



## **NUTRITIONAL AND PROXIMATE COMPOSITION OF SELECTED LEAFY VEGETABLES FROM SOUTH-WESTERN NIGERIA AS AFFECTED BY DIFFERENT DRYING METHODS**

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### **Abstract**

Leafy vegetables are important in most of the daily diets of man and can be used to alleviate nutrient deficiencies. This study investigated the effect of different drying methods on the nutritional and proximate quality of five selected leafy vegetables commonly eaten in dry form in South-Western Nigeria, to identify the best drying method for nutrient retention. Fresh samples of *Talinum triangulare* (waterleaf), *Vernonia amygdalina* (bitterleaf), *Amaranthus viridis* (green amaranth), *Telfairia occidentalis* (fluted pumpkin) and *Corchorus olitorius* (jute mallow) were subjected to four commonly used drying methods namely: oven-drying, smoke-drying, sun-drying or air-drying. Plant analysis revealed that sun-dried samples contained the highest values in most of the nutritional parameters evaluated, followed by sun-drying and the least by oven-drying and smoke-drying. Air-dried samples retained the highest moisture, ash, lipid, crude fibre and protein followed by sun-drying and the least by oven-drying and smoke-drying. Plant sampled contained the highest carbohydrate content under smoke-drying method. The study concluded that sun-drying is the best drying technique for nutrient retention while air-drying is the most appropriate for retaining high proximate value in the leafy vegetables.

**Keywords:** Leafy vegetables, preservation, drying techniques, nutritional content

### **Introduction**

Leafy vegetables constitute major source of food for man worldwide as they may be eaten raw as salads, cooked in soup or used to spice up meals. They have a unique place in human diet because of their color, flavor, nutrient content and health benefits (Idah *et al.*, 2010). In the developing nations like Nigeria where malnutrition is still a challenge, leafy vegetables constitute largely as an alternative source of essential nutrients as they contain considerable amount of protein,  $\beta$  carotene and ascorbic

acid (Naikwade *et al.*, 2011; Eze and Agbo, 2011; Mogle *et al.*, 2013; Naikwade 2014a; Naikwade 2014b); digestible carbohydrates, minerals and vitamins (Studman, 1999); and some with essential oil that can be higher than that of most cereals (Alegbejo, 2013). Some vegetables like amaranth grain is used as livestock feed which gives production results comparable to those from feeding corn/soybean ration (Acar *et al.*, 1988). It is also a useful energy supplement for broiler diets and can be incorporated at levels up to 400 g per kg without adverse effects

(Ravindran *et al.*, 1996). The whole dried plant of amaranth species can be burnt to produce ash, which when dissolved in water, the precipitate of the filtrate can be used as salt (Fox and Norwood, 1982). Many vegetables have medicinal values; *Vernonia amygdalina* is used for treatment of high blood sugar and mixed with *Ocimum gratissimum* for the treatment of pile. The root juice of amaranth is used in the treatment of inflammation during urination and constipation (Manandhar, 2002).

In Nigeria's farming systems, leafy vegetables are often regarded as 'backyard crops'. Depending on local agro-climatic situations, most of them are grown under the traditional mixed cropping system where they also play a prominent role in generating income for the growers. They are generally regarded as perishables because of their high-water content which aid their quick deterioration. Due to high availability during the raining season and scarcity in the dry season, preservation has been suggested to be the only way-out to ensure availability all the year round (Idah *et al.*, 2010). One of the oldest forms of preservation is drying. The primary objective of drying is removal of moisture which microorganisms require for growth. This helps in minimizing spoilage, decay and waste; it increases shelf life and reduces economic loss to farmers (Eze and Agbo, 2011).

The rate of drying depends on various parameters such as solar radiation, ambient temperature, wind velocity, relative humidity, and initial moisture content, type of crops, crop absorptive and mass of product per unit exposed area (Belekar *et al.*, 2018). Several studies have shown that fresh vegetables often contain more nutrients than dried ones (Ahmed *et al.*, 2013). For example, Sagar and Kumar

(2010) discovered that retention of vitamin C in freeze-dried products is significantly higher than that of oven- and sun-dried products. Microwave and vacuum drying methods can also reduce loss of ascorbic acid due to low levels of oxygen. Microwave, Refractance Window, low pressure superheated steam and vacuum drying can also reduce loss of vitamins due to a low level.

