The effect of different drying methods on the elemental and nutritional composition of *Vernonia amygdalina* (bitter leaf)

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**ABSTRACT**

*Vernonia amygdalina* (VA) popularly known as bitter leaf is a common and popular vegetable in Nigeria used as a spice in many delicacies and as medicine. Most people believe that when vegetable like bitter leaf is preserved by the drying method, most of the essential minerals are lost. In this study, the effect of air, sun, oven and solar drying methods on the organic and dietary elemental composition of its leaves was evaluated using standard analytical procedures. Drying increased significantly the concentration of all the organic constituents evaluated. The ashed content was markedly enhanced by drying and it range from 2.56% in fresh sample to 11.20% in sun-dried sample, the fibre content range from 1.62% in fresh sample to 4.02% in air-dried sample, also the lipid content from 0.62% in fresh sample to 2.64% in air-dried sample. A significant increase in mineral content was observed upon drying except magnesium and copper whose concentrations were found to be high (48.23 and 0.31 mg/100 g) in fresh sample. The lead content also decreases upon drying, showing a way of reducing the quantity of lead intake. The concentrations of calcium and iron increased upon drying. The results of this study suggest that drying improves the concentration of both organic and dietary elemental constituents and oven–solar drying methods could be useful in preserving VA leaves in a more hygienic way and ensure its all-the-year round availability and possibly elimination of most nutrient deficiencies.

1. Introduction

*Vernonia amygdalina* (VA) is commonly called bitter leaf because of its bitter taste [1,2]. It is a popular plant in the tropical part of the world that grows up to 3 m above the sea level [3,4]. Over 500 species of these *Vernonia* plants are found in Asia and Africa, about 300 species in Mexico, South and Central America [5]. The leaves have a sweet and bitter taste, popularly used for food [6]. Its medicinal properties were also proven by medical research [7]. In Nigeria and South Africa for example, VA is used for the treatment of diabetes [8].

The human body requires a number of minerals in order to maintain good health. A number of minerals essential to human nutrition are accumulated in different parts of plants like VA as it accumulates minerals essential for growth from the environment [9]. Macro- and microelements influence biochemical processes in the human organism [10]. Study of elements with respect to indigenous medicinal plants such as VA reveals that major and trace elements have significant roles in combating a variety of human ailments and disease [11].

Green leafy vegetable production has less competitive advantage among other agricultural products. The green leafy vegetable production appears to less attractive to farmers. It has been confirmed that the production, practices, processing and marketing of vegetables, especially the commonly consumed ones such as VA have received negligible attention [12]. In Nigeria, leafy vegetables are rarely processed, presumably due to the general lack of basic preservation facilities for freezing, canning or dehydration. Fresh medicinal plants including VA may deteriorate a few days after harvesting; therefore, there is a need for preservation to extend their shelf-life [13,14]. Drying is one of the ancient preservative methods used in extending a herb’s shelf-life [15]. The outstanding preservative method practised in many homes in Nigeria is sun-drying. A relatively small quantity of harvested leafy vegetables are, however, sun-dried resulting in poor quality products with variable moisture contents and microbial loads thus affecting storage stability [12]. Deficiency in nutrients like iron, calcium, potassium etc. are among the cases of malnutrition [11]. Dried vegetables could be the solution to seasonality of vegetables consumption and possibly elimination of these micronutrient deficiencies.

To the best of our knowledge, no comparative studies were reported on elemental compositions and value of dried and fresh bitter leaf (VA) in Zaria. The impetus of this study is therefore to determine the effect of drying methods on some elemental nutritional composition of...
VA commonly consumed in Zaria community of Kaduna State.

2. Materials and methods

2.1. Hypotheses

2.1.1. Hypothesis I

\[ H_0: \] Drying has significant effect on the mean proximate composition of the vegetable.

\[ H_1: \] Drying does not have significant effect on the mean proximate composition of the vegetable.

