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Research Article

Optimization of Drying Time and Temperature for Preparation of Antioxidant Rich Vegetable Powders from Unconventional Leafy Greens

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Abstract

Drying time and temperature were optimized for four unconventional leafy greens namely turnip (*Brassica rapa),* radish (*Raphanus sativus),* cauliflower (*Brassica oleracea)* and carrot *(Daucus carota)* at the temperature ranging between 40 to 60˚C and time varying between 4 to 18 hours. The results showed that the optimized drying time at 40˚C was 12 hours for turnip and 14 hours for radish, cauliflower and carrot leaves. Twelve hours had been optimized for turnip, radish and carrot leaves at 50˚C while optimized time for cauliflower leaves was 10 hours. At higher temperature i.e., 60˚C, the optimized time for all the vegetable leaves was 10 hours. The radish leaf powder had maximum antioxidant activity (87.04%) at 40˚C closely followed by carrot leaf powder (82.64%) at 50˚C and turnip leaf powder (82.34%) at 40˚C. The least antioxidant activity among dried leaf powder was observed in case of cauliflower leaves (38.84 to 51.38%) when dried for optimized time periods at 40 to 60˚C. Prolonged drying i.e. 2-4 hours beyond optimized time had a detrimental effect on antioxidant activity, the percent reduction in antioxidant activity being maximum in carrot leaf powder i.e., 79.47%. The optimized antioxidant rich vegetable leaf powders can be enriched in various food products with sufficient health promoting properties.

Keywords: Vegetable leaf powder, optimization, drying time, drying temperature, antioxidant activity, bioactive compounds

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Introduction

Green leafy vegetables had an enormous nutritive potential and can be used in the prevention of radical-induced diseases. The antioxidant activity and nutraceutical value of green leafy vegetables has been in limelight and an important area of the nutritional and phytotherapic research [1]. Average intake of green leafy vegetables in the Indian population is much less than the recommended levels. About 600 species constitute the global diversity in vegetable crops but only one fourth is utilized as a major vegetable crops and rest are named as underutilized vegetables [2]. Unconventional greens are rich source of phytochemicals and phenolic compounds that contribute to the antioxidant activity in the diet [3]. Nutritive potential of some less commonly used and inexpensive vegetable greens has not yet been adequately studied. Many varieties of vegetable greens for instance the leaves of carrot, cauliflower, chickpea, colocasia, radish and turnip are rich in micronutrients and antioxidants, but are usually discarded or not used for human consumption [4]. These vegetable byproducts are easily available in market at no cost and not utilized by general masses rather used for cattle feed due to lack of awareness about their nutritional value. Intake of unconventional greens in daily diet can be one of the strategies for improving the nutritional status.

Dehydration has been considered as a conventional processing method into food industry for preserving vegetable greens. It is an effective technique to make convenient food products such as dry soup mixes, baby foods, food gravies, frozen entrees, and dairy products [5]. Unconventional leafy greens can be incorporated into existing products as natural fortificants and can be used in the formulation of health foods. Easy to preserve, feasibility, cost effectiveness, convenience and off-season availability are some of the advantages of incorporating dehydrated greens in food products. Dehydrated unconventional leafy greens are concentrated source of micronutrients and bioactive compounds, therefore, can be used to supplement traditional recipes as well as commercially available convenience foods [6]. The most effective technique to dry the greens is freeze drying, however being very expensive, the next slant to effectively preserve the greens is the oven drying at optimum time and temperature with minimum losses of the nutrients and bioactive compounds in the dried leaves [7]. Looking into the increasing prevalence of chronic degenerative diseases globally, the need for exploration of unconventional leafy greens is significant to overcome the health disorders. Unconventional vegetable greens being reservoir of essential vitamins, micronutrients, protein and other phytonutrients have a potential to play a major role in strategies to attain nutritional security and can be explored to overcome micronutrient malnutrition and also to prevent degenerative diseases. The basic idea is to find novel methods by which consumption of greens can be increased. Vegetable powders can be produced with a view of good consumer appeal and varied use. Dehydrated vegetable greens can be used for improving efficacy of different products as nutraceutical and pharmacological products, hence there is a need to optimize the drying conditions so that the vegetable powders prepared from underutilized greens with optimum antioxidant potential can be formulated for enrichment in various food products having sufficient health promoting properties.

Materials and Methods

Procurement of vegetable greens: Unconventional leafy greens mainly considered as vegetative waste of common vegetables namely, turnip (*Brassica rapa)*, radish (*Raphanus sativus)*, cauliflower (*Brassica oleracea*) and carrot *(Daucus carota)* were procured from a local vegetable market in the early morning.

