PRINT: ISSN 0973-5070 ONLINE: ISSN 2456-6772
Ethno Med, 13(2): 62-70 (2019)
DOI: 10.31901/24566772.2019/13.02.574

Effect of Vacuum Drying on Nutrient Retention of Some Commonly Consumed Herbs

Gurpreet Kaur[1], Neerja Singla[2] and Amandeep Singh[3]

Punjab Agricultural University, Ludhiana 141 004, Punjab, India
E-mail: [1]<gurpreet_kaur881@yahoo.com>, [2]<singlaneerja@pau.edu>

KEYWORDS Basil. Bioactive Compounds. Drumstick. Leaves. Mint

ABSTRACT The objective of the paper was to evaluate the effect of vacuum drying on nutrient retention of some commonly consumed herbs. Fresh herbs (basil leaves (*Ocimum tenuiflorum*), drumstick leaves (*Moringa oleifera*) and mint leaves (*Mentha*)) were procured from Department of Agronomy, PAU, Ludhiana. The leaves of herbs were cleaned and dried in vacuum oven at 50±5ºC, ground to form powder and stored in zip pouches for further use. Herbs were analysed for their proximate composition, minerals (iron, zinc and calcium), vitamins (vitamin C and β-carotene) bioactive compounds (total phenols, flavonoids and antioxidant activity), and anti-nutritional factors (phytin phosphorous and oxalates). The percent increase in protein content after drying was maximum in BL (80.26%) followed by ML (77.91%) and DL (76.13%). A significant decrease ($p<0.01$) was found in moisture content of all herbs after drying while ash, crude protein, crude fat, crude fibre, carbohydrate and energy content of herbs increased significantly ($p<0.01$) after drying. Percent decrease in ascorbic acid content was 49.82, 49.97 and 63.13 percent in BL, ML and DL, respectively. β-carotene content of leaves of fresh herbs ranged from 1489.20-17992 µg/100g and 1989.01-32100 µg/100g in dried leaves. Calcium content increased by 74.01, 82.88 and 82.78 percent after drying in BL, ML and DL, while zinc content was 74.26, 73.22and 68.56 percent in BL, ML and DL. Dried herbs like DL, BL and ML increased in phytate and oxalate content by 30.4, 25.9 and 25.9 percent and 16.8, 26.3 and 12.4 percent, respectively. Percent increase in total phenol content after drying was 48, 49 and 46 percent in BL, ML and DL, respectively. Percent increase in DPPH content after drying was 78.46, 82.82 and 81.80 percent in BL, ML and DL, respectively. Percent increase in TAC by ABTS after drying was maximum in BL (87.85%) followed by ML (86.12%) and DL (74.03%). Range of FRAP for fresh leaves of herbs was 112.05-142.31 TE/100g and it was 843.49-886.23 mg TE/100g in dried leaves. Percent increase was 83.12, 87.36 and 79.27 percent in BL, ML and DL, respectively. Content of bioactive compounds increased significantly ($p<0.01$) after drying. It was concluded that drying of herbs led to significant increase in proximate composition except moisture, in bioactive compounds, in mineral content and β-carotene, while a decrease in vitamin C and moisture content was also observed. Maximum percent increase of phytate content was found in drumstick leaves followed by basil leaves and mint leaves after drying.

INTRODUCTION

Herbs have been reported to be used as food and also for cure of some common ailments since ancient times. The extracts of commonly used culinary herbs, spices and herbal teas contain some volatile essential oils, which are reported to suppress cholesterol synthesis and tumor growth by inhibiting mevalonate synthesis. They are also potent source of antioxidant compounds which help to protect against chronic diseases by protecting low density lipoproteins (LDL) cholesterol from oxidation, inhibit lipid peroxidation, inhibit cyclooxygenase and lipoxygenase enzymes and have antiviral or antitumor activity.

Herbs not only enhance the taste and flavour of foods but their antimicrobial and antifungal properties also help to increase the shelf life. Many low cost but valuable medicinal herbs are easily available and are very useful due to their nutraceutical properties. However, their use in culinary is limited only as a flavour enhancer in freshly cooked foods.

Tulsi (*Ocimum sanctum*) has been used as a common herb in many of the Indian households for treatment of minor ailments like from regular fever to some of the most fatal bacterial and viral infections since ancient times. It is alternatively known as holy basil (*Ocimum sanctum*) and contains a significant amount of phytonutrients, essential oils, vitamin A and C. Regular consumption of tulsi can also help in balancing various bodily processes. It is beneficial for diabet-

Address for correspondence:
Gurpreet Kaur
Punjab Agricultural University,
Ludhiana 141 004, Punjab, India
E-mail: Gurpreet_kaur881@yahoo.com

ics as it helps to reduce elevated blood sugar levels. It can also aid in minimizing the risk of developing kidney stones by regulating uric acid levels in body. Normal levels of the stress hormone cortisol in the body can also be maintained by regular consumption of tulsi. Harmful effects of free radicals in the body can be reduced by this holy herb. It can also be used in treating conditions like hepatitis, malaria, tuberculosis, dengue and swine flu etc. (Mishra and Bhatt 2017).

