.1	14.41±0.16	14.56±0.48	14.62±0.44	15.24±0.36	16.33±0.40	16.66±0.22
	480	50	15.24±0.16	15.69±0.49	16.33±0.38	16.68±0.48	17.59±0.13	18.27±0.45	18.58±0.34
	480	60	16.53±0.15	17.51±1.72	17.62±0.37	17.63±0.52	18.66±0.27	19.56±0.11	20.54±0.39

Table 3: Effect of drying methods and storage period on rehydration ratio of bitter gourd

Drying method	Power (W)	Temperature (°C)	Storage period (months) 0	1	2	3	4	5	6
CD		40	3.62±0.02	3.45±0.03	3.21±0.02	3.03±0.03	2.73±0.03	2.31±0.01	2.15±0.03
		50	3.82±0.01	3.73±0.02	3.33±0.02	3.02±0.01	2.91±0.01	2.74±0.04	2.52±0.01
		60	3.75±0.04	3.63±0.02	3.50±0.01	2.93±0.02	3.02±0.03	2.93±0.02	2.82±0.01
MACD	320	40	4.22±0.02	4.14±0.04	4.04±0.04	3.73±0.03	3.63±0.04	3.49±0.02	3.49±0.04
	320	50	4.53±0.03	4.44±0.04	4.35±0.04	4.22±0.02	4.01±0.01	3.94±0.03	3.43±0.03
	320	60	4.64±0.04	4.51±0.01	4.43±0.03	4.21±0.01	4.02±0.01	3.79±0.02	3.82±0.02
	400	40	4.53±0.01	4.41±0.01	4.33±0.05	4.11±0.01	3.91±0.03	3.73±0.04	3.64±0.04
	400	50	4.41±0.01	4.32±0.02	4.21±0.02	4.14±0.04	3.84±0.04	3.72±0.02	3.53±0.05
	400	60	4.81±0.01	4.74±0.04	4.62±0.02	4.54±0.03	4.34±0.03	4.12±0.02	3.92±0.02
	480	40	4.63±0.04	4.51±0.01	4.42±0.03	4.24±0.04	4.02±0.03	3.75±0.04	3.54±0.03
	480	50	4.71±0.01	4.61±0.01	4.53±0.05	4.53±0.05	4.02±0.03	3.82±0.02	3.62±0.02
	480	60	4.95±0.04	4.81±0.01	4.82±0.03	4.82±0.05	4.24±0.03	4.04±0.04	3.83±0.04

Rehydration ratio: Rehydration is an important quality index of dried vegetables. A higher rehydration ratio is related to the better quality of dried product because water reenters the cells through the pores upon rehydration[17]. The drying method also affected the rehydration ratio of dried bitter gourd (Table 3). The higher rehydration ratio was observed in samples dried by using microwave assisted convective drying as compared to the convective drying. The higher rehydration ratio of 4.95 was observed in a sample dried at 60°C and 480 W microwave power and the lowest value of 3.62 was observed at 40°C. The higher rehydration ratio at higher temperatures is attributed to the structural changes occurred in the sample during drying[18]. However, rehydration ratio showed continuous decrease with increasing duration of storage in both drying methods, but were consistently superior in microwave assisted dried methods.

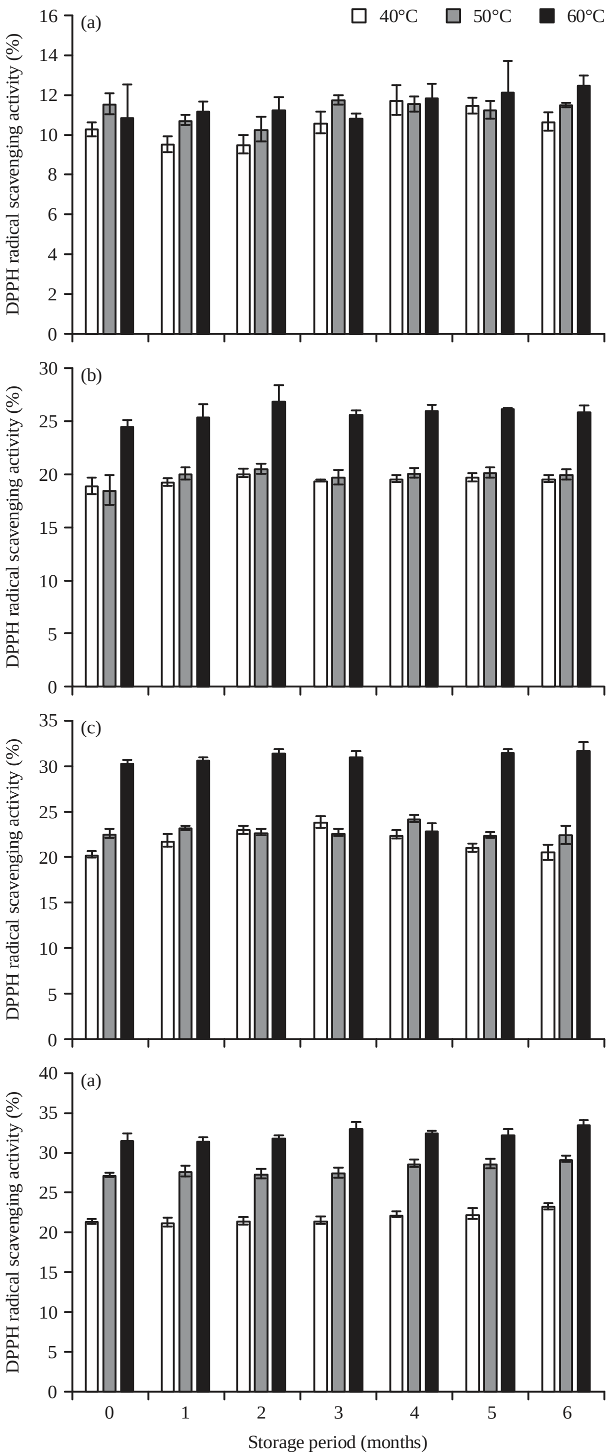

Fig. 3(a-d): Effect of drying methods and storage period on the DPPH radical scavenging activity of bitter gourd (a) CD, (b) 320 W, (c) 400 W and (d) 480 W

CONCLUSION

Drying of bitter gourd by microwave assisted convective drying limited the loss of quality attributes. Higher losses of quality attributes were observed in convective drying as compared to the microwave assisted convective drying. During storage ascorbic acid, total phenolic content, vitamin A content showed a continuous decline while an increase in DPPH radical scavenging activity and total color change was observed. The retention of ascorbic acid, total phenolics, vitamin A, antioxidant activity, surface color and rehydration capacity was better retained in microwave assisted convective dried bitter gourd due to faster and shorter drying.

SIGNIFICANCE STATEMENT

This study discovered that microwave assisted convective drying, which is faster and shorter drying technique was more effective than convective drying in reducing the degradation of ascorbic acid, total phenolics, color and antioxidant activity. Therefore, if microwave assisted convective can be practically applied in the drying of bitter gourd, the efficiency of drying units would be remarkably increased. This study will help the researchers to uncover the critical areas of bitter gourd that many researchers were not able to explore. Thus a new theory on microwave assisted convective drying may be arrived at.

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