Preparation of samples: The fresh green leaves of the selected vegetables were brought in the Nutrition laboratory of department of Food and Nutrition, Punjab Agricultural University, Ludhiana. The leaves were washed with tap water to remove soil or other impurities. The leaves were chopped with knife and processed immediately in order to prevent chemical changes during storage if any.

Optimization of drying conditions: The hot air oven temperature varying between 40 to 60ºC and time varying between 4 to 18 hours were optimized for determination of dry matter. Dried leaves were grinded into fine powder and packed into airtight plastic pouches. The pouches were stored in deep freezer at -18ºC until further analysis.

Vegetable leaf powder yield: One hundred grams of fresh leaves were weighed and dried in hot air oven at three temperatures i.e., 40, 50 and 60ºC till constant weight. Vegetable leaf powder yield was calculated by the formula:

$$\text{Moisture (\%)} = \text{Loss of weight (g)}/\text{Weight of sample (g)} \times 100$$

$$\text{Vegetable leaf powder yield (\%)} = 100 - \text{\%Moisture}$$

Ascorbic acid: The samples were analyzed for ascorbic acid by Association of Official Analytical Chemist method (AOAC) [8]. One gram of the sample was grinded to slurry using 20 ml of 6 % metaphosphoric acid. The slurry was filtered followed by the addition of 30 ml metaphosphoric acid to residue and filtered again. Three separating funnels (50 ml) were set and labeled as A, B and C - A for sample, B for dye and C for standard. 5 ml of filterate was pipetted into a separating funnel A, 0.1 ml of standard ascorbic acid solution into funnel C. 5 ml acetate buffer was added to all three funnels followed by 2 ml the dye solution. 10 ml of xylene solution was quickly added and the contents were shaken for 5 to 10 seconds. The contents were allowed to separate into two layers. The bottom layer was discarded. The xylene layer was transferred into a test tube and the optical density was read in a spectrophotometer at 500 nm using the formula:

$$\text{Ascorbic acid (mg)} = 0.1\,(b-a) / (b-c)$$

Where b = OD of blank; a = OD of sample; c = OD of standard

Chlorophyll: The chlorophyll content was determined by the method of Thimmaiah [9] where 1 g of sample was homogenized with 10 ml of 80 % acetone and centrifuged at 5000 rpm for 5 min to collect the filtrate. The residue was again extracted with 80 % acetone until the residue became colourless. The final volume was made to 100 ml with 80 % acetone and the absorbance was measured at 663 nm and 645 nm on spectrophotometer. The amount of chlorophyll pigments was calculated using the following formula:

$$\text{mg total chlorophyll (per g tissue)} = 20.2\,(A_{645}) + 8.02(A_{663}) \times V/1000 \times W$$

Where, A = absorbance at specific wavelength; V= final volume of the chlorophyll extract in 80% acetone and W= fresh weight of the tissue extracted.

Flavonoids: The aluminum chloride colorimetric method was used to determine flavonoids in the samples [10]. One gram of sample was extracted with 25 ml of 95% ethanol under 200 rpm shaking for 24 hours. After filtration, the filtrate was adjusted to 25 ml with 80% ethanol. 0.5 ml extract was taken in a test tube, 0.5 ml of 96% ethanol, 0.1 ml of 10 % aluminium chloride, 0.1 ml of 1M potassium acetate and 2.8 ml of distilled water was added. The mixture was incubated at room temperature for 30 minutes. The absorbance of the mixture was read at 415 nm. Quercetin was used to make the calibration curve. Ten milligrams of quercetin were dissolved in 80% ethanol and then diluted to 25, 50 and 100µg/ml. The diluted standard solutions (0.5 ml) were separately mixed with 1.5 ml of 95% ethanol, 0.1 ml of 10% aluminium chloride, 0.1 ml of 1M potassium acetate and 2.8 ml of distilled water. The absorbance was read at 415 nm.

Antioxidant activity: The free radical scavenging activity was determined by using the DPPH assay (0.1mM) [11]. Two grams of sample was extracted with 20 ml of methanol by shaking for two hours. Extraction process was repeated twice. The extract was pulled together and centrifuged at 10000 rpm for 15 minutes. The supernatant was stored at -20° C till analysis. 100 µl of the aliquot of extract was taken in test tubes and added 2.9 ml of DPPH solution. The mixture was vortexed for 1 minute and incubated in dark for 3 minutes. Discolouration of DPPH was measured against blank at 517 nm. The DPPH scavenging effect was measured using by formula:

$$\text{Percent inhibition} = A_B\text{-}A_A/A_B \times 100$$

Where, A_B = absorbance of blank; A_A = absorbance of sample

Statistical analysis: All the experiments were conducted thrice. Mean and standard deviations for the various parameters were computed. Analysis of Variance (ANOVA) was employed to assess the difference in parameters as influenced by drying time and temperature using Microsoft Excel (2003) Statistical Analysis Tool Pack. Least Significant Difference (LSD) at 5% was calculated for the comparison among the parameters.