Moringa oleifera is also known by other common names like Mallungay in Philippines, Horse Raddish tree in Florida, Zogale in Hausa, Okwe Oyibo in Igbo, Ewé Ìgbálè in Yoruba and Jeghel-agede in Tiv as reported by Fahey (2005). The drumstick leaves have been reported to prevent and treat protein-energy malnutrition and other nutrition related diseases (Tete-Benissan et al. 2012). However, its seeds and flowers also have good nutritional and therapeutic values. Leaves of drumstick are low in fat and carbohydrate but are good source of amino acids mainly sulphur containing amino-acids such as methionine and cysteine (Liu et al. 2007).

Mint belongs to the *Lamiaceae* family which has 25-30 species. The most popular specie is common mint or spearmint. Peppermint (*Mentha piperita*) has been used as a common remedy for the treatment of some of common digestive tract problems like nausea, indigestion, flatulence and even for hiccups. Mint is reported to contain anti-microbial, anti-fungal, anti-viral, insecticidal, antioxidant, antiamoebic, and antihaemolytic properties but is also reported to act as a sedative that is, suppressant for central nervous system and allergen (Choudhury et al. 2006). It has also been demonstrated by Mimica-Dukic and Bozin (2008) that a wide range of pharmacological properties such as antioxidant, antiulcer, chemopreventive, anti-inflammatory, heptoprotectiven and anti diabetogenic in mint are due to presence of phenolic compounds.

Green leafy vegetables and herbs are used as an important part of the daily diet in all parts of the world. They are rich sources of bioactive compounds, minerals, and dietary fibres but due to their perishable nature they deteriorate very quickly after harvest. Besides, some of them are not available throughout the year, so they need to be preserved for their use in off-season. Among various methods of preservation, drying has been considered to be as one of the most effective method which helps to increase the shelf life of greens by inhibiting the growth of microorganisms and also by preventing some of the biochemical reactions which result in changes in the organoleptic and nutritional parameters of dried leaves. It also helps to retain the biological activity of important phytoconstituents including antioxidants. However, it must be performed carefully in order to preserve the appearance, aroma and nutritional characteristics of the fresh greens, as some of the volatilities are lost or formation of new volatilities takes place due to oxidation and esterification reactions as demonstrated by Crivelli et al. (2002). Therefore, the proper method and conditions can help to minimize nutrient loss and quality deterioration during dehydration.

Objectives

To evaluate the effect of vacuum drying on nutrient retention of some commonly consumed herbs.

METHODOLOGY

Procurement and Processing of Raw Material

Fresh herbs (basil leaves (*Ocimum tenuiflorum*), drumstick leaves (*Moringa oleifera*) and mint leaves (*Mentha*)) were procured from Department of Agronomy, PAU, Ludhiana. The leaves of herbs were cleaned and dried in vacuum oven at 50±5ºC, ground to form powder and stored in zip pouches for further use.

Nutritional Evaluation of Fresh and Dehydrated Herbs

Herbs were analysed for their proximate composition, minerals (iron, zinc and calcium), vitamins (vitamin C and β-carotene), bioactive compounds (total phenols, flavonoids and antioxidant activity), and anti-nutritional factors (phytin phosphorous and oxalates).

Proximate Analysis

All the samples were analyzed in duplicates. Moisture, crude ash, crude protein, crude fat

and crude fibre content was evaluated on dry matter basis by AOAC (2000) method. Carbohydrate and energy was calculated on the basis of above parameters.

Vitamins and Minerals

Estimation of Ascorbic Acid was done by AOAC (2000) and β-Carotene by AACC (1995). Elements namely iron, zinc and calcium were estimated using atomic absorption spectrophotometer (AAS, Varian model) (Piper 1950). Sample was digested with diacid mixture (nitric acid: perchloric acid, 5: 1 v/v) and then analyzed by AAS.

Anti-nutritional Factors

The method for phytin phosphorus was determined by Haung and Lantzsch (1983). In this method, 1 g of sample was added to HCL for extraction which was followed by addition of ferric solution and bipyridine solution. Absorbance was read at 519 nm. Oxalates were estimated by the procedure given by Abeza et al. (1968).

Bioactive Components

Extraction of bioactive components was done with known quantity (2 g) of weighed sample taken in 100 ml conical flask. Fifteen ml of 80 percent methanol which was acidified to pH 2.0 with 6 N hydrochloric acid was added to sample and then shaken at room temperature for 30 minutes. Supernatants were decanted and the residue re-extracted for complete removal of phenolic and antioxidant compounds. This procedure was repeated two times. The three supernatants were pooled, centrifuged at 6000 rpm for 15 mins and filtered through Whatman No.1 filter paper. The volume was made up to 50 ml with the solvent. The sample was transferred to micro centrifuge tubes and stored at -20°C for total phenolic content (TPC) and total antioxidant capacity (TAC) determination. Total phenols were estimated by Singleton et al. (1999) and Flavonoid content by Zhishen et al. (1999) method. Total antioxidant capacity was determined by four methods: Ferric Reducing Antioxidant Power (FRAP) assay (Benzie and Strain 1999) as modified by (Tadhani et al. 2009), Reducing Power Assay (RPA) (Oyaizu 1986), ABTS Radical Scavenging Activity (Re et al. 1999) and DPPH (2,2-Diphenyl-1-picrylhydrazyl) Radical Scavenging Activity by Brand-Williams et al. (1995) as modified by Tadhani et al. (2009).

Statistical Analysis

Data obtained from the mean values and standard deviation for each sample were computed using MS Excel. Analysis of variance (ANOVA) (Tukey's test) was employed to assess the significant difference between the treatments in terms of their nutrient content. The statistical procedures were performed using SPSS (version 16.0).

