

VITAMIN AND PROVITAMIN PROFILES OF SELECTED VEGETABLES AS AFFECTED BY STORAGE AND DIFFERENT DRYING METHODS

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Abstract: Effects of drying methods on the vitamin and provitamin compositions of selected vegetables during storage were assessed in this study. *Telfaria occidentalis*, *Celosia argentea* (green), *Vernonia amygdalina*, *Moringa oleifera*, *Launaea taraxacifolia*, *Curcubita maxima* and *Celosia argentea* (red) were subjected to air drying (AD), oven drying (OD) and freeze drying (FD). The experiment was a 3x7 factorial arrangement in a completely randomized design. Dried leaves were milled and assayed for vitamins (pyridoxine, riboflavin, ascorbic acid and tocopherol) and provitamins (total carotene and ergocalciferol). Samples were stored in opaque airtight containers after drying and assayed periodically at weeks 0, 3, 6, 9, 12, 15 and 18 of storage. Air-dried samples had significantly higher ($P<0.05$) total carotene (1177.49 $\mu\text{g}/100\text{g}$), pyridoxine (0.59 mg/100g), riboflavin (0.46 mg/100g), ascorbic acid (39.11 mg/100g), ergocalciferol (46.55 $\mu\text{g}/100\text{g}$) and tocopherol (57.52 $\mu\text{g}/100\text{g}$) compared with samples dried by other methods. *Moringa oleifera* leaf type had significantly higher ($P<0.05$) total carotene (1079.48 $\mu\text{g}/100\text{g}$), riboflavin (0.41 mg/100g), ergocalciferol (46.40 $\mu\text{g}/100\text{g}$) and α -tocopherol (58.45 $\mu\text{g}/100\text{g}$) while *Cucurbita maxima* had significantly higher ($P<0.05$) pyridoxine (0.73 mg/100g). Effects of the interaction of drying methods and leaf type were significant ($P<0.05$) on the vitamin and provitamin compositions of samples. The effect of the interaction of the oven drying method and leaf type was highly significant ($P<0.05$) on inherent vitamin and provitamin of samples. Vitamin and provitamin compositions of samples were stable until week six. Air-dried samples contained more vitamins and provitamins which were also more retained in storage.

Key words: dried leaves, phytonutrient profile, vitamin/provitamin assays, drying methods, storage duration.

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Introduction

Green vegetables are a rich source of nutrients for animals (Rickman et al., 2007). In an environment where there is the increasing challenge of getting alternative feedstuffs, there is a need to explore ways of preserving green vegetables which are ubiquitous and often available all year round (Voster Ineke et al., 2007). Drying is a method that provides a simple manageable way of preserving leafy vegetables. Freeze drying was initially proposed as the best method of preserving local green vegetables, but Lee and Labuza (1975) reported that this method heavily reduced the levels of ascorbic acid in the vegetables. There are several communities in the developing world where freezers are not available, so the drying method that will be adopted should be the one that offers good potential by ensuring that nutrients can be preserved as much as possible.

Leafy vegetables contain vitamins and minerals which could contribute greatly to dietary provision for normal growth and protection against diseases (Achikanu et al., 2013). Phytonutrient-rich leafy vegetables and plants are available in the tropics (Akoroda, 1990; Oluwole et al., 2003; Achikanu et al., 2013) with viable potentials as dietary sources of vitamins and minerals. One of the main limitations to the use of green leaves as alternative nutritional additive for livestock and poultry is the innate moisture content and the challenges of its removal without damaging the valuable phytochemicals.

Most green vegetables are seasonal, and drying methods help in their preservation by reducing the high moisture contents (Naikwade et al., 2012). The consideration of the effects of drying methods are, therefore, very crucial because of their critical implications on phytonutrients and the residual phytochemicals of dried leaves, as well as the stability of the nutrients.

There is scanty information on the retention of vitamins by plants and green leafy vegetables when subjected to different drying methods and also how long the retained vitamins and provitamins would remain stable in storage. This research was therefore aimed at evaluating the effects of three different drying methods on vitamin and provitamin profiles of seven different vegetable leaves, as well as the stability of their inherent nutrients during storage.

Materials and Methods

The experiment was carried out at the Central Laboratory, Department of Animal Science, University of Ibadan, Ibadan, Nigeria. Seven vegetables assessed were: fluted pumpkin (*Telfairia occidentalis*); African wild lettuce (*Launaea taraxacifolia*); African spinach – green (*Celosia argentea*); gourd melon pumpkin (*Curcubita maxima*); African spinach – red (*Celosia argentea*); moringa leaves

(*Moringa oleifera*) and bitter leaf (*Vernonia amygdalina*). Freeze drying, air drying and oven drying at 55 °C were the methods of drying.