Table 1 Optimization of drying time and temperature in hot air oven for the selected vegetable leaves

Time, Hours	Vegetable leaf powder (%)			
	Turnip	**Radish**	**Cauliflower**	**Carrot**
Temperature: 40˚C				
4	$24.05^a \pm 3.48$	$23.09^a \pm 5.85$	$31.70^a \pm 5.36$	$29.26^a \pm 6.98$
6	$23.12^a \pm 2.04$	$15.85^b \pm 1.31$	$30.80^a \pm 0.09$	$27.96^a \pm 3.19$
8	$19.43^b \pm 2.31$	$15.40^b \pm 0.83$	$18.74^b \pm 2.74$	$22.66^{ab} \pm 2.74$
10	$16.67^{bc} \pm 0.96$	$15.30^b \pm 2.44$	$17.84^b \pm 2.43$	$21.58^b \pm 3.78$
12	$14.50^c \pm 1.12$	$11.16^c \pm 1.17$	$16.75^b \pm 0.81$	$20.17^b \pm 2.97$
14	$14.48^c \pm 1.08$	$10.99^c \pm 1.35$	$15.58^b \pm 1.29$	$19.82^b \pm 2.98$
16	$14.42^c \pm 1.09$	$10.95^c \pm 1.23$	$15.58^b \pm 1.18$	$19.80^b \pm 2.98$
18	$14.38^c \pm 1.08$	$10.94^c \pm 1.32$	$15.55^b \pm 0.81$	$19.74^b \pm 2.72$
LSD at 5%	2.83	3.80	3.70	5.81
Temperature: 50˚C				
4	$20.56^a \pm 4.58$	$16.00^a \pm 0.69$	14.73 ± 4.73	$22.21^a \pm 4.74$
6	$17.51^a \pm 1.42$	$14.27^a \pm 0.99$	14.56 ± 3.46	$22.06^a \pm 3.49$
8	$16.08^{ab} \pm 3.09$	$14.08^a \pm 2.04$	13.87 ± 0.84	$21.66^a \pm 2.10$
10	$13.76^{ab} \pm 2.10$	$12.21^{ab} \pm 0.84$	12.80 ± 2.50	$21.34^a \pm 2.38$
12	$12.78^b \pm 1.57$	$11.76^b \pm 1.73$	12.77 ± 2.14	$16.23^b \pm 1.40$
14	$12.75^b \pm 1.60$	$11.76^b \pm 1.73$	12.63 ± 2.53	$16.20^b \pm 1.41$
16	$12.49^b \pm 1.48$	$11.48^b \pm 1.63$	12.21 ± 1.42	$16.03^b \pm 1.31$
LSD at 5%	4.13	2.40	NS	4.44
Temperature: 60˚C				
4	$16.48^a \pm 2.01$	14.09 ± 0.57	16.71± 4.67	18.05 ± 2.46
6	$15.28^a \pm 0.43$	13.88 ± 0.11	14.86 ± 1.62	16.96 ± 1.88
8	$13.52^{ab} \pm 0.62$	13.76 ± 1.29	13.60 ± 1.43	16.87 ± 1.90
10	$12.67^b \pm 1.39$	12.75 ± 1.29	12.45 ± 3.07	15.95 ± 3.34
12	$12.06^b \pm 1.21$	12.65 ± 1.12	12.44 ± 1.96	15.94 ± 2.70
14	$12.04^b \pm 1.26$	12.39 ± 1.01	12.26 ± 1.58	15.91 ± 2.87
LSD at 5%	2.27	NS	NS	NS

Values are Mean±SD
Superscripts with same alphabets imply non significant difference at 5% level of significance
Superscripts with different alphabets imply significant difference at 5% level of significance