RESULTS AND DISCUSSION

Nutritional Evaluation of Fresh and Dried Herbs

Herbs are known to have beneficial effects on human health due to significant amounts of micronutrients, vitamins, antioxidants and fibre. The results of nutritional evaluation of fresh and dried herbs are being discussed below.

Fresh Herbs

Proximate Composition

Proximate composition of fresh herbs has been shown in Table 1. The moisture content of leaves of fresh herbs ranged from 73.60-86.44 percent. It was maximum in basil leaves (BL) followed by mint (ML) and drumstick (DL) leaves. Moisture content of ML was significantly ($p<0.05$) higher than BL and DL in fresh leaves. Lakshmi and Vimala (2000) reported moisture content as eighty seven percent on fresh weight basis in drumstick leaves. Dìaz-Maroto et al. (2002) reported that fresh *lamiaceae* herbs as spearmint usually contain seventy five to eighty percent water and the water levels need to be lowered to less than fifteen percent for their successful preservation. Eric (2013) showed the initial moisture content of 91.20 percent±0.96 in the fresh basil leaves. Ash content of leaves fresh ranged from 1.62-2.92 g/100g. Mint leaves had maximum ash con-

Table 1: Nutrient composition in fresh herbs (per 100g)*

Herbs	*BL*	*ML*	*DL*
Proximate Composition			
Moisture (g)	$86.44^{a} \pm 0.59$	$83.95^{b} \pm 0.25$	$73.60^{c} \pm 0.95$
Ash (g)	$1.62^{c} \pm 0.02$	$2.92^{a} \pm 0.07$	$2.64^{b} \pm 0.07$
Crude protein (g)	$4.05^{b} \pm 0.21$	$4.82^{b} \pm 0.12$	$6.85^{a} \pm 0.21$
Crude fat (g)	$0.62^{b} \pm 0.06$	$0.77^{b} \pm 0.29$	$1.76^{a} \pm 0.10$
Crude fibre (g)	$2.80^{a} \pm 0.19$	$1.50^{b} \pm 0.22$	$2.00^{b} \pm 0.20$
CHO (g)	$4.70^{c} \pm 1.20$	$6.04^{b} \pm 3.20$	$13.15^{a} \pm 4.52$
Energy (kcal)	$39.66^{c} \pm 5.02$	$50.37^{b} \pm 4.56$	$95.84^{a} \pm 9.63$
Vitamins			
Vitamin C (mg)	$14.45^{c} \pm 1.21$	$18.33^{b} \pm 1.08$	$38.90^{a} \pm 1.00$
Beta carotene (µg)	$2989.20^{c} \pm 11.2$	$4625.00^{b} \pm 6.50$	$6992.00^{a} \pm 9.60$
Total Minerals (mg)			
Calcium	$192.00^{c} \pm 9.60$	$197.71^{b} \pm 12.5$	$344.00^{a} \pm 10.5$
Iron	$4.14^{c} \pm 0.20$	$9.56^{a} \pm 0.96$	$5.30^{b} \pm 0.52$
Zinc	$0.87^{a} \pm 0.02$	$0.79^{a} \pm 0.05$	$0.72^{a} \pm 0.10$
Soluble Minerals (mg)			
Calcium	$80.01^{c} \pm 0.55$	$85.21^{b} \pm 0.22$	$160.00^{a} \pm 0.45$
Iron	$2.10^{b} \pm 0.10$	$4.12^{a} \pm 0.08$	$2.62^{b} \pm 0.08$
Zinc	$0.39^{a} \pm 0.06$	$0.27^{a} \pm 0.02$	$0.32^{a} \pm 0.12$
Anti-nutrients			
Phytin phosphorous (mg)	$49.57^{c} \pm 5.20$	$52.13^{b} \pm 4.50$	$113.64^{a} \pm 6.30$
Oxalates (mg)	$58.61^{c} \pm 5.20$	$81.56^{b} \pm 1.40$	$111.59^{a} \pm 2.60$
Bioactive Components			
Total phenols (mg)	$81.31^{a} \pm 3.30$	$75.99^{b} \pm 4.80$	$38.70^{c} \pm 5.60$
Flavonoids (mg RE/ 100g)	$1517.11^{c} \pm 12.50$	$3170.69^{a} \pm 10.20$	$1993.23^{b} \pm 9.60$
DPPH (mg GAE/100g)	$425.98^{b} \pm 10.12$	$497.49^{a} \pm 8.54$	$420.14^{c} \pm 6.25$
ABTS (mg TE/ 100g)	$9.77^{b} \pm 1.23$	$10.49^{b} \pm 2.54$	$18.25^{a} \pm 1.08$
FRAP (mg TE/ 100g)	$142.31^{b} \pm 5.78$	$112.05^{c} \pm 4.51$	$175.39^{a} \pm 7.45$
RPA (mg TE/ 100g)	$673.46^{c} \pm 8.50$	$809.40^{a} \pm 7.41$	$734.38^{b} \pm 4.50$

Values are expressed as mean ± SD, BL: Basil leaves, ML: Mint leaves, DL: Drumstick leaves, NS- Non significant, Statistical test: Analysis of variance (ANOVA) (Tukey's test)
*Results are on dry weight basis

tent followed by drumstick and basil leaves. Ash content represents mineral content of herbs. Ash content of ML was significantly ($p<0.05$) higher than BL and DL. Crude protein content ranged from 4.05-6.85 g/100g. Fresh leaves of drumstick had maximum protein content that is, 6.85 g/100g followed by mint that is, 4.82 g/100g and basil 4.05 g/100g. Protein content of DL was significantly ($p<0.05$) higher than BL and DL. Dìaz-Maroto et al. (2002) reported 4.50 mg/g±0.13 protein in the fresh parsley leaves and Eric (2013) reported 4.50 mg protein per g in fresh basil leaves.