Freeze drying: Fresh leaves were plucked at six weeks of plant growth or regrowth in the case of moringa. The leaves were separated from the stems of plant samples, washed with de-ionised water and drained before storing in a freezer at 20°C before transfer to a freeze dryer. Freeze-dried samples were ground to fine powder for immediate analyses. The portion of the freeze-dried sample was stored in an opaque airtight container and analysed at weeks 3, 6, 9, 12, 15 and 18, respectively. All analyses were done in triplicate.

Oven drying: Fresh leaves were plucked at six weeks of plant growth or regrowth in the case of moringa. Leaf samples were cleaned with de-ionised water, drained, weighed and placed in the Gallenkamp BS 300 electric oven with the fan automatically regulated and the temperature set at 55°C. Samples were turned at eight-hour intervals until dried to a constant weight which was achieved at 18 hours of drying. The leaves were then put in a desiccator and reweighed after cooling before grinding to fine powder for immediate analyses. The sample was thereafter stored in an opaque airtight container and analysed at weeks 3, 6, 9, 12, 15 and 18, respectively. All analyses were done in triplicate.

Air drying: Fresh leaves were plucked at six weeks of plant growth or regrowth in the case of moringa. Leaf samples were cleaned with de-ionised water, drained, blotted dry with absorbent paper and spread inside perforated plastic trays placed indoors on tables to dry at room temperature to a constant weight while turning the samples regularly at six-hour intervals for a total period of 72 hours. The leaves were then weighed and milled to powder for analyses at once. The sample was thereafter stored in an opaque airtight container and analysed at weeks 3, 6, 9, 12, 15 and 18, respectively. All analyses were done in triplicate.

The phytochemical assay for total carotene pyridoxine, riboflavin, ascorbic acid, tocopherol and ergocalciferol in the samples was conducted according to AOAC (2000).

Data analyses

Data were subjected to analysis of variance (SAS 2000) and means were separated at $\alpha_{0.05}$ using the Duncan's option of the same software.

Results and Discussion

The main effects of drying methods on vitamin and provitamin indices are shown in Table 1. There were significant variations ($P < 0.05$) in vitamin and provitamin profiles of the vegetables due to different drying methods. The air drying method had the least effect on residual phytochemicals with significantly higher ($P < 0.05$) levels of 1177.49 $\mu\text{g}/100\text{g}$ total carotene, 0.59 $\text{mg}/100\text{g}$

pyridoxine, 0.46 mg/100g riboflavin, 39.11 mg/100g ascorbic acid, 46.55 µg/100g ergocalciferol and 57.52 µg/100g α-tocopherol. The highest impact on vitamin and provitamin parameters was observed in oven-dried samples with significantly lower ($P<0.05$) compositions of 936.97 µg/100g total carotene, 0.39 mg/100g pyridoxine, 0.22 mg/100g riboflavin, 23.06 mg/100g ascorbic acid, 35.42 µg/100g and 44.07 µg/100g α-tocopherol. This observation was in agreement with reports that the air drying method preserved higher amounts of vitamins in green leafy vegetables (Lakshi and Vimala, 2000; Krokida and Maroulis, 2007; Saga and Suresh, 2010; Naikwade, 2014), but was contrary to the report of Negi and Roy (2000) that oven drying at low temperature had the least effect on the innate nutrient composition of vegetables. The report from this study is also in agreement with the findings of Kiremire et al. (2010) that oven drying caused higher nutrient losses.

The freeze drying method was earlier reported (Krokida and Maroulis, 2007) to cause higher porosity in freeze-dried plant materials than air drying which may be the reason for its higher impact on inherent nutrients compared with air drying. The loss of crispness of vegetables and their nutrients when freeze-dried was documented (Onayemi and Badifu, 1987). This was attributed to freeze-thaw damage syndrome which has the largest impact on the loss of inherent nutrients. Findings in this study were also at variance with those of Oladele and Aborisade (2009) that air drying resulted in the greatest loss of ascorbic acid in vegetables. The levels of 40.097mg/100g ascorbic acid in *Telfaria occidentalis* in this study was higher than 35.97 mg/100g documented by Ukegbu and Okereke (2013) in *Vernonia amygdalina*. The observations for other phytochemicals conformed to the findings of Nangula et al. (2010) although the riboflavin content obtained in this study was higher.

Table 1. The main effect of drying methods on the vitamin composition of dried vegetable leaves.

Drying method	Total carotene (µg/100g)	Pyridoxine (mg/100g)	Riboflavin (mg/100g)	Ascorbic acid (mg/100g)	Ergocalciferol (µg/100g)	Tocopherol (µg/100g)
Air drying	1177.49 ^a	0.59 ^a	0.46 ^a	39.11 ^a	46.55 ^a	57.52 ^a
Oven drying	936.97 ^c	0.39 ^c	0.22 ^c	23.06 ^c	35.42 ^c	44.07 ^c
Freeze drying	971.37 ^b	0.56 ^b	0.39 ^b	34.18 ^b	44.79 ^b	53.38 ^b
SEM	3.50	0.01	0.004	0.24	0.26	0.24

Means with different superscripts in the same columns are significantly different ($P<0.05$); SEM – Standard error of the means.