In South-Western Nigeria, leafy vegetables are either prepared and eaten fresh or dry depending on the availability of the vegetable and the taste and choice of the individuals. The preference depends on the gender and age of consumers, as well as cultural background and geographical location (Jansen-Van-Rensberg *et al.*, 2004). It can be prepared from a single species or from a combination of different species. Interestingly, dry leafy vegetables are available in the markets at both rural and urban areas. Sun-drying, air-drying, smoke-drying and oven-drying are methods often used to preserve the vegetables (Adeboye and Babajide, 2007). Because of ignorance and the high illiteracy level among the Nigerian farmers, many prefer consuming the vegetables in dry form even during the raining season when production is abundant, with less concerns given to effects the processing techniques might have on the nutritional component of the vegetables. Considering the fact that plants respond differently to various drying techniques depending on the sensitivity of the nutrients in the plant and various other conditions like oxygen, heat, pH and light (Morris *et al.*, 2004), this research is aimed at identifying the drying technique(s) that can substantially retain the nutrient composition of the vegetables at a comparative level.

## **Materials and method**

### **Selection of vegetables**

Five leafy vegetable species were selected for this research. *Talinum triangulare* (waterleaf), *Vernonia amygdalina* (bitterleaf), *Amaranthus*

*viridis* (green amarath), *Telfairia occidentalis* (fluted pumpkin), and *Corchorus olitorius* (jute mallow) were selected based on the fact that they are among the most consumed leafy vegetables in dry form in South-Western Nigeria. They are mostly cultivated but some are found growing naturally without cultivation, available in surplus quantities and affordable prices in markets during the wet season of the year. This gives opportunities to individuals to preserve them for the lean season of the year (dry season).

#### **Source of the vegetables**

Fresh samples of the vegetables were purchased from the Akungba-Akoko Main Market, in Ondo State, Nigeria.

#### **Drying techniques used**

The shoot being the edible part of each vegetable was subjected to four drying techniques. After washing, each vegetable was cut into smaller sizes and subjected to air-drying, smoke-drying, oven-drying or sun-drying as separate treatments by adopting the methods of Abioye *et al.* (2014) and Belekar *et al.* (2018). For oven-drying, vegetables were kept in the oven at 80°C for fast drying until constant weight was reached. Sun-drying method involved keeping the vegetables in trays and set in the open sunlight. Keeping the vegetables in copper-net tray and placed on charcoal fire for drying served as the smoke-drying method while arranging the plant materials on wooden racks and kept on the laboratory bench at room temperature (25-27°C) to dry was regarded as air-drying method. The samples were considered to be dry when constant weight was reached, and were packed separately in air-tight containers and well-labeled.

#### **Nutritional and proximate analysis**

Nutritional and proximate analysis of plant samples was carried out at the Central Laboratory of the National Horticultural

Institute (NIHORT) at Ibadan, Nigeria. Dried samples were milled into fine powder with the aid of milling machine. Moisture, crude protein, crude fat, carbohydrate, crude fibre and ash contents were determined according to AOAC (2005). Nitrogen was determined by the modified Kjeldahl method; potassium by flame photometry (Corning, UK model 405); phosphorous was determined colourimetrically using spectronic 20 (Gallenkemp, UK); Mg by EDTA titration while calcium was by Atomic Absorption Spectrophotometer (Buck 210).

#### **Results**

N, K and Mg were retained best in sun-dried vegetables with 89.94±0.05, 176.68±0.08 and 250.22±0.07 mg/100g respectively (Table 1). This was significantly ( $p < 0.05$ ) different from other treatments. However, P and Ca were highest in air-dried leaves of *A. viridis* with 33.67± 0.09 and 72.71±0.09 mg/100g respectively, but only Ca was significantly ( $p < 0.05$ ) different from others. Vegetables that were air-dried had the highest moisture content, crude fibre and lipid contents, with 10.22±0.2, 8.17±0.01 and 4.01±0.01% respectively, which differed significantly from other treatments (Table 2). The amount of ash content (14.86±0.02), and crude protein (23.62±0.01) were highest under sun-drying method. These differed significantly from other treatments while crude protein differed significantly from only smoke-dried *A. Viridis*. Sun-dried leaves of *C. olitorius* had the highest nutritional content including N (85.49±0.13), P (39.95±0.01), K (155.79±0.02), Ca (59.37± 0.06) and Mg (100.72±0.03) (mg/100g), which are significantly differed from other treatments (Table 3).