Crude fat in fresh leaves of basil, mint and drumstick was 0.62, 0.77 and 1.76 g/100g, respectively. Fat content of DL was significantly ($p<0.05$) higher than BL and DL. Crude fibre ranged from 1.5-2.8 g/100g. Fibre content of BL was significantly ($p<0.05$) higher than ML and DL. CHO content of herbs ranged from 4.47-13.15 g/100g being maximum of DL and minimum in BL. Carbohydrate content of DL was significantly ($p<0.05$) higher than BL and ML in both fresh leaves. Energy content of DL was significantly ($p<0.05$) higher than BL and ML. Gopalan et al. (2017) reported 84.24, 2.78, 4.66, 0.65, 1.40, 2.39 g and 155 KJ per 100g moisture, ash, protein, fat, fibre, carbohydrates and energy in fresh mint leaves and 75.65, 2.46, 6.91, 1.64, 2.10, 5.62 g and 282 KJ per 100g in drumstick leaves, respectively.

Vitamin and Mineral Content

Vitamin and mineral content of herbs has been presented in Table 1. The content of ascorbic acid in herbs ranged from 14.45-38.90 mg/100g. Ascorbic acid content of basil, mint and drumstick was 14.45, 18.33 and 38.90 mg/100g in fresh leaves, which was significantly ($p<0.05$) higher in DL than BL and ML.

β-carotene content of leaves of fresh herbs ranged from 2989.20-6992.00 µg/100g. DL showed higher content of β-carotene that is,

6992.00 µg/100g in fresh leaves followed by ML that is, 4625 µg/100g and DL that is, 8100.50 µg/100g, respectively. β-carotene content of DL was significantly ($p<0.05$) higher than BL and ML. Gopalan et al. (2017) reported ascorbic acid and β-carotene content as 17.16 mg and 18693 µg per 100g in fresh mint leaves and 108 mg and 38765 µg per 100g in fresh drumstick leaves, respectively. Kowsalya and Vidhya (2004) reported 196 mg per 100g vitamin C in fresh drumstick leaves. β-carotene content of mint was reported to be 1565 µg per 100g on fresh weight matter basis by Lakshmi and Vimala (2000). Seshadri and Nambiar (2003) reported 19.21 µg per 100g β-carotene in fresh drumstick leaves.

Among mineral Ca, Fe and Zn content were estimated for each herb and data has been represented in Table 1. Calcium content of herbs ranged from 192.00 to 344.00 mg/100g. Calcium content of fresh BL, ML and DL was 192.00, 197.71 and 344.00 mg/100g. The soluble calcium content varied from 80.01-160.00 mg per 100g in fresh herbs. Calcium content of DL was significantly ($p<0.05$) higher than BL and ML.

Iron content of leaves of fresh herbs ranged from 4.14-9.56 mg/100g. The soluble iron content ranged from 2.10-4.12 mg per 100g. Total and soluble iron content of ML was significantly ($p<0.05$) higher than BL and DL. Zinc content of herbs was 0.87, 0.79 and 0.72 mg/100g in fresh leaves of basil, mint and drumstick, respectively. The soluble zinc content of fresh and herbs ranged from 0.27-0.39 mg per 100g.

Gopalan et al. (2017) reported calcium, iron and zinc content as 205, 8.56 and 0.75 mg per 100g in fresh mint leaves and 314, 4.56 and 0.72 mg per 100g in fresh drumstick leaves, respectively. Mlitan et al. (2014) reported that the percentages of minor mineral elements ranged from 0.98 to 4.35 mg/100g (Fe) and 10.44 to 17.72 mg/100g (Zn) in the leaves of *Ocimum gratissinum* from three different locations in Misurata region.

Anti-nutritional Factors

Phytate and oxalate content of fresh herbs leaves has been depicted in Table 1. Phytate content of fresh leaves of basil, mint and drumstick was 49.57, 52.12 and 113.64 mg/100g. Leaves of drumstick has shown maximum oxalate content that is, 111.56 mg/100g followed by mint and basil that is, 81.56 mg/100g and 58.61 mg/100g, respectively. Phytate and oxalate content of DL was significantly ($p<0.05$) higher than BL and ML. Gopalan et al. (2017) reported phytate and oxalate content of fresh mint leaves as 48.65 and 97.07 mg per 100g and of drumstick leaves as 128 and 120 mg per 100g, respectively. Bedi (2004) reported 925 mg/100g oxalic acid in fresh drumstick leaves.

Bioactive Compounds

Bioactive components includes phenols, flavonoids and total antioxidant capacity. Content of bioactive compounds has been presented in Table 1. Total phenol content in fresh leaves of herbs ranged from 38.70-81.31 mg GAE/100g. Total phenol content of BL was significantly ($p<0.05$) higher than ML and DL. Padma and Anita (2005) found total phenol as 5-60 mg/100g in drumstick leaves. Saini et al. (2014) reported high amounts of total phenolic content (512.0 mg/100 g FW) in leaves of *M. oleifera*. Gopalan et al. (2017) reported phenol content as 79.99 and 29.90 mg per 100g in fresh mint and drumstick leaves, respectively. Flavonoid content of herbs ranged from 1517.10-3170.69 mg RE/100g which was significantly ($p<0.05$) higher in ML than BL and DL. Justesen and Knuthsen (2001) measured moderate amounts of the flavonoids apigenin (18-99 mg/100g fresh weight) and luteolin (11–42 mg/100g fresh weight) in mint varieties.