Findings in this study showed that air drying was the least invasive method out of the three methods of drying. Although the freeze drying method was conducted also at a very low temperature, the effect of freezing and moisture extraction would cause leaves to break and become porous, resulting in higher losses of the inherent nutrients. Vitamins in naturally sourced materials such as green leafy vegetables are highly labile and heat sensitive (Sablani, 2006). The subjection of vegetable leaves to heat at a temperature as low as 55°C will still affect the inherent vitamins, leading to significant losses as observed in this study. Sablani (2006) earlier reported that drying of vegetables nowadays was not only based on prolonging shelf life, but also on the retention of the nutritive value and flavour.

The main effect of leaf type on vitamin and provitamin parameters is shown in Table 2. *Cucurbita maxima* had the highest ($P<0.05$) level of pyridoxine with 0.73 mg/100g and the least was 0.38 mg/100g in *Celosia argentea* (green), which was significantly lower than 0.52 mg/100g in red *Celosia argentea*. *Moringa oleifera* (0.42 mg/100g pyridoxine, 0.41 mg/100g riboflavin, 39.61 mg/100g ascorbic acid, 58.45 µg/100g α-tocopherol, 1079.48 µg/100mg total carotene and 46.40 µg/100g ergocalciferol) and *Vernonia amygdalina* (0.46 mg/100g pyridoxine, 0.40 mg/100g riboflavin, 38.68 mg/100g ascorbic acid, 47.33 µg/100g α-tocopherol, 1072.70 µg/100mg total carotene and 47.02 µg/100g ergocalciferol) had the overall highest ($P<0.05$) retention of vitamin and provitamin contents among leaf types.

Table 2. The main effect of leaf type on the vitamin composition of dried vegetable leaves.

Vitamin parameters	TO	CA (green)	VA	MO	LT	CM	CA (red)	SEM
Pyridoxine (mg/100g)	0.54 ^b	0.38 ^f	0.46 ^d	0.42 ^e	0.55 ^b	0.73 ^a	0.52 ^c	0.01
Riboflavin (mg/100g)	0.36 ^c	0.38 ^b	0.40 ^a	0.41 ^a	0.26 ^e	0.29 ^d	0.26 ^c	0.01
Ascorbic acid (mg/100g)	40.10 ^a	32.35 ^c	38.68 ^b	39.61 ^a	23.81 ^e	26.10 ^d	24.18 ^e	0.36
α-Tocopherol (µg/100g)	50.06 ^d	52.63 ^c	47.33 ^f	58.45 ^a	55.03 ^a	48.17 ^e	49.96 ^d	0.37
Total carotene (µ/100g)	1059.45 ^b	1056.11 ^b	1072.70 ^a	1079.48 ^a	982.44 ^c	958.14 ^d	991.96 ^c	5.34
Ergocalciferol (µ/100g)	40.66 ^c	39.93 ^c	47.02 ^a	46.40 ^a	41.70 ^b	38.25 ^d	41.82 ^b	0.40

Means with different superscripts along the same row are significantly different ($P<0.05$). SEM – Standard error of the means; TO – *Telfaria occidentalis*; CA(g) – *Celosia argentea* green variety, VA – *Vernonia amygdalina*, MO – *Moringa oleifera*, CM – *Cucurbita maxima*, CA (red) – *Celosia argentea* red.

The green *Celosia argentea* had significantly higher ($P < 0.05$) total carotene, riboflavin, ascorbic acid and tocopherol compared with the red variety which contained higher ($P < 0.05$) pyridoxine and ergocalciferol only. The total carotene of 958.14 $\mu\text{g}/100\text{g}$ in *Cucurbita maxima* was lower than 13520 $\mu\text{g}/100\text{g}$ as reported by Sahabi et al. (2012). The 32.35 mg/100g ascorbic acid in *Celosia argentea* (green) was lower than 42.1 mg/100g as reported by Mensah et al. (2008).

Leaf type as well as the drying method affected vitamin and provitamin compositions of vegetable leaves. This is in agreement with the findings of Oduro et al. (2008) that the nutrient composition of *Moringa oleifera* leaves differed significantly from that of *Ipomoea batatas*. The differences observed in this study may be due to differences in the species of the selected vegetables. The differences in variety where the leaves were of similar species were also implicated in the differences observed in this study. This observation is particularly true for the two varieties of *Celosia argentea* which had significant differences ($P < 0.05$) in their inherent vitamin and provitamin compositions. Oduro et al. (2008) also reported differences in the nutrient composition of seven different varieties of *Ipomoea batatas* leaves. The findings in this study strongly indicate that different varieties of the same species of vegetable would not connote the same nutrient content.