Results and Discussion

Optimization of Drying Time for the Preparation of Vegetable Leaf Powder

Optimization of drying time for four vegetable leaves at 40, 50 and 60˚C are presented in **Table 1**. The fresh leaves of turnip, radish, cauliflower and carrot were subjected to drying times ranging from 4 to 18 hours and temperature varying between 40 to 60˚C in hot air oven in order to optimize the drying time for the preparation of their corresponding vegetable leaf powders. At 40˚C, turnip leaves were dried completely at 12 hours with vegetable leaf powder yield of 14.50%. No significant reduction in moisture was observed beyond 12 hours. On the other hand, radish, cauliflower and carrot leaves attained constant weight after 14 hours, the vegetable leaf powder yield being 10.99, 15.58 and 19.82%, respectively. The dehydration of cauliflower, mint, coriander, bengal gram, spinach and amaranth leaves at 40˚C for 4-6 hours resulted in a vegetable leaf powder yield of 13.2, 11.8, 13.1, 24.9, 5.8 and 16.5%, respectively [12]. Turnip, radish and carrot leaves attained constant weight after 12 hours of drying at 50˚C, and no further loss of moisture was observed, the vegetable leaf powder yield being 12.78, 11.76 and 16.23%, respectively. Cauliflower leaves attained constant weight *i.e* 12.80% vegetable leaf powder yield after 10 hours of drying. Dehydration of wheatgrass in hot air oven at 50˚C for 8 hours resulted in vegetable leaf powder yield of 11.4%. Goyal *et al* [13] carried out dehydration of spinach, carrot and tomato in mechanical tray drier at 50-55˚C for 6-15 hours and observed vegetable powder yield of 5.1, 11.75 and 3.65%, respectively. The effect of different modes of drying on moisture content and drying time of selected vegetables [14]. It was inferred that dehydration of vegetables at 55˚C for 4-8 hours in cabinet tray dryer was the most efficient method of dehydration. When the leaves were dried at higher temperature i.e., 60˚C, all the four vegetable leaves took lesser time, the vegetable leaf powder yield being 12.67, 12.75, 12.45 and 15.95% for turnip, radish, cauliflower and carrot leaves, respectively. *Bathua* leaves attained constant weight after 10 to 12 hours of dehydration at 60˚C and observed vegetable leaf powder yield being 13.3% [15]. The dehydration of *araikeerai* leaves, coriander leaves, curry leaves, drumstick leaves, mint leaves and *mullakeerai* leaves in oven drier at 60˚C for 12 hours and observed vegetable leaf powder yield of 19.1, 15.6, 34.3, 22.5, 19 and 19.8%, respectively [16]. The vegetable leaf powder yield of 12.2, 7.8, 14.3, 11.6 and 12.4% in leaves of *Amaranthys gangetics*, *Chenopodium album*, *Centella asaitia*, *Amaranthus tricolor* and *Trigonella foenum graecum* dehydrated at 60˚C for 10-12 hours [17]. The variation in vegetable leaf powder yield is attributed to difference in physiological characteristics of different leaves.

The above observations helped to optimize drying times for turnip, radish, cauliflower and carrot leaves in hot air oven. The optimized time for turnip was 12 hours at 40˚C while for radish, cauliflower and carrot leaves it was 14 hours at 40˚C. The lesser time i.e., 12 hours has been optimized for turnip, radish and carrot leaves at 50˚C while optimized time for cauliflower leaves was 10 hours. At higher temperature i.e., 60˚C the optimized time for all the four vegetable leaves was 10 hours (**Table 2** and **Figure 1**).

Table 2 Antioxidant activity of standardized vegetable leaf powder of selected vegetable leaves at optimized and prolonged drying times in hot air oven

Drying Temperature	**Optimized Dehydration time, hours**	**Antioxidant Activity (%)**			**LSD at 5% among drying times**
		At Optimized Time	**2 hours after optimized time**	**4 hours after optimized time**	
Turnip					
40˚C	12	82.34±4.38	79.36±5.37	76.8±7.18	NS
50˚C	12	75.08±5.53	73.01±9.08	66.06± 0.83	NS
60˚C	10	74.54±0.69	72.09±1.72	57.65±10.45	18.19
LSD at 5% among drying temperatures	-	NS	NS	21.78	-
Radish					
40˚C	14	87.04±3.38	80.89±1.74	64.83 ± 6.11	12.33
50˚C	12	70.57±4.90	70.41±8.16	65.37±5.06	NS
60˚C	10	71.71±5.92	61.85±2.32	31.42±2.86	11.95
LSD at 5% among drying temperatures	-	14.39	14.85	14.46	-
Cauliflower					
40˚C	14	38.84 ± 5.09	35.55 ± 4.15	33.64 ± 2.69	NS
50˚C	10	51.38 ± 3.58	49.85 ± 0.66	37.69 ± 1.06	6.50
60˚C	10	42.51 ± 2.77	41.28 ± 1.99	36.39 ± 7.13	NS
LSD (5%)	-	11.68	7.97	NS	-
Carrot					
40˚C	14	82.11 ± 1.73	63.46 ± 6.83	63.38 ± 5.28	15.06
50˚C	12	82.64 ± 0.46	22.86 ± 5.31	16.97 ± 2.70	10.25
60˚C	10	51.91 ± 3.16	18.35 ± 4.85	13.91 ± 0.48	9.97
LSD at 5% among drying temperatures	-	6.23	15.30	12.62	-