Total antioxidant capacity (TAC) as measured by DPPH was significantly ($p<0.05$) higher in ML than BL and DL. ABTS content of BL, ML and DL ranged from 9.77-18.25 mg TE/100g in fresh leaves, which was significantly ($p<0.05$) higher than BL and ML in fresh leaves. TAC when measured by FRAP was found to be significantly ($p<0.05$) higher in DL than BL and ML. RPA of basil, mint and drumstick leaves showed that it was significantly ($p<0.05$) higher in ML than BL and DL. Gatade et al. (2013) reported that total phenolic content of drumstick leaves was 260 mg/g whereas free radical scavenging activity was 36.06 µg/ml. Zheng and Wang (2001) measured low to moderate levels of phenolics and antioxidant activity in spearmint, peppermint and orange mint. Justesen and Knuthsen (2001) measured moderate amounts of the flavonoids apigenin (18-99 mg/100g fresh weight)

Table 2: Nutrient composition in dried herbs (per 100g)*

Herbs	*BL*	*ML*	*DL*
Proximate Composition			
Moisture (g)	8.65[a]± 0.29	8.03[a]± 0.09	7.76[a]± 0.23
Ash (g)	3.10[c]± 0.25	5.65[a]± 0.05	5.04[b]± 0.45
Crude protein (g)	7.82[c]± 0.01	9.72[b]± 0.02	13.15[a]± 0.05
Crude fat (g)	1.22[c]± 0.12	1.49[b]± 0.08	3.45[a]± 0.05
Crude fibre (g)	5.20[a]± 0.25	2.80[c]± 0.59	3.75[b]± 0.75
CHO (g)	74.01[b]± 5.68	72.31[c]± 4.96	85.05[a]± 4.29
Energy (kcal)	297.50[b]± 9.45	291.14[c]± 8.52	299.12[a]± 8.63
Vitamins			
Vitamin C (mg)	10.25[c]± 0.08	14.17[b]± 0.41	28.34[a]± 0.90
Beta carotene (µg)	3229.01[c]± 10.2	5259.00[b]± 5.90	8100.50[a]± 6.30
Total Minerals (mg)			
Calcium	240.12[c]± 12.50	245.01[b]± 10.20	422.20[a]± 9.60
Iron	5.15[c]± 0.56	11.70[a]± 0.20	6.65[b]± 0.59
Zinc	1.08[a]± 0.06	0.98[a]± 0.02	0.89[a]± 0.12
Soluble Minerals (mg)			
Calcium	100.00[c]± 0.76	110.12[b]± 0.62	199.00[a]± 0.92
Iron	2.60[c]± 0.03	5.13[a]± 0.03	3.32[b]± 0.12
Zinc	0.49[a]± 0.12	0.34[a]± 0.01	0.40[a]± 0.06
Anti-nutrients			
Phytin phosphorous (mg)	63.26[c]± 4.30	67.43[b]± 5.60	143.28[a]± 7.20
Oxalates (mg)	70.57[c]± 2.50	98.16[b]± 2.60	134.11[a]± 1.20
Bioactive Components			
Total phenols (mg)	120.40[a]± 5.20	113.59[b]± 3.20	56.65[c]± 2.50
Flavonoids (mg RE/ 100g)	2168.19[c]± 11.20	4525.94[a]± 9.60	2893.48[b]± 10.80
DPPH (mg GAE/100g)	650.68[b]± 8.52	766.03[a]± 4.56	628.08[c]± 6.57
ABTS (mg TE/ 100g)	15.09[a]± 5.74	15.76[a]± 2.31	27.27[b]± 2.78
FRAP (mg TE/ 100g)	213.49[b]± 9.78	169.23[c]± 7.45	266.12[a]± 7.12
RPA (mg TE/ 100g)	1014.17[c]± 12.98	1221.10[a]± 10.20	1116.45[b]± 9.88

Values are expressed as mean ± SD, BL: Basil leaves, ML: Mint leaves, DL: Drumstick leaves, NS- Non significant, Statistical test: Analysis of variance (ANOVA) (Tukey's test)
*Results are on dry weight basis

and luteolin (11-42 mg/100g fresh weight) in mint varieties.

Dried Herbs

Proximate Composition

Proximate composition of dried herbs has been shown in Table 2. The moisture content of leaves of dried herbs ranged from 7.76-8.65 percent. The percent decrease in moisture content after drying was maximum in ML (90), and BL (90) followed by DL (89). Difference in moisture content was non-significant in dried leaves of all three herbs. Lakshmi and Vimala (2000) reported moisture content 9.6 percent on dry weight basis, respectively. Kowsalya and Vidhya (2004) analyzed the nutrient composition of sun-dried drumstick leaves and reported to contain 24.0, 2.9 and 8.5 g/100g of protein, fibre and ash, respectively. Dìaz-Maroto et al. (2002) reported that the water levels need to be lowered to less than fifteen percent for their successful preservation. Eric (2013) showed that hot-air-dried leaves had the lowest moisture content (14.06%±1.97), whilst sun-dried leaves had the highest moisture of 19.71 percent±0.50.