Effects of the interaction of drying methods and leaf type on vitamin and provitamin compositions of the selected vegetable leaves are shown in Table 3. The inherent vitamin and provitamin profiles significantly varied ($P < 0.05$) with the method of drying. *Cucurbita maxima* contained 0.91 mg/100g, 0.84 mg/100g and 0.43 mg/100g pyridoxine in freeze-, air- and oven-dried samples, respectively. Most of the samples followed this trend with significant differences in their vitamin and provitamin compositions as a result of the different drying methods. However, α -tocopherol compositions in air- and freeze-dried *Telfaria occidentalis* were similar ($P > 0.05$) to 55.28 and 54.75 $\mu\text{g}/100\text{g}$, respectively. Effects of the interaction of drying methods and leaf type also resulted in similar ($P > 0.05$) composition of ergocalciferol in air-dried *T. occidentalis* (44.48 $\mu\text{g}/100\text{mg}$), and green *C. argentea* (44.98 $\mu\text{g}/100\text{mg}$) freeze-dried *T. occidentalis* (43.94 mg/100g) and air-dried *Cucurbita maxima* (45.81 mg/100g) significantly differed ($P < 0.05$) from each other, but both were also similar ($P > 0.05$) to air-dried *T. occidentalis* and green *C. argentea*. Riboflavin concentration was higher ($P < 0.05$) in air-dried *Telfaria occidentalis* (0.56 mg/100g) compared with other treatments. The observation differed in *Launea taraxacifolia* where higher riboflavin concentration ($P < 0.05$) was 0.43 mg/100g in freeze-dried samples and lower ($P < 0.05$) 0.20 and 0.17 mg/100g were found in air- and freeze-dried *L. taraxacifolia*, respectively.

Table 3. Effects of interaction of drying methods and leaf types on vitamin and provitamin indices of selected leafy vegetables.

DM	LT	Pyridoxine (mg/100g)	Riboflavin (mg/100g)	Ascorbic acid (mg/100g)	α -tocopherol (μ g/100g)	Total carotene (μ g/100g)	Ergocalciferol (μ g/100g)
AIR DRYING	1	0.79 ^c	0.56 ^a	45.09 ^a	55.28 ^d	1238.78 ^b	44.48 ^{ei}
	2	0.41 ^{ml}	0.52 ^b	42.56 ^b	58.54 ^c	1219.07 ^c	44.98 ^{ef}
	3	0.55 ^g	0.50 ^b	44.62 ^a	55.49 ^d	1264.78 ^a	51.82 ^b
	4	0.42 ^{kl}	0.51 ^b	45.43 ^a	62.01 ^a	1239.42 ^b	51.07 ^b
	5	0.51 ^h	0.20 ⁱ	20.14 ^j	60.54 ^b	928.86 ^{fgh}	47.58 ^d
	6	0.84 ^b	0.44 ^c	37.37 ^f	59.36 ^{bc}	1129.54 ^d	45.81 ^e
	7	0.61 ^f	0.45 ^c	38.58 ^{def}	51.43 ^f	1122.04 ^{bc}	40.14 ^h
OVEN DRYING	1	0.47 ^{ij}	0.32 ^g	34.13 ^g	40.15 ⁱ	994.69 ^e	33.56 ^k
	2	0.35 ^{op}	0.31 ^g	15.82 ^l	44.23 ^h	1007.97 ^e	32.53 ^{kl}
	3	0.38 ^{mn}	0.32 ^{fg}	33.95 ^g	36.64 ^j	1008.96 ^e	41.03 ^{gh}
	4	0.34 ^p	0.34 ^f	34.44 ^g	53.09 ^e	999.96 ^e	38.57 ⁱ
	5	0.45 ^{kj}	0.17 ^j	17.09 ^l	49.52 ^g	886.56 ⁱ	35.08 ^j
	6	0.43 ^{kl}	0.03 ^l	14.69 ^l	44.74 ^h	831.00 ^j	35.33 ^j
	7	0.29 ^q	0.07 ^k	11.30 ^m	40.15 ⁱ	829.65 ^j	31.82 ^l
FREEZE DRYING	1	0.37 ^{no}	0.21 ^l	41.07 ^c	54.75 ^d	944.91 ^f	43.94 ^f
	2	0.36 ^{no}	0.31 ^g	38.66 ^{de}	55.11 ^d	941.30 ^{fg}	42.29 ^g
	3	0.46 ^j	0.38 ^e	34.48 ^{ef}	49.87 ^g	944.35 ^f	48.23 ^{cd}
	4	0.49 ^{hi}	0.38 ^e	41.06 ^d	60.24 ^b	999.07 ^e	49.55 ^c
	5	0.70 ^d	0.43 ^{cd}	34.19 ^g	55.03 ^d	1131.92 ^d	42.43 ^g
	6	0.91 ^a	0.41 ^d	26.25 ^h	40.41 ⁱ	913.87 ^h	33.61 ^k
	7	0.66 ^e	0.25 ^h	22.67 ⁱ	58.29 ^c	924.20 ^{gh}	53.50 ^a
SEM		0.02	0.01	0.63	0.64	9.26	0.70