The moisture content (9.05±0.01), ash content (10.83±0.01) and crude fibre (7.94±0.01) were highest in *C. olitorius* leaves that were air-dried compared to other

treatments (Table 4). These values didn't differ significantly from those sun-dried but there were significant differences when compared to those smoke-dried and oven-dried. The lipid content was significantly highest in oven-dried leaves, while crude protein ( $25.77 \pm 1.01$ ) and carbohydrate ( $50.62 \pm 0.04$ ) (%) were best under sun-dried and smoke-dried respectively. The results in Table 5 show that sun-dried leaves of *T. triangulare* retained the highest of N, P, K and Ca while Mg was best in oven-dried vegetables with  $37.35 \pm 0.12$ ,  $30.09 \pm 0.07$ ,  $102.71 \pm 0.18$  and  $64.88 \pm 0.05$  (mg/100g) respectively. There were significant differences when compared with other treatments. Moisture content ( $6.60 \pm 0.01$ ), ash content ( $10.53 \pm 0.01$ ) and crude lipid ( $2.22 \pm 0.01$ ) were highest in *T. triangulare* leaves that were air-dried relative to other treatments (Table 6). However, protein ( $10.14 \pm 0.01$ ) and carbohydrate ( $68.56 \pm 0.20$ ) (%) were highest when the leaves were dried under sun and smoke respectively. Ash content was also best under sun-drying but without significant ( $p < 0.05$ ) difference from other treatments. Table 7 presents the effect of drying methods on the nutritional composition of *T. occidentalis*. N, P, K, Ca and Mg for sun-

dried *T. occidentalis* were highest, with values  $43.79 \pm 0.02$ ,  $26.72 \pm 0.03$ ,  $348.83 \pm 0.12$ ,  $70.31 \pm 0.27$ ,  $302.52 \pm 0.09$  mg/100g respectively. They differed significantly from other treatments with the exception of P. The moisture content, crude protein and lipid content in sun-dried *T. occidentalis* leaves were higher than other treatments. No significant ( $P < 0.05$ ) differences were observed in moisture content and crude protein but lipid content differed significantly. Air-dried sample retained the highest ash and crude fibre with significant difference from other treatments. Moreover, smoke-dried *T. occidentalis* contained the highest amount of carbohydrate. P ( $19.54 \pm 0.1$ ), Ca ( $80.74 \pm 0.11$ ) and Mg ( $66.62 \pm 1.38$ ) were highest in sun-dried *V. amygdalina* leaves (Table 9). N ( $59.54 \pm 0.16$ ) was highest in smoke-dried sample while K ( $20.72 \pm 0.02$ ) was best retained in oven-dried samples. No significant difference was recorded for Mg, but there were significant differences in N, P, K and Ca contents compared to other methods. *V. amygdalina* that was air-dried had the highest value of moisture content ( $8.92 \pm 0.02$ ), ash content ( $8.32 \pm 0.02$ ), crude fibre ( $7.43 \pm 0.02$ ), lipid content ( $3.24 \pm 0.02$ ) and crude protein ( $14.23 \pm 0.02$ ), but carbohydrate ( $62.85 \pm 0.04$ ) was highest in smoke-drying method (Table 10).

**Table 1: Effect of drying methods on the nutritional composition of *Amaranthus viridis* (green amaranth)**

Nutritional composition (mg/100g)	Drying method			
	Smoke-drying	Oven-drying	Air-drying	Sun-drying
<b>Nitrogen</b>	$86.68 \pm 0.19^a$	$87.49 \pm 0.13^b$	$88.19 \pm 0.09^c$	$89.94 \pm 0.05^d$
<b>Phosphorus</b>	$31.91 \pm 0.03^a$	$33.52 \pm 0.03^a$	$33.67 \pm 0.09^a$	$30.83 \pm 0.33^a$
<b>Potassium</b>	$171.91 \pm 0.28^a$	$174.56 \pm 0.34^b$	$175.06 \pm 0.30^b$	$176.68 \pm 0.08^c$
<b>Calcium</b>	$70.41 \pm 0.12^a$	$70.91 \pm 0.03^b$	$72.71 \pm 0.09^d$	$71.69 \pm 0.08^c$
<b>Magnesium</b>	$238.80 \pm 0.13^a$	$249.59 \pm 0.13^b$	$246.68 \pm 0.14^d$	$250.22 \pm 0.07^c$

Each value is a mean of three replicates  $\pm$  standard error of mean. Values having the same alphabet(s) as superscript in the same row are not significantly different (Tukey HSD test at  $p = 0.05$  probability level).