2.1.2. Hypothesis II

\[ H_0: \] Drying has significant effect on the mean concentration of the elemental nutrient constituents of the bitter leaf.

\[ H_1: \] Drying does not have significant effect on the mean concentration of the elemental constituents of the bitter leaf.

2.2. Preparation of sample

Large quantity of fresh mature VA leaves (Figure 1) was bought from the popular Sabo market in Zaria town. The leaves were washed in running water to remove dirt that adheres to it, spread for the water to drain out to constant weight \[ 5 \]. The leaves were divided into five portions: fresh, sun-dried, air-dried, solar-dried and oven-dried. The dried vegetables were reduced in size using a laboratory grinder and the un-dried portion was sliced with a stainless steel knife which was taken for proximate composition analysis \[ 16 \].

2.3. Proximate composition analysis

The proximate composition was carried out using standard analytical procedure. Moisture and dried matter contents were carried out using hot air oven at 105°C for 4 h. Ash content was determined using furnace at 550°C for 8 h. Crude lipid was obtained using soxhlet and \( n \)-hexane, and crude fibre determination was carried out using the method by Bonsi et al. \[ 17 \].

Figure 1. Bitter leaf (\( V. \) amygdalina).

2.4. Elemental composition analysis

About 3 g of each portion of ground sample were weighed into clean platinum crucibles and ashed with the muffle furnace at 450°C, then cooled to room temperature in the desiccator. The ashed portions were digested by adopting digestion procedure reported by \[ 18 \] with 20 cm\(^3\) concentration of HNO\(_3\) and 20 cm\(^3\) of conc. H\(_2\)SO\(_4\). The resulting solution was filtered to obtain the filtrate used for the elemental analysis. Each filtrate of the digested sample was aspirated into the AAS (Varian\(^*\) Model AA375 Australia) and the absorbance recorded. Concentrations of respective micronutrients were read up from standard curves of absorbance (A) versus concentrations (mg/100 g). A simple graphical description of the experimental process is shown in Figure 2.

Figure 2. Graphical description of the research activities.

3. Results and discussion

The result of proximate analysis of VA leaves samples analysed is presented in Table 1. Moisture removal by heat generally improve the digestibility of foods, increases concentration of nutrients and can make some nutrients more available. The moisture content was high in the fresh sample and was significantly decreased using different drying methods with solar-dried sample having lowest moisture content (12.80%). The high moisture content for the fresh VA (73.38%) was not a surprise; fresh foods, especially vegetables contain high moisture. The present observation agreed with those of many \[ 12 \]. The low moisture values for sun-dried, solar-dried, air-dried and oven-dried were expected. Drying is known to reduce moisture to improve the shelf-life of foods and increase dry matter \[ 19 \]. Moisture content of fruits and vegetables provide an enabling environment for growth of microorganisms and preservation by drying help to inhibit autolytic enzymes. Drying has been reported to be effective in reducing moisture content and make the preservation possible without deterioration by microorganisms \[ 19 \]. Moisture in food determines the rate of food absorption and assimilation within the body. From the results obtained, the moisture content of fresh (73.38%), solar-dried (12.80%), sun-dried (15.25%), oven-dried (13.07%)
and air-dried (20.40) samples indicated that fresh VA leaf may not be stored at room for a long period of time.

The dry matter content was significantly higher in all the drying methods with 87.20% in solar-dried, 86.93% in oven-dried, 84.75% in sun-dried and 79.60% in air-dried as compared to the fresh sample with 26.62%. The high value of dry matter in the dried vegetable was due to loss of moisture during the drying process. Many workers had reported similar phenomenon [20]. It is known that loss of moisture increases nutrient content and extends keeping quality of vegetables [20].