Means with different superscripts along the same column are significantly different ($P < 0.05$); SEM – Standard error of the means, 1 – *Telfaria occidentalis*, 2 – *Celosia argentea* (green), 3 – *Vernonia amygdalina*, 4 – *Moringa oleifera*, 5 – *Launea taraxacifolia*, 6 – *Curcubita maxima*, 7 – *Celosia argentea* (red); DM – Drying methods, LT – Leaf type.

Observations so far from this study support the earlier reports (Kiremire et al., 2010; Ukegbu and Okereke, 2013) that oven drying results in more significant loss of inherent vitamin and provitamin contents compared with air or freeze drying. It also corroborates the assertion that the air drying method had the least destructive effect on inherent nutrients in most of the vegetable leaves.

The effect of the relationship between drying methods and duration of storage on the pyridoxine composition of samples is shown in Figure 1. The regression curve indicated that the optimum levels of 0.59 and 0.39 mg/100g pyridoxine were in air-dried and oven-dried samples at week six, respectively. Prolonged storage resulted in significant reductions in the pyridoxine content of samples from week nine. In Figure 1, freeze-dried samples with 0.57 mg/100g pyridoxine at week 6 declined to 0.24 mg/100g at week 18 of storage. The effect of the drying methods during storage on pyridoxine compositions resulted in the expressed quadratic equations 1, 2 and 3 below with the highly significant and positive R^2 values of

0.9969, 0.9785 and 0.9898, respectively. It was surmised that the levels of pyridoxine composition were strongly dependent on the duration of storage irrespective of the drying method used.

$Y = -0.0123x^2 + 0.0469x + 0.5517$ ($R^2 = 0.9969$) (air-dried samples) (1)

$Y = -0.0094x^2 + 0.0234x + 0.5574$ ($R^2 = 0.9785$) (freeze-dried samples) (2)

$Y = -0.0081x^2 + 0.021x + 0.3768$ ($R^2 = 0.9898$) (oven-dried samples) (3)

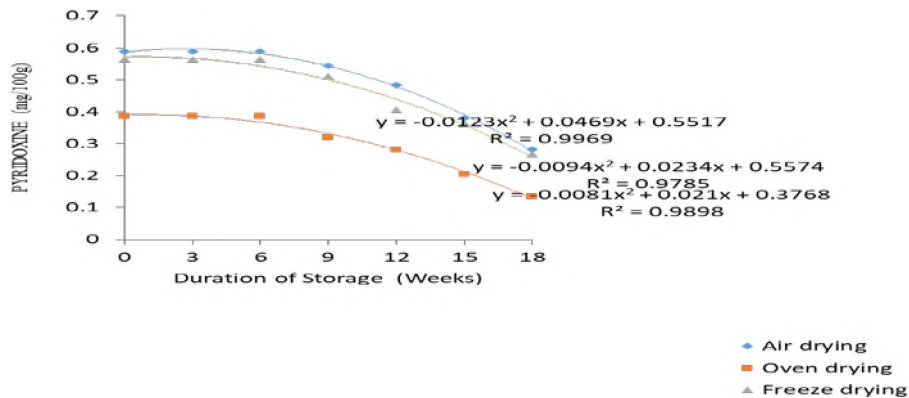


Figure 1. The effects of the relationship between drying methods and storage duration on the pyridoxine composition (mg/100g) of selected leaves.

The effect of the relationship between storage duration and drying methods on the riboflavin composition of vegetable is shown in Figure 2. The regression curves show that optimum concentrations of 0.47, 0.35 and 0.24 mg/100g riboflavin were attained at week six from air-, freeze- and oven-dried samples, respectively. Longer duration beyond week six of storage significantly reduced ($P < 0.05$) the riboflavin concentration of dried samples. The determination factors (R^2) are shown in Equations 4, 5 and 6 below:

$Y = -0.0082x^2 + 0.0271x + 0.4386$ ($R^2 = 0.9711$) (air-dried samples) (4)

$Y = -0.0049x^2 + 0.0091x + 0.3407$ ($R^2 = 0.9785$) (freeze-dried samples) (5)

$Y = -0.0034x^2 + 0.004x + 0.2263$ ($R^2 = 0.9729$) (oven-dried samples) (6)