Ash content of leaves dried herbs ranged from 3.10-5.65 g/100g, respectively. Mint leaves had maximum ash content followed by drumstick and basil leaves. Ash content of ML was significantly ($p<0.05$) higher than BL and DL after drying. Crude protein content ranged from 7.82-13.15 g/100g in leaves of dried herbs. Dried leaves of drumstick had maximum protein content that is, 13.15 g/100g followed by mint that is, 9.50 g/100g and basil 7.82 g/100g. The percent increase in protein content was maximum in ML (97%) followed by BL (94%) and DL (92%). Protein content of DL was significantly ($p<0.05$)

higher than BL and DL. Dìaz-Maroto et al. (2002) reported 4.01 mg/g±0.10 of protein in the microwave dried leaves compared with 4.50 mg/g±0.13 in the fresh leaves. This represented about eighty nine percent (wt) of the protein preserved in the microwave dried leaves in relation to that of fresh leaves. This was followed by oven drying (3.05±mg/g 0.13) which was approximately sixty eight percent (wt), whilst leaves dried in the room at ambient temperature had the smallest amount of protein (0.50 mg/g±0.10), about eleven percent left over. 4.10 mg per g protein was reported by Eric (2013) in microwave dried basil leaves compared to 4.50 mg per g in fresh basil leaves and this was followed by oven drying that is, 0.50 mg per g.

Crude fat in leaves of dried herbs ranged from 1.22-3.45 g/100g. Crude fat in dried leaves of basil, mint and drumstick was 1.22, 1.49 and 3.45 g/100g, respectively. Increase in fat content was observed after drying of samples and it was maximum in BL (97%) followed by DL (96%) and minimum in ML (93%). Crude fibre ranged from 2.80-5.20 g/100g in leaves of dried herbs. It was maximum in dried leaves of basil (5.20 g/100g) followed by DL (3.75 g/100g) and ML (2.80 g/100g). Percent increase after drying was eighty seven percent in ML and DL and eighty six percent in BL. Fibre content of BL was significantly ($p<0.05$) higher than ML and DL in dry leaves.

CHO content of dried forms of BL, ML and DL was 74.01, 72.31 and 85.05 g/100g, respectively. Carbohydrate content of DL was significantly ($p<0.05$) higher than BL and ML in dry leaves. Energy content of herbs ranged from 291.14-299.12 kcal/100g in dried leaves. Energy content of DL was significantly ($p<0.05$) higher than BL and ML in dry leaves. Mlitan et al. (2014) reported the percentage of crude protein content, moisture, lipids, ash and carbohydrate of the leaves on dry weight basis as 9.10, 10.60, 41.3, 50.35, 10.08 percent, 9.80, 10.40, 11.0, 14.5, 52.45 percent and 9.22, 10.60, 22.55, 13.19, 11.16 percent, respectively in the leaves of *Ocimum gratissinum* from three different locations in Misurata region.

Vitamin and Mineral Content

The ascorbic acid content in herbs ranged from 10.25-28.34 mg/100g in dried leaves (Table 2). Percent decrease in ascorbic acid content was seen after drying. It was twenty nine, thirty three and twenty seven percent in BL, ML and DL, respectively. Vitamin C content of DL was significantly ($p<0.05$) higher than BL and ML in dry leaves.

DL had higher content of β-carotene that is, 8100.50 µg/100g in dried leaves followed by ML that is, 5259.0 µg/100g and DL that is, 3229.01 µg/100g, respectively. The percent increase after drying was fourteen, fourteen and sixteen percent in BL, ML and DL, respectively. Seshadri and Nambiar (2003) reported 660 mg per 100g in sundried drumstick leaves. β-carotene content of mint was reported to be 1565 and 10260 µg per 100g in fresh weight and dry matter basis, respectively by Lakshmi and Vimala (2000). Calcium content of herbs ranged from 240.12-422.20 mg/100g in dried leaves (Table 2). Calcium content of dried BL, ML and DL was 1380.12, 1155.01 and 1998.20 mg/100g, respectively. Percent increase in calcium content after drying in BL, ML and DL was twenty five, twenty four and twenty three percent, respectively. The soluble calcium content varied from 100.00-199.00 mg per 100g in dry herbs. Percent increase after drying was twenty five, twenty nine and twenty four percent in BL, ML and DL, respectively. Calcium content of DL was significantly ($p<0.05$) higher than BL and ML in dry leaves.

Iron content of leaves of dried herbs ranged from 5.15-11.70 mg/100g. It was maximum in ML that is, 11.70 mg/100g followed by DL that is, 6.65 mg/100g and BL that is, 5.15 mg/100g in dried forms. The percent increase after drying was twenty-four, twenty-two and twenty-five percent in BL, ML and DL, respectively. The soluble iron content ranged from 2.60-5.13 mg per 100g in dry herbs. The percent increase after drying was twenty four to twenty five percent. Iron content of ML was significantly ($p<0.05$) higher than BL and DL in dry leaves. Eric (2013) reported that about forty two percent iron was retained in oven-dried leaves of basil as compared to twenty two percent of microwave dried leaves. Zinc content was found to be 1.08, 0.98 and 0.89 mg/100g in dried leaves of basil, mint and drumstick, respectively. Percent increase in zinc content was same that is, twenty four percent. The soluble zinc content of dry herbs ranged from 0.34-0.49 mg per 100g, respectively which increased in the range of twenty five to

twenty six percent as compared to the fresh leaves.