Values are Mean±SD
NS: Non significant

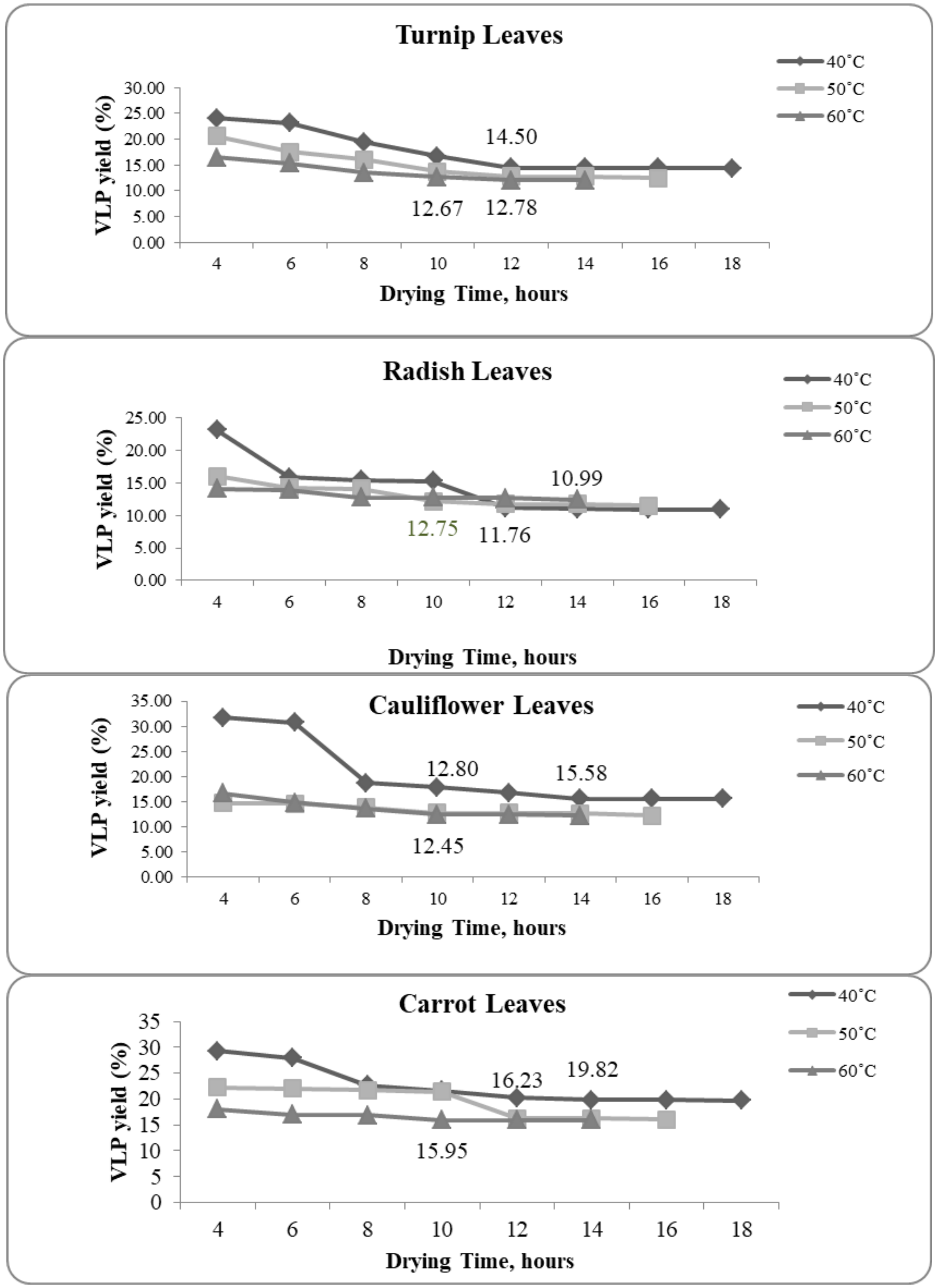

Figure 1 Optimization of drying time for the preparation of vegetable leaf powder (VLP) of turnip, radish, cauliflower and carrot leaves

Antioxidant Activity of Optimized Vegetable Leaf Powders

The antioxidant activity of vegetable leaf powders of selected vegetable leaves at optimized and prolonged drying times and percent reduction in antioxidant activity of selected vegetable leaves on prolonged drying times has been discussed in Table 2 and **Table 3**. The antioxidant activity of the optimized vegetable leaf powders of selected unconventional leafy greens namely turnip, radish, cauliflower and carrot was assessed. The vegetable leaves were dried for optimized time periods at 40 to 60˚C.