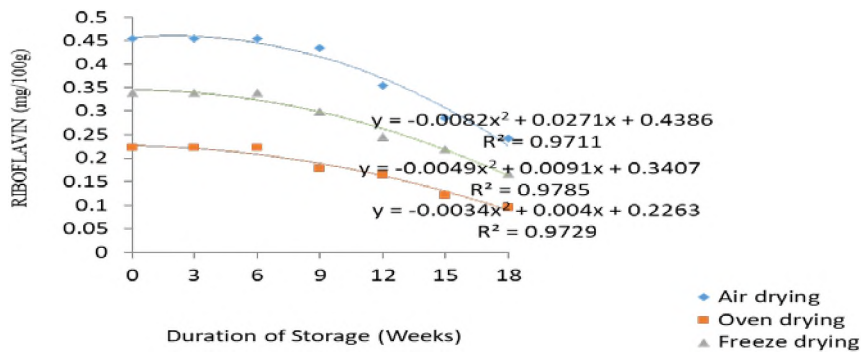


Figure 2. The effects of the relationship between storage duration and drying methods on the riboflavin composition of leaves (mg/100g).

The ascorbic acid compositions of selected vegetable leaves as affected by the drying methods in the duration of storage are shown in Figure 3. An optimum concentration of 36 mg/100g ascorbic acid was observed in freeze-dried leaves.

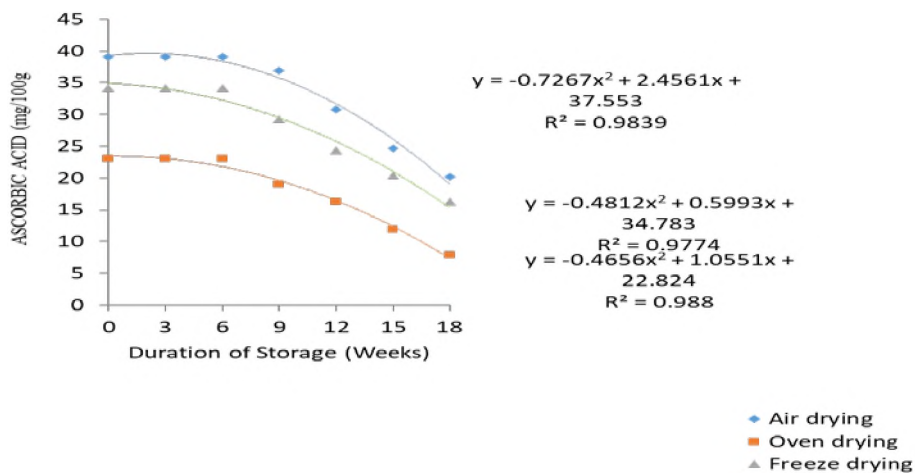


Figure 3. The effects of the relationship between drying methods and storage duration on the ascorbic acid composition (mg/100g) of selected leaves.

The regression equations for the different drying methods indicated strong and positive relationships between the ascorbic acid composition and the storage duration. The longer the duration of storage, the more rapid the decline. The determination factors (R^2) for ascorbic acid are shown in Equations 7, 8 and 9 below:

$$Y = -0.7267x^2 + 2.4561x + 37.553 \quad (R^2 = 0.9839) \quad \text{(air-dried samples)} \quad \dots\dots\dots (7)$$

$$Y = -0.4812x^2 + 0.5993x + 34.783 \quad (R^2 = 0.9774) \quad \text{(freeze-dried samples)} \quad \dots\dots\dots (8)$$

$$Y = -0.4656x^2 + 1.0551x + 22.824 \quad (R^2 = 0.9880) \quad \text{(oven-dried samples)} \quad \dots\dots\dots (9)$$

The effects of the relationships between drying methods and duration of storage on the α -tocopherol composition of selected vegetables are shown in Figure 4. The optimal α -tocopherol compositions of 52.50, 59.00 and 0.46 $\mu\text{g}/100\text{mg}$ were obtained at week six of storage in freeze-, air- and oven-dried samples, respectively. The regression equations were highly significant ($P < 0.05$) and the relationships were quadratic for all dried samples during storage. The relationships are as shown in Equations 10, 11 and 12 below:

$$Y = -1.0156x^2 + 3.7906x + 54.736 \quad (R^2 = 0.9809) \quad \text{(air-dried)} \quad \dots\dots\dots (10)$$

$$Y = -0.7134x^2 + 0.7635x + 54.514 \quad (R^2 = 0.9731) \quad \text{(freeze-dried)} \quad \dots\dots\dots (11)$$

$$Y = -0.805x^2 + 1.5972x + 44.084 \quad (R^2 = 0.9791) \quad \text{(oven-dried)} \quad \dots\dots\dots (12)$$