Mlitan et al. (2014) reported that the percentages of minor mineral elements content were 0.98 to 4.35 mg/100g from iron, 10.44 to 17.72 mg/100g from zinc in the leaves of *Ocimum gratissinum* from three different locations in Misurata region. Eric (2013) reported that oven dried leaves contained more iron than in other dried basil leaves. About forty two percent (wt) of iron was retained in the oven-dried leaves compared with twenty two percent (wt.) for microwave dried leaves.

Anti-nutritional Factors

Phytate content of dried leaves of basil, mint and drumstick was 63.26, 67.43 and 143.28 mg/100g, respectively as shown in Table 2. Percent increase in phytate content herbs after drying was maximum in ML (29) followed by BL (27) and DL (26).

Oxalate content of dried herbs ranged from 70.57-134.11 mg/100g, respectively. Phytate and oxalate content of DL was significantly ($p<0.05$) higher than BL and ML in dried form. There was twenty percent increase in the oxalate content of all the three dried herbs as compared to fresh herbs.

Bioactive Compounds

As evident from Table 2, total phenol in dried leaves of herbs ranged from 56.65-120.40 mg GAE/100g. Percent increase after drying was forty eight, forty nine and forty six percent in BL, ML and DL, respectively. Total phenol content of BL was significantly ($p<0.05$) higher than ML and DL in dry leaves. Padma and Anita (2005) found 5-60 mg/100g total phenol in drumstick leaves. Saini et al. (2014) analysed nutritionally important phytoconstituents and feasible commercially used dehydration method to preserve these in dehydrated leaves of *M. oleifera* and reported high amounts of total phenolic content (512.0 mg/100 g FW) in leaves. Flavonoid content of herbs ranged from 3168.19-4525.94 mg/100g in dried leaves, whereas that of flavonoid content of fresh BL, ML and DL was 2168.19, 4525.94 and 2893.48 mg/100g, respectively leading to an increase of forty three to forty five percent after drying. Flavonoids content of ML was significantly ($p<0.05$) higher than BL and DL in dry leaves.

Total antioxidant activity as analysed by DPPH ranged from 628.08-766.03 mg TE/100g in dried leaves of the herbs analysed under study. DPPH content of basil, mint and drumstick leaves were 425.98, 650.68, 766.03 and 628.08 mg TE/100g in dried leaves, respectively. Percent increase in DPPH content after drying was fifty two, fifty four and forty nine percent in BL, ML and DL, respectively. DPPH content of ML was significantly ($p<0.05$) higher than BL and DL in dry leaves. ABTS content of BL, ML and DL ranged from 15.09-27.27 mg TE/100g in dried form. Percent increase after drying was maximum in BL (54%) followed by ML (50%) and DL (49%). ABTS content of DL was significantly ($p<0.05$) higher than BL and ML in dried leaves.

Antioxidant activity done by FRAP for basil, mint and drumstick was found to be 213.49, 169.23 and 266.12 mg TE/100g in dried leaves, respectively. Percent increase was fifty, fifty one and fifty two in BL, ML and DL, respectively, when compared to the fresh leaves. FRAP content of DL was significantly ($p<0.05$) higher than BL and ML in dry leaves. RPA value for dried herbs ranged from 1014.17-1221.10 mg TE/100g, respectively. RPA of basil, mint and drumstick leaves was 1014.17, 1221.10 and1116.45 mg TE/100g in dried form, respectively. Percent increase in RPA after drying was maximum in DL (52%) followed by ML (51%) and ML (50%). RPA content of ML was significantly ($p<0.05$) higher than BL and DL in dry leaves.

CONCLUSION

It was concluded that drying of herbs led to significant increase in proximate composition except moisture, in bioactive compounds, in mineral content and β-carotene, while a decrease in vitamin C and moisture content was also observed. Maximum percent increase of phytate content was found in drumstick leaves followed by basil leaves and mint leaves after drying.

RECOMMENDATIONS

Vacuum drying of herbs led to increase in ash, fibre, minerals and bioactive components content. It can be recommended that vacuum drying which is done at lower temperature and pressure can result in products of better quality due to less shrinkage of the product and hence more retention of nutrients.

REFERENCES

AACC 1995. *Approved Methods of American Association of Cereal Chemists Method.* St. Paul, Minnesota, USA: The Association. pp. 14-50.

Abeza RH, Black JT, Fischer EJ 1968. Oxalates determination: Analytical problems encountered with certain plant species. *J Assoc Off Analyt Chem,* 51: 853-855.

AOAC 2000. *Official Methods of Analysis.* Gaithersburg, Maryland, USA: Association of Official Analytical Chemists.

Bedi R 2004. *Development of Recipes to Enhance the Bioavailability of Iron from Mungbean (Vigna Radiate).* MSc Thesis. Ludhiana: Punjab Agricultural University.

Benzie IF, Strain JJ 1999. Ferric acid reducing/antioxidant power assay: Direct measure of total antioxidant activity of biological fluids and modified version for simultaneous measurement of total antioxidant power and ascorbic acid concentration. *Methods in Enzymology,* 299: 15-27.

Brand-Williams W, Cuvelier ME, Berset CLWT 1995. Use of a free radical method to evaluate antioxidant activity. *Food Science and Technology,* 28: 25-30.