**Table 2: Effect of drying methods on the proximate composition of *Amaranthus viridis* (green amaranth)**

Proximate composition (%)	Drying method			
	Smoke-drying	Oven-drying	Air-drying	Sun-drying
<b>Moisture content</b>	8.15±0.01 <sup>a</sup>	8.59±0.02 <sup>b</sup>	10.22±0.02 <sup>d</sup>	9.41±0.03 <sup>c</sup>
<b>Ash content</b>	13.16±0.01 <sup>a</sup>	13.66±0.01 <sup>c</sup>	13.55±0.02 <sup>b</sup>	14.86±0.02 <sup>d</sup>
<b>Crude fibre</b>	7.61±0.01 <sup>a</sup>	7.82±0.01 <sup>b</sup>	8.17±0.01 <sup>d</sup>	8.02±0.01 <sup>c</sup>
<b>Lipid content</b>	3.78±0.02 <sup>a</sup>	3.86±0.01 <sup>b</sup>	4.01±0.01 <sup>d</sup>	3.92±0.01 <sup>c</sup>
<b>Crude protein</b>	22.44±0.01 <sup>a</sup>	23.44±0.01 <sup>c</sup>	23.34±0.01 <sup>b</sup>	23.62±0.01 <sup>d</sup>
<b>Carbohydrate</b>	44.85±0.01 <sup>d</sup>	42.64±0.03 <sup>c</sup>	40.70±0.05 <sup>b</sup>	40.18±0.02 <sup>a</sup>

Each value is a mean of three replicates ± standard error of mean. Values having the same alphabet(s) as superscript in the same row are not significantly different (Tukey HSD test at p=0.05 probability level).

**Table 3: Effect of drying methods on the nutritional compositions of *Corchorus olitorius* (jute mallow)**

Nutritional composition (mg/100g)	Drying method			
	Smoke-drying	Oven-drying	Air-drying	Sun-drying
<b>Nitrogen</b>	83.47±0.24 <sup>a</sup>	84.82±0.08 <sup>bc</sup>	84.49±0.08 <sup>b</sup>	85.49±0.13 <sup>c</sup>
<b>Phosphorus</b>	38.73±0.01 <sup>a</sup>	34.44±0.05 <sup>b</sup>	39.63±0.03 <sup>c</sup>	39.95±0.01 <sup>d</sup>
<b>Potassium</b>	148.92±0.01 <sup>a</sup>	151.46±3.04 <sup>a</sup>	153.72±0.61 <sup>a</sup>	155.79±0.02 <sup>a</sup>
<b>Calcium</b>	56.48±0.09 <sup>a</sup>	58.10±0.06 <sup>b</sup>	47.76±0.68 <sup>ab</sup>	59.37±0.06 <sup>b</sup>
<b>Magnesium</b>	97.44±0.06 <sup>b</sup>	98.48±0.08 <sup>b</sup>	57.96±0.68 <sup>a</sup>	100.72±0.03 <sup>c</sup>

Each value is a mean of three replicates ± standard error of mean. Values having the same alphabet(s) as superscript in the same row are not significantly different (Tukey HSD test at p=0.05 probability level).

**Table 4: Effect of drying methods on the proximate compositions of *Corchorus olitorius* (jute mallow)**

Proximate composition (%)	Drying method			
	Smoke-drying	Oven-drying	Air-drying	Sun-drying
<b>Moisture content</b>	6.61±0.01 <sup>a</sup>	7.13±0.01 <sup>b</sup>	9.05±0.01 <sup>d</sup>	8.29±0.18 <sup>c</sup>
<b>Ash content</b>	8.24±0.01 <sup>a</sup>	9.08±0.02 <sup>b</sup>	10.83±0.01 <sup>d</sup>	10.41±0.01 <sup>c</sup>
<b>Crude fibre</b>	6.74±0.01 <sup>a</sup>	6.95±0.02 <sup>b</sup>	7.94±0.01 <sup>d</sup>	7.84±0.01 <sup>c</sup>
<b>Lipid content</b>	3.96±0.02 <sup>a</sup>	4.78±0.01 <sup>d</sup>	4.30±0.00 <sup>b</sup>	4.65±0.02 <sup>c</sup>
<b>Crude protein</b>	23.83±0.02 <sup>a</sup>	24.68±0.01 <sup>a</sup>	25.03±0.01 <sup>a</sup>	25.77±1.01 <sup>a</sup>
<b>Carbohydrate</b>	50.62±0.04 <sup>c</sup>	47.41±0.04 <sup>b</sup>	42.84±0.01 <sup>a</sup>	43.03±1.02 <sup>a</sup>