The ash content was significantly high in all the drying methods in comparison with fresh leaves. Although, ash content is an index of total mineral element, it is also used to test the extent of contamination with sand from the surroundings [20]. In this study, ash content of the dried samples ranged from 10.38% to 11.20% and was found to be high in sun-dried portion. This observation is therefore not surprising as vegetables are exposed to uncontrolled dust during the drying process. The low ash value for the fresh vegetable strongly suggested that fresh VA is not a good source of ash with ash content of 2.56%.

The fibre content was significantly higher in all the drying methods with 3.54% in oven-dried, 3.63% in solar-dried, 3.89% in sun-dried and 4.02% in air-dried as compared to the fresh sample with 1.62%. The higher fibre values for the dried VA were due to loss of moisture and vegetables are good sources of fibre. In addition, it is known that the loss of moisture increases nutrient density in foods of which fibre is among the nutrients. Fibre taken as part of diet cleanses the digestive tract by removing potential carcinogens from the body and hence prevents the absorption of excess cholesterol. Fibre also adds bulk to food and reduces the intake of excess starchy food which is the characteristics of the diet of the indigenes in this locality and hence guards against metabolic conditions such as hypertension and diabetes mellitus. The lipid content was significantly high in all the drying methods with air-dried 2.64%, oven-dried 2.53%, solar-dried 2.49% and sun-dried 1.84% as compared to the fresh sample with 0.62%. Fats are needed to keep cell membranes functioning properly, to insulate body organs against shock, to keep body temperature stable and to maintain healthy skin and hair. The body does not manufacture certain fatty acids (termed essential fatty acids) and diet like bitter leaf must supply these [21,22].

The result of elemental analysis indicated significant differences in the drying methods employed. Magnesium, copper and lead were found to be high in the fresh sample while calcium and iron were high in the dried sample (Table 2).

| Sample state | Moisture content (%) | Dry matter content (%) | Ash content (%) | Fibre content (%) | Lipid content (%) |
|--------------|----------------------|------------------------|-----------------|-------------------|-------------------|
| Fresh        | 73.38 ± 1.86         | 26.62 ± 1.42           | 2.56 ± 0.04     | 1.62 ± 0.09       | 0.62 ± 0.06       |
| Air-dried    | 20.40 ± 0.24         | 79.60 ± 0.41           | 10.38 ± 0.02    | 4.02 ± 0.05       | 2.64 ± 0.13       |
| Sun-dried    | 15.25 ± 0.18         | 84.75 ± 0.16           | 11.20 ± 0.06    | 3.89 ± 0.12       | 1.84 ± 0.22       |
| Oven-dried   | 13.07 ± 0.02         | 86.93 ± 0.03           | 10.92 ± 0.03    | 3.54 ± 0.06       | 2.53 ± 0.21       |
| Solar-dried  | 12.80 ± 0.01         | 87.20 ± 0.01           | 11.15 ± 0.04    | 3.63 ± 0.03       | 2.49 ± 0.17       |

Note: Values are means ± standard deviation.

Copper is also a key mineral in many different systems. Copper plays a role in haemoglobin formation and its deficiency leads to anaemia. The values obtained for iron are: fresh (2.40 mg/100 g), sun-dried (3.12 mg/100 g), oven-dried (2.73 mg/100 g), solar-dried (2.81 mg/100 g) and air-dried (2.95 mg/100 g). The recommended dietary allowance value for iron is 15 mg [24] and VA leaf can contribute 9% of iron to the RDA when in fresh state. This indicates that VA leaf can contribute meaningful amount of dietary calcium which is required for growth, maintenance of bone, teeth and muscle by eating significant quantity.

Magnesium plays a vital role in calcium metabolism in bone. It is an important mineral element in connec-
tion with circulatory diseases such as ischemic heart disease [23]. The results obtained from magnesium ranged from 40.29 to 43.04 mg/100 g with the control sample (fresh sample) having the highest value of 48.23% and air-dried having the lowest value. The recommended dietary allowance value for magnesium is 350 mg [24] and VA leaf can contribute 14% for fresh and 12% for dried. The low values for dried samples indicated that none of the drying methods was beneficial to increase magnesium in the vegetable.