Choudhury RP, Kumar A, Garg AN 2006. Analysis of Indian mint (*Mentha spicata*) for essential, trace and toxic elements and its antioxidant behaviour. *J Pharmacy Biochem Analy,* 41: 825-832.

Crivelli G, Nani RC, Di Cesare LF 2002. Influence of processing on the quality of dried herbs. *Giornate Scientifiche,* 2: 463-464.

Díaz-Maroto MC, Pérez-Coello MS, Cabezudo MD 2002. Effect of different drying methods on the volatile components of parsley (*Petroselinum crispum L.*). *Eur Food Res Tech,* 215: 227-230.

Eric DB 2013. Effect of drying methods on nutrient quality of basil (*Ocimum viride*) leaves cultivated in Ghana. *Intern Food Res J,* 20: 1569-1573.

Fahey JW 2005. *M. oleifera*: A review of the medical evidence for its nutritional, therapeutic and prophylactic properties. Part 1. *Trees for Life Journal: A Forum on Beneficial Trees and Plants,* 1: 5.

Gatade AA, Ranveer RC, Sahoo AK 2013. Nutritional analysis, total phenolic content, free radical scavenging activity and phytochemical analysis of leaves powder of *Moringa oleifera* (drumstick) and *Cicer arietinum* (chick pea). *Int J Pharm Bio Sci,* 4(3): 922-933.

Gopalan C, Ramasastri BV, Balasubramaniam 2017. *Nutritive Value of Indian Foods.* Hyderabad: National Institute of Nutrition, Indian Council of Medical Research.

Haung W, Lantzsch HT 1983. Sensitive method for rapid determination of phytate in cereals and cereals products. *J Sci Fd Agric,* 34: 1423-1425.

Justesen U, Knuthsen P 2001. Composition of flavonoids in fresh herbs and calculation of flavonoid intake by use of herbs in traditional Danish dishes. *Food Chem,* 73: 245-250.

Kowsalya S, Vidhya MR 2004. Nutritive value of selected dehydrated green leafy vegetables. *Ind J Nutr Dietet,* 41: 279-286.

Lakshmi B, Vimala V 2000. Nutritive value of dehydrated green leafy vegetable powders. *J Food Sci Tech,* 37: 465-471.

Liu J, Dietz T, Carpenter SR, Folke C, Alberti M, Redman CL, Schneider SH, Ostrom E, Pell AN, Lubchenco J, Taylor WW, Ouyang Z, Deadman P, Kratz T, Provencher W 2007. Coupled human and natural systems. *Ambio,* 36: 639-649.

Mimica-Dukic N, Bozin B 2008. *Mentha L.* species (*lamiaceae*) as promising sources of bioactive secondary metabolite. *Curr Pharm Des,* 14: 3141-3150.

Mishra P, Bhatt DK 2017. Optimisation of food supplement for development of nutritious pasta by utilizing tulsi powder. *J Environ Sci Toxic Food Technol,* 11: 1-6.

Mlitan AM, Sasi MS, Alkherraz AM 2014. Proximate and minor mineral content in some selected basil leaves of *Ocimum gratissimum L* in Libya. *Intern J Chem Engineer Applica,* 5: 502-505.

Oyaizu M 1986. Studies on products of browning reaction: Antioxidative activities of products of browning reaction prepared from glucosamine. *Japnese J Nutr,* 44: 307-315.

Padma PR, Anita R 2005. Effect of heat on antioxidant status of selected green leafy vegetables. *Ind J Nutr Dietet,* 42: 248-258.

Piper CS 1950. *Soil and Plant Analysis.* New York: Interscience Publication Inc.. pp. 212-215.

Re R, Pellegrini N, Proteggente A, Pannala A, Yang M, Rice-Evans C 1999. Antioxidant activity applying an improved ABTS radical cation decolorization assay. *Free Radical Biology and Medicine,* 26: 1231-1237.

Saini RK, Shetty NP, Prakash M, Giridhar P 2014. Effect of dehydration methods on retention of carotenoids, tocopherols, ascorbic acid and antioxidant activity in *Moringa oleifera* leaves and preparation of a RTE product. *J Food Sci Technol,* 51: 2176-2182.

Seshadri S, Nambiar VS 2003. Kanjero (*Digera Arvensis*) and drumstick leaves (*Moringa oleifera*): Nutrient profile and potential for human consumption. *Plants Hum Health Nutr Policy,* 91: 41-59.

Singleton V, Orthofer R, Lamulea-Raventos RM 1999. Colorimetry of total phenolics with phosphomolybdic phototungstic acid reagents. *Am J Enol Vitic,* 16: 144-158.

Tadhani MB, Patel VH, Subhash R 2009. *In vitro* antioxidant activities of *Stevia rebaudiana* leaves and *callus*. *J Food Composition and Analysis,* 20: 323-329.

Tete-Benissan A, Quashie MLA, Lawson-Evi K, Kokou K, Gbeassor M 2012. Nutritional recovery of HIV positive and HIV negative undernourished patients utilizing *Moringa oleifera* leaves. *J Anim and Plant Sci,* 15: 2184-2199.

Zheng W, Wang SY 2001. Antioxidant activity and phenolic compounds in selected herbs. *J Agri Fd Chem,* 49(11): 5165-5170.

Zhishen J, Mengcheng T, Jianming W 1999. The determination of flavonoid contents in mulberry and their scavenging effects on superoxide radicals. *Food Chemistry,* 64(4): 555-559.

Paper received for publication on July 2018
Paper accepted for publication on February 2019