Each value is a mean of three replicates ± standard error of mean. Values having the same alphabet(s) as superscript in the same row are not significantly different (Tukey HSD test at p=0.05 probability level).

**Table 5: Effect of drying methods on the nutritional compositions of *Talinum triangulare* (water leaf)**

Nutritional composition (mg/100g)	Drying method			
	Smoke-drying	Oven-drying	Air-drying	Sun-drying
<b>Nitrogen</b>	30.86±0.21 <sup>a</sup>	36.90±0.03 <sup>bc</sup>	36.33±0.17 <sup>b</sup>	37.35±0.12 <sup>b</sup>
<b>Phosphorus</b>	28.94±0.04 <sup>a</sup>	29.81±0.03 <sup>c</sup>	29.43±0.06 <sup>b</sup>	30.09±0.07 <sup>d</sup>
<b>Potassium</b>	96.62±0.17 <sup>a</sup>	101.52±0.03 <sup>c</sup>	99.55±0.17 <sup>b</sup>	102.71±0.18 <sup>d</sup>
<b>Calcium</b>	61.59±0.10 <sup>a</sup>	63.45±0.21 <sup>c</sup>	62.63±0.12 <sup>b</sup>	64.88±0.05 <sup>d</sup>
<b>Magnesium</b>	85.43±0.08 <sup>a</sup>	87.26±0.02 <sup>c</sup>	86.88±0.06 <sup>b</sup>	87.21±0.04 <sup>c</sup>

Each value is a mean of three replicates ± standard error of mean. Values having the same alphabet(s) as superscript in the same row are not significantly different (Tukey HSD test at p=0.05 probability level).

**Table 6: Effect of drying methods on the proximate compositions of *Talinum triangulare* (waterleaf)**

Proximate composition %	Drying method			
	Smoke-drying	Oven-drying	Air-drying	Sun-drying
<b>Moisture content</b>	5.77±0.17 <sup>a</sup>	6.12±0.02 <sup>ab</sup>	6.60±0.01 <sup>c</sup>	6.32±0.20 <sup>bc</sup>
<b>Ash content</b>	9.94±0.01 <sup>a</sup>	10.13±0.01 <sup>b</sup>	10.53±0.01 <sup>d</sup>	10.34±0.01 <sup>c</sup>
<b>Crude fibre</b>	9.23±0.02 <sup>a</sup>	9.72±0.01 <sup>a</sup>	10.30±0.01 <sup>a</sup>	12.16±2.01 <sup>a</sup>
<b>Lipid content</b>	1.99±0.02 <sup>a</sup>	2.08±0.01 <sup>b</sup>	2.22±0.01 <sup>d</sup>	2.16±0.01 <sup>c</sup>
<b>Crude protein</b>	9.50±0.01 <sup>a</sup>	9.71±0.24 <sup>ab</sup>	9.86±0.03 <sup>ab</sup>	10.14±0.01 <sup>b</sup>
<b>Carbohydrate</b>	68.56±0.20 <sup>c</sup>	62.00±0.01 <sup>b</sup>	60.47±0.02 <sup>a</sup>	60.88±0.03 <sup>a</sup>

Each value is a mean of three replicates ± standard error of mean. Values having the same alphabet(s) as superscript in the same row are not significantly different (Tukey HSD test at p=0.05 probability level).