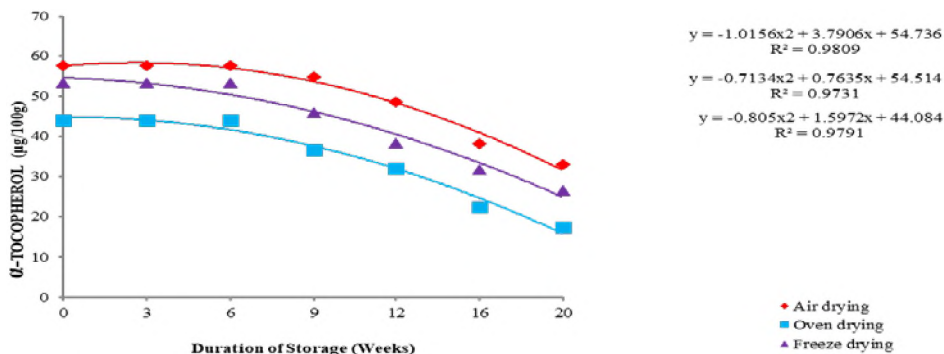


Figure 4. The effects of the relationship between storage duration and drying methods on the α -tocopherol composition ($\mu\text{g}/100\text{g}$) of selected vegetable samples.

The effects of the relationships between drying methods and duration of storage on the total carotene composition of selected vegetables are shown in Figure 5. The regression curves showed optimum concentrations of 960, 1000 and 1200 $\mu\text{g}/100\text{g}$, respectively were obtained in oven-, freeze- and air-dried samples in zero to week six of storage. A significant decline ($P < 0.05$) in the total carotene

concentration was observed as storage duration increased. Highly significant determination factors were recorded for air-dried (0.93), oven-dried (0.98) and freeze-dried (0.98) samples as shown in Equations 13, 14 and 15 below.

$$Y = -13.694x^2 + 25.945x + 1211.8 \quad (R^2 = 0.9282) \quad \text{(air-dried samples)} \quad \dots\dots\dots (13)$$

$$Y = -16.015x^2 + 37.997x + 963.28 \quad (R^2 = 0.9763) \quad \text{(air-dried samples)} \quad \dots\dots\dots (14)$$

$$Y = -17.925x^2 + 40.598x + 928.07 \quad (R^2 = 0.9847) \quad \text{(air-dried samples)} \quad \dots\dots\dots (15)$$

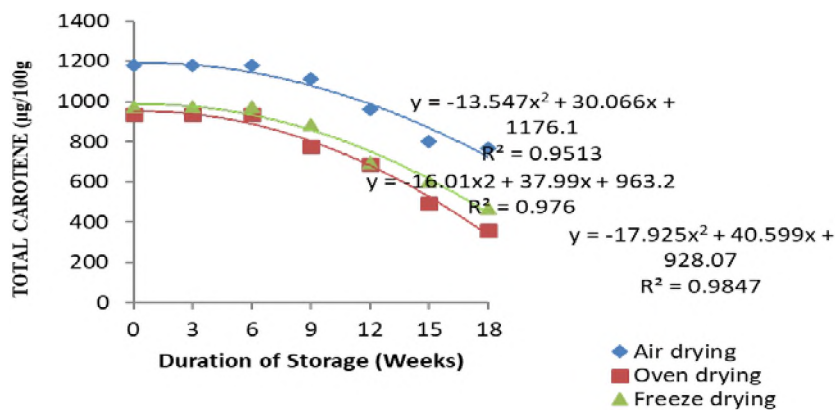


Figure 5. The effects of the relationship between drying methods and storage duration on the total carotene compositions (µg/100g) in selected vegetable samples.

The ergocalciferol compositions of selected vegetables as influenced by drying methods and duration of storage are shown in Figure 6. Longer duration of storage resulted in a significant decline of ergocalciferol from week six of storage irrespective of the drying methods. The optimal ergocalciferol concentrations of 36.03, 44.00 and 47.82 µg/100g were obtained at week six for oven-, freeze- and air-dried vegetable samples, respectively. The regression was highly significant (P<0.05) and the quadratic relationships as shown in Equations 16, 17 and 18 below indicated that ergocalciferol compositions of the stored samples diminished rapidly after week six of storage.

$$Y = -0.7273x^2 + 2.5965x + 44.768 \quad (R^2 = 0.9827) \quad \text{(air-dried samples)} \quad \dots\dots\dots (16)$$

$$Y = -0.6824x^2 + 1.3118x + 44.929 \quad (R^2 = 0.9791) \quad \text{(air-dried samples)} \quad \dots\dots\dots (17)$$

$$Y = -0.6625x^2 + 1.4476x + 35.204 \quad (R^2 = 0.9812) \quad \text{(air-dried samples)} \quad \dots\dots\dots (18)$$