Table 3 Percent reduction in antioxidant activity of selected vegetable leaves on prolonged drying times in hot air oven

Drying Temperature	Reduction in antioxidant activity	
	2 hours after optimized time	**4 hours after optimized time**
Turnip		
40˚C	3.62	6.69
50˚C	2.76	12.01
60˚C	3.29	22.66
Radish		
40˚C	7.07	25.52
50˚C	0.23	7.37
60˚C	13.75	56.18
Cauliflower		
40˚C	8.47	13.39
50˚C	2.98	26.64
60˚C	2.89	14.40
Carrot		
40˚C	22.71	22.81
50˚C	72.34	79.47
60˚C	64.45	73.20

The results revealed that antioxidant activity of turnip leaf powder was highest at drying temperature of 40˚C and drying time of 12 hours i.e., 82.34%. Prolonged drying i.e., 2 hours after optimized time resulted in a lesser decrease of antioxidant activity (2.76 to 3.62%) in comparison to longer drying time i.e., 4 hours after optimized time (6.69 to 22.66%).

The antioxidant activity of radish leaf powder was 87.04% at 14 hours of drying time at the temperature of 40˚C. A significant ($p \leq 0.05$) reduction in antioxidant activity was observed when radish leaves were dried at higher temperatures (50 to 60˚C). Antioxidant activity of radish leaf powder 2 and 4 hours after the optimized time was 80.89 and 64.83%, respectively. A significant ($p \leq 0.05$) reduction in antioxidant activity was observed after 4 hours of drying. The results clearly indicated that extended drying time has detrimental effect on antioxidant activity. In case of radish leaves, drying of leaves after optimized time resulted in 13.75% reduction in antioxidant activity at 60˚C. But after 4 hours beyond the optimized time it was reduced by 56.18%.

The antioxidant activity of cauliflower leaf powder was 38.84, 51.38 and 42.51% when dried for optimized time periods at 40, 50 and 60˚C, respectively. A higher reduction i.e., 13.39 to 26.64% was observed after optimized time periods.

The carrot leaf powder had antioxidant activity of 82.11, 82.64 and 51.91% when dried at optimized time periods at 40, 50 and 60˚C, respectively. The maximum reduction in antioxidant activity was found 4 hours after optimized time (79.47%) at 50˚C followed by drying at 60˚C (73.2%). Even drying 2 hours after the optimized time periods, the enormous reduction in antioxidant activity was observed, the percent reduction being 72.34 and 64.45% at 50 and 60˚C, respectively.

The data depicted in **Figure 2** revealed that radish leaf powder had maximum antioxidant activity (87.04%) at 40˚C closely followed by carrot leaf powder (82.64%) at 50˚C and turnip leaf powder (82.64%) at 40˚C. The least antioxidant activity among vegetable leaf powder was observed in case of cauliflower leaves (38.84 to 51.38%) when dried for optimized time periods at 40 to 60˚C.

The optimized time of drying in hot air oven for preparation of vegetable leaf powders from unconventional green leaves were 40˚C for turnip and radish leaves with antioxidant activity of 82.34 and 87.04%, respectively, and 50˚C for cauliflower and carrot leaves with antioxidant activity of 51.38 and 82.64%, respectively.

An antioxidant activity ranged between 23.89 to 91.27% in four green leafy vegetables dehydrated at 60˚C for 8 to 10 hours has been reported [18]. In another study, it was observed that the increase in temperature reduced the antioxidant activity [19] as an antioxidant activity of 70.79, 82.21, 58.76 and 43.42% in coriander leaves dehydrated in oven dryer at 40˚C for 4 hours, 60˚C for 3 hours, 80˚C for 2 hours and 100˚C for one hour, respectively was reported. Similar results have been found in the present study. Devi [7] reported antioxidant activity of 33.82% in wheatgrass dehydrated in hot air oven at 50˚C for 8 hours. Rajeshwari *et al* [20] reported antioxidant activity of 76.5% in shade dried *Anthem sowa* leaves. Lakshmi and Kohila [21] reported antioxidant activity of 90.44 to 96.26 in four oven dried leafy vegetables. Janci Rani and Sarojini [22] reported antioxidant activity of 63.80% and 79.95% in shade dried *brahmi* and moringa leaves, respectively. A variation in the antioxidant activity of different vegetable leaves dehydrated at varied temperatures as reported in the present study as well as in literature may be attributed to physiological characteristics of individual vegetable leaves. Hence, the optimization of drying time and temperature for each vegetable leaves holds a great significance.