**Table 7: Effect of drying methods on the nutritional composition of *Telfairia occidentalis* (fluted pumpkin)**

Nutritional composition mg/100g	Drying method			
	Smoke-drying	Oven-drying	Air-drying	Sun-drying
<b>Nitrogen</b>	40.73±0.04 <sup>a</sup>	42.73±0.08 <sup>b</sup>	42.61±0.08 <sup>b</sup>	43.79±0.02 <sup>c</sup>
<b>Phosphorus</b>	21.84±3.33 <sup>a</sup>	25.80±0.15 <sup>a</sup>	26.50±0.03 <sup>a</sup>	26.72±0.03 <sup>a</sup>
<b>Potassium</b>	318.68±0.13 <sup>a</sup>	340.80±0.27 <sup>c</sup>	325.48±0.11 <sup>b</sup>	348.83±0.12 <sup>d</sup>
<b>Calcium</b>	66.46±0.04 <sup>a</sup>	69.78±0.13 <sup>c</sup>	68.69±0.05 <sup>b</sup>	70.31±0.27 <sup>c</sup>
<b>Magnesium</b>	296.20±0.81 <sup>a</sup>	301.89±0.04 <sup>b</sup>	301.63±0.10 <sup>b</sup>	302.52±0.09 <sup>b</sup>

Each value is a mean of three replicates ± standard error of mean. Values having the same alphabet(s) as superscript in the same row are not significantly different (Tukey HSD test at p=0.05 probability level).

**Table 8: Effect of drying methods on the proximate composition of *Telfairia occidentalis* (fluted pumpkin)**

Proximate composition %	Drying method			
	Smoke-drying	Oven-drying	Air-drying	Sun-drying
<b>Moisture content</b>	8.16±0.12 <sup>a</sup>	8.40±0.16 <sup>a</sup>	8.37±0.01 <sup>a</sup>	8.55±0.01 <sup>a</sup>
<b>Ash content</b>	6.47±0.02 <sup>b</sup>	6.36±0.02 <sup>a</sup>	7.84±0.01 <sup>d</sup>	7.54±0.01 <sup>c</sup>
<b>Crude fibre</b>	13.26±0.01 <sup>a</sup>	13.94±0.01 <sup>b</sup>	14.83±0.02 <sup>d</sup>	14.76±0.01 <sup>c</sup>
<b>Lipid content</b>	4.17±0.01 <sup>a</sup>	4.45±0.02 <sup>b</sup>	5.24±0.01 <sup>c</sup>	5.36±0.00 <sup>d</sup>
<b>Crude protein</b>	24.96±0.01 <sup>a</sup>	25.83±1.67 <sup>a</sup>	28.56±0.33 <sup>a</sup>	28.67±0.03 <sup>a</sup>
<b>Carbohydrate</b>	43.10±0.04 <sup>b</sup>	42.68±0.18 <sup>b</sup>	35.52±0.02 <sup>a</sup>	36.12±1.03 <sup>a</sup>

Each value is a mean of three replicates ± standard error of mean. Values having the same alphabet(s) as superscript in the same row are not significantly different (Tukey HSD test at p=0.05 probability level).

**Table 9: Effect of drying methods on the nutritional composition of *Vernonia amygdalina* (bitterleaf)**

Nutritional composition (mg/100g)	Drying method			
	Smoke-drying	Oven-drying	Air-drying	Sun-drying
<b>Nitrogen</b>	59.54±0.16 <sup>a</sup>	51.36±0.07 <sup>c</sup>	50.48±0.15 <sup>b</sup>	52.61±0.11 <sup>d</sup>
<b>Phosphorus</b>	17.47±0.03 <sup>a</sup>	19.03±0.03 <sup>b</sup>	18.91±0.04 <sup>b</sup>	19.54±0.01 <sup>c</sup>
<b>Potassium</b>	18.94±0.01 <sup>a</sup>	20.72±0.02 <sup>c</sup>	19.82±0.02 <sup>b</sup>	20.53±0.17 <sup>c</sup>
<b>Calcium</b>	78.36±0.15 <sup>a</sup>	79.76±0.08 <sup>b</sup>	79.48±0.08 <sup>b</sup>	80.74±0.11 <sup>c</sup>
<b>Magnesium</b>	63.54±0.16 <sup>a</sup>	66.52±0.08 <sup>a</sup>	65.91±0.05 <sup>a</sup>	66.62±1.38 <sup>a</sup>

Each value is a mean of three replicates ± standard error of mean. Values having the same alphabet(s) as superscript in the same row are not significantly different (Tukey HSD test at p=0.05 probability level).