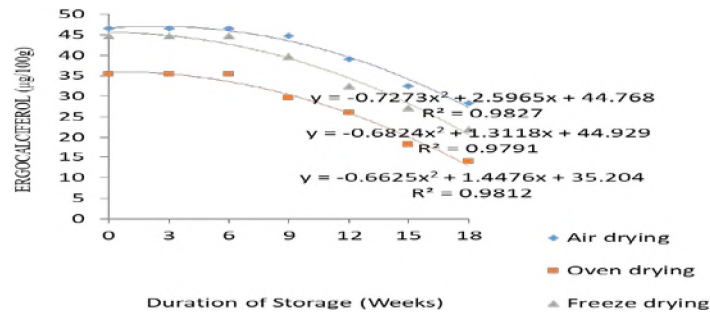


Figure 5. The effects of the relationship between storage duration and drying methods on total carotene ($\mu\text{g}/100\text{g}$).

The regression analysis showed a high level of stability for a period that is comparable with industry standards recommended for efficacy of vitamins in commercial proprietary vitamin and mineral premixes. There were significant differences ($P < 0.05$) across the board on the basis of storage. All values observed were stable for up to 9 weeks, and a decline was observed in all drying methods from week 9 at which point the samples began to lose their inherent nutrient stability. The equations highlighted for the air-, oven- and freeze-dried samples gave R^2 values which indicated strong and positive relationships, showing that vitamin and provitamin concentrations were strongly dependent on the storage period irrespective of the drying method.

Conclusion

Air, oven and freeze drying methods preserved the vitamins and provitamins of selected green vegetables. However, air drying had the least effect on the innate vitamin and provitamin of dried vegetables followed by freeze drying and the least effective method of drying for vitamin retention was oven drying. Even in storage, air drying proved the most effective in retaining the vitamins of all the selected vegetables.

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VITAMINSKI I PROVITAMINSKI PROFILI ODABRANOG POVRĆA USLOVLJENI SKLADIŠTENJEM I RAZLIČITIM METODAMA SUŠENJA

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R e z i m e

U ovom istraživanju procenjeni su uticaji metoda sušenja na vitaminski i provitaminski sastav odabranog povrća tokom skladištenja. *Telfaria occidentalis*, *Celosia argentea* (zelena), *Vernonia amygdalina*, *Moringa oleifera*, *Launaea taraxacifolia*, *Curcubita maxima* i *Celosia argentea* (crvena) bile su podvrgnute sušenju na vazduhu (engl. *air drying* – AD), sušenju u peći (engl. *oven drying* – OD) i sušenju smrzanjem (engl. *freeze drying* – FD). Ogled je bio trofaktorijalni (3x7), postavljen u potpuno slučajnom planu. Osušeni listovi su samleveni i analizirani radi utvrđivanja sastava vitamina (piridoksin, riboflavin, askorbinska kiselina i tokoferol) i provitamina (ukupni karoten i ergokalciferol). Nakon sušenja uzorci su čuvani u neprovidnim posudama koje obezbeđuju hermetičnost i ispitivani periodično u 0, 3, 6, 9, 12, 15. i 18. nedelji skladištenja. Uzorci sušeni na vazduhu imali su značajno viši ($P < 0,05$) ukupni karoten (1177,49 $\mu\text{g}/100\text{g}$), piridoksin (0,59 mg/100g), riboflavin (0,46 mg/100g), askorbinsku kiselinu (39,11 mg/100g), ergokalciferol (46,55 $\mu\text{g}/100\text{g}$) i tokoferol (57,52 $\mu\text{g}/100\text{g}$) u poređenju sa uzorcima koji su sušeni drugim metodama. Tip lista biljke *Moringa oleifera* imao je značajno viši ($P < 0,05$) ukupni karoten (1079,48 $\mu\text{g}/100\text{g}$), riboflavin (0,41 mg/100g), ergokalciferol (46,40 $\mu\text{g}/100\text{g}$) i α -tokoferol (58,45 $\mu\text{g}/100\text{g}$), dok je biljka *Cucurbita maxima* imala značajno viši ($P < 0,05$) piridoksin (0,73 mg/100g). Interakcija metoda sušenja i tipa listova značajno je imala uticaj ($P < 0,05$) na vitaminski i provitaminski sastav uzoraka. Interakcija metoda sušenja u peći i tipa listova veoma značajno ($P < 0,05$) je uticala na inherentne vitamine i provitamine u uzorcima. Vitaminski i provitaminski sastav uzoraka bili su stabilni do šeste nedelje. Uzorci sušeni na vazduhu sadržali su više vitamina i provitamina, koji su se takođe zadržali i tokom skladištenja.

Ključne reči: osušeni listovi, profil fitonutrijenata, analiza vitamina/provitamina, metode sušenja, vreme skladištenja.

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