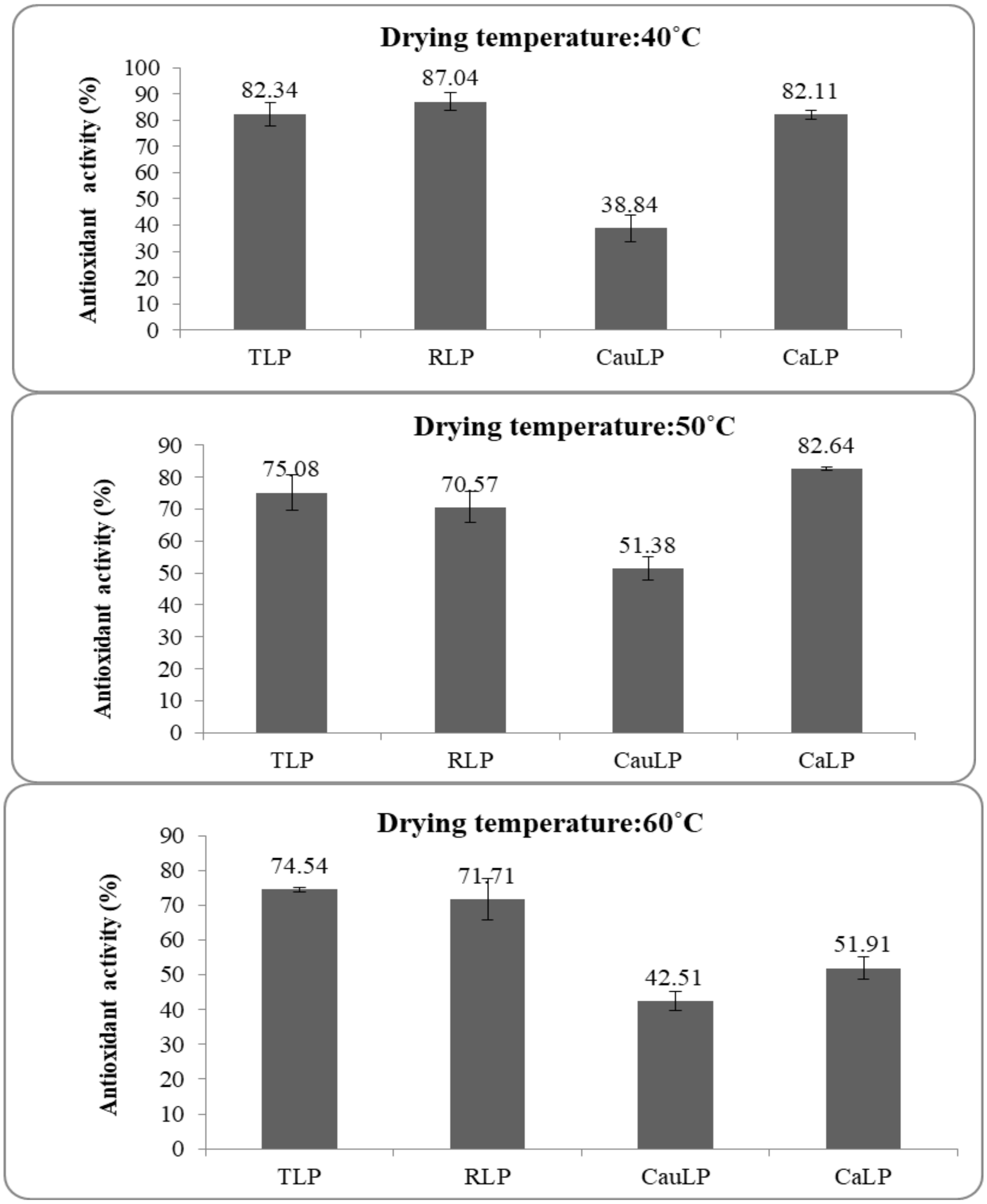

Figure 2 A comparison of antioxidant activity of turnip (TLP), radish (RLP), cauliflower (CauLP) and carrot (CaLP) leaf powder dried in hot air oven at different temperatures

Ascorbic acid, bioactive compounds and antioxidant activity of optimized vegetable leaf powders