**Table 10: Effect of drying methods on the proximate compositions of *Vernonia amygdalina* (bitterleaf)**

Proximate composition (%)	Drying method			
	Smoke-drying	Oven-drying	Air-drying	Sun-drying
<b>Moisture content</b>	7.66±0.01 <sup>a</sup>	8.22±0.01 <sup>b</sup>	8.92±0.02 <sup>d</sup>	8.48±0.01 <sup>c</sup>
<b>Ash content</b>	6.64±0.01 <sup>a</sup>	6.87±0.02 <sup>b</sup>	8.32±0.02 <sup>d</sup>	7.82±0.02 <sup>c</sup>
<b>Crude fibre</b>	6.11±0.01 <sup>a</sup>	7.15±0.0 <sup>b</sup>	7.43±0.02 <sup>d</sup>	7.28±0.00 <sup>c</sup>
<b>Lipid content</b>	2.83±0.02 <sup>a</sup>	2.93±0.01 <sup>b</sup>	3.24±0.02 <sup>d</sup>	3.09±0.01 <sup>c</sup>
<b>Crude protein</b>	13.93±0.02 <sup>a</sup>	14.03±0.01 <sup>b</sup>	14.23±0.02 <sup>c</sup>	14.17±0.01 <sup>c</sup>
<b>Carbohydrate</b>	62.85±0.04 <sup>d</sup>	60.79±0.03 <sup>c</sup>	57.86±0.06 <sup>a</sup>	59.16±0.03 <sup>b</sup>

Each value is a mean of three replicates ± standard error of mean. Values having the same alphabet(s) as superscript in the same row are not significantly different (Tukey HSD test at p=0.05 probability level).

## Discussion

In this study, sun-dried plant samples appeared to retain more nutrients (N, P, K, Ca and Mg) in all the vegetables than other methods including air-drying, oven-drying and smoke-drying which retained similar amount of nutrients. It has earlier been reported by Oni *et al.* (2015) that all the mineral contents in some common Nigerian edible botanicals were higher in air-dried samples than oven- and sun-dried ones except for nitrogen and phosphorus which were inconsistent. A similar result was obtained in Ginger (*Zingiber officinale*) by Ajayi *et al.*, (2017). This contradicts what was obtained in this research which might be due to the fact that plants respond differently to various drying techniques depending on the sensitivity of the nutrients in the plant and other various conditions (Morris *et al.*, 2004). However, similar to what was recorded in this study, Abioye *et al.* (2014) found that iron and calcium content of baobab (*Adansonia digitata*) leaves were better significantly by drying with solar dryer than other methods including air-drying. This is further corroborated by Ukegbu and Okereke (2013) that solar drying was observed to produce relatively better product in terms of nutrient composition in spinach (*Amaranthus hybridus*), fluted pumpkin (*Telferia occidentalis*), and okra (*Hibiscus esculentus*) compared to other drying methods. Likewise, sun-dried sample of Baobab (*Adansonia digitata* L.) leaves had the highest value of ash content compared to other methods (Abioye *et al.*, 2014).

All the parameters including moisture content, ash content, crude protein, lipid, crude fibre and carbohydrate were found more in the air-dried vegetables than those subjected to other drying methods. This result is consistent with many previous

reports. Oni *et al.* (2015) discovered that all the vegetables that were air-dried were richer in protein and fibre than those that were sun-dried and oven-dried. Also, Izli *et al.* (2017) found a decrease of 18.4-54.6% of antioxidant capacity in the edible portion of mango (*Mangifera indica*) fruit exposed to sun-drying and attributed it to the scorching effect of sun on the fruit. Plant samples subjected to shade-drying had the highest protein content in all the drying treatments with a value of 12.80% which was significantly higher than other drying methods. Furthermore, the samples of Baobab (*Adansonia digitata* L.) leaves subjected to shade-drying retained the highest fat content (Abioye *et al.*, 2014). The reduced level of nutritional and proximate compositions under oven-drying has been corroborated by that of Oni *et al.* (2015) who found that *A. hybridus* that was oven-dried had the lowest values of fibre and carbohydrate content among the drying techniques used. The variations observed in the plant samples might be attributed to the type of vegetable used, soil condition and maturity level of the vegetables (Ukegbu and Okereke, 2013).

## Conclusion

It was discovered in this study that sun-dried plant samples contained the highest amount of N, P, K, Ca and Mg while air-dried plants retained the highest ash, protein, crude fibre, lipid and moisture content. The least nutrient content was obtained in oven- and smoke-dried samples. However, if carbohydrate is the target, smoke-drying will be most appropriate.

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