Ascorbic acid, bioactive compounds and antioxidant activity of vegetable leaf powders of turnip, radish, cauliflower and carrots have been given in **Table 4**. There was a significant ($p \leq 0.05$) difference observed in ascorbic acid, chlorophyll, total carotenoids, flavonoids, total phenols and antioxidant activity among the dried leaf powders prepared from four selected vegetable leaves. The ascorbic acid content of vegetable leaf powders of turnip, radish, cauliflower and carrot was maximum in turnip leaves (33.07 mg per 100 g) followed by radish leaves (29.43 mg per 100 g). The least ascorbic acid was found in cauliflower leaves (16.93 mg per 100 g). Sartorelli [23] reported ascorbic acid content of 34.93 mg/100 g dried carrot leaves. Ascorbic acid content of the dried leaf powders was less than the fresh leaves. Ascorbic acid is most labile of all the vitamins in food. It is very sensitive to heat and rapidly destroyed during dehydration. This was the only nutrient, which reduced after drying as it is oxidized rapidly on exposure to heat and air. A significant reduction in ascorbic acid content of vegetable leaves after dehydration has been reported in literature [17, 24, 25]

Table 4 Ascorbic acid, bioactive compounds and antioxidant activity in optimized vegetable leaf powders

Parameter	Vegetable leaf powder				LSD at 5%
	Turnip	Radish	Cauliflower	Carrot	
Ascorbic Acid (mg/100 g)	33.07[a] ± 5.97	29.43[a] ± 3.39	16.93[b] ± 2.43	24.39[ab] ± 5.17	10.45
Chlorophyll (mg/100 g)	546.71[a] ± 6.57	507.58[b] ± 9.78	641.14[c] ±12.81	306.16[d] ± 0.88	20.45
Total Carotenoids (mg/100 g)	29.85[a] ± 0.04	26.85[b] ± 0.05	33.36[c] ± 0.03	12.60[d] ± 0.04	0.09
Flavonoids (mg QE/100 g)	1146.06[a]±13.25	815.45[b] ± 7.14	1016.97[c] ± 14.46	1336.85[d] ± 9.52	26.93
Total Phenols (mg GAE/100 g)	784.9[a] ± 5.87	527.61[b] ± 7.51	626.94[c] ± 7.89	441.90[d] ± 13.73	21.69
Antioxidant Activity (%)	82.34[a] ± 4.38	87.04[a] ± 3.38	51.38[b] ± 3.58	82.43[b] ± 0.46	7.75

Values are Mean±SD
Superscripts with same alphabets imply non significant difference at 5% level of significance
Superscripts with different alphabets imply significant difference at 5% level of significance

The cauliflower leaves had significantly ($p \leq 0.05$) higher chlorophyll (641.14 mg per 100 g) followed by turnip leaves (546.71 mg per 100 g), radish leaves (507.58 mg per 100 g) and carrot leaves (306.16 mg per 100 g). Ankita and Prasad [26] reported chlorophyll content in the range of 294 to 539 mg/100 g in radish leaf powder dehydrated at temperature of 50 to 90˚C. Total carotenoids was the highest in cauliflower leaves (33.36 mg per 100 g) followed by turnip leaves (29.85 mg per 100 g), radish leaves (26.85 mg per 100 g) and carrot leaves (12.60 mg per 100 g). Flavonoids were found to be maximum in carrot leaves (1336.85 mg QE per 100 g) followed by turnip leaves (1146.06 mg QE per 100 g), cauliflower leaves (1016.97 mg QE per 100 g) and radish leaves (815.45 mg QE per 100 g). Total phenols was highest in turnip leaves (784.9 mg GAE per 100 g) followed by cauliflower leaves (626.94 mg GAE per 100 g), radish leaves (527.61 mg GAE per 100 g) and carrot leaves (441.90 mg GAE per 100 g).

Among vegetable leaf powders, maximum antioxidant activity was observed in radish leaf powder (87.04%) closely followed by carrot leaf powder (82.43%), turnip leaf powder (82.34%). The least antioxidant activity was found in cauliflower leaf powder (51.38%). The radical scavenging activity on DPPH as 52.20% in dried turnip leaves and as 78.17% in shade dried radish leaves has been observed [27, 28]. It is mainly attributed to concentration effect of drying in the compounds. The total carotenoids, antioxidant activity, total phenols and flavonoids content increased after dehydration has been reported [29-31].

Conclusions

The study concluded that the radish leaf powder had maximum antioxidant activity (87.04%) at drying time of 14 hours at 40˚C closely followed by carrot leaf powder (82.64%) at 50˚C and turnip leaf powder (82.34%) at 40˚C at the optimized drying time of 12 hours. The least antioxidant activity among dried leaf powder was observed in case of cauliflower leaves (38.84 to 51.38%) when dried for optimized time at different temperatures. Hence, the leaves of selected vegetable greens must be dehydrated at optimized time and temperature for retention of maximum antioxidant activity. Extended drying has a detrimental effect on antioxidant activity.

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