The concentration of heavy metals (iron, copper and lead) as affected by the different drying methods is presented in Table 2.

Iron is required for haemoglobin formation and its deficiency leads to anaemia. The values obtained for iron are: fresh (2.40 mg/100 g), sun-dried (3.12 mg/100 g), oven-dried (2.73 mg/100 g), solar-dried (2.81 mg/100 g) and air-dried (2.95 mg/100 g). The recommended dietary allowance value for iron is 15 mg [24]. Dried VA can contribute 20% of iron to RDA while fresh can contribute 16% (Tables 3–6).

Copper plays a role in haemoglobin formation and it contribute to iron and energy metabolism. Copper is also required in one’s body for enzyme production and biological transfer of electron within one body [23]. Copper is also a key mineral in many different systems.
Table 2. The effect of drying methods on the elemental values of the five portions in mg/100g.

| Sample state   | Mg     | Ca      | Fe      | Cu      | Pb      | Total     |
|----------------|--------|---------|---------|---------|---------|-----------|
| Fresh          | 48.23 ± 0.06 | 64.73 ± 0.02 | 2.40 ± 0.12 | 0.31 ± 0.00 | 0.08 ± 0.00 | 114.75     |
| Air-dried      | 40.29 ± 0.03 | 71.16 ± 0.04 | 2.95 ± 0.06 | 0.29 ± 0.00 | 0.06 ± 0.00 | 112.77     |
| Sun-dried      | 43.04 ± 0.04 | 69.28 ± 0.01 | 3.12 ± 0.05 | 0.28 ± 0.00 | 0.05 ± 0.00 | 112.33     |
| Oven-dried     | 41.87 ± 0.01 | 67.43 ± 0.02 | 2.73 ± 0.07 | 0.26 ± 0.00 | 0.04 ± 0.00 | 110.9    |
| Solar-dried    | 42.46 ± 0.02 | 67.08 ± 0.01 | 2.81 ± 0.06 | 0.24 ± 0.00 | 0.04 ± 0.00 | 110.97    |

Note: Under: Values are means ± standard deviation.

Table 3. Result of proximate analysis with each chi-square expected value.

| Sample state | Moisture content (%) | Dry matter content (%) | Ash content (%) | Fibre content (%) | Lipid content (%) | Total     |
|--------------|----------------------|------------------------|-----------------|-------------------|-------------------|-----------|
| Air-dried    | 20.40                | 79.60                  | 10.38           | 4.02              | 2.64              | 117.02    |
| Sun-dried    | 15.25                | 84.75                  | 11.20           | 3.89              | 1.84              | 116.93    |
| Oven-dried   | 13.07                | 86.93                  | 10.92           | 3.54              | 2.53              | 116.99    |
| Solar-dried  | 12.80                | 87.20                  | 11.15           | 3.63              | 2.49              | 117.35    |

Table 4. Calculate expected value for proximate analysis from chi-square.

| $O$ | $E$ | $(O-E)$ | $(O-E)^2$ | $(O-E)^2/E$ |
|-----|-----|---------|-----------|-------------|
| 20.40 | 15.37 | 5.03 | 25.30 | 1.646 |
| 79.60 | 84.60 | -5.00 | 25.00 | 0.296 |
| 10.38 | 10.91 | -0.53 | 0.28 | 0.026 |
| 4.02 | 3.77 | 0.25 | 0.06 | 0.017 |
| 2.62 | 2.37 | 0.25 | 0.06 | 0.026 |
| 15.25 | 15.36 | -0.11 | 0.01 | 0.0008 |
| 84.75 | 84.54 | 0.21 | 0.04 | 0.0005 |
| 11.20 | 10.90 | 0.30 | 0.09 | 0.008 |
| 3.89 | 3.76 | 0.13 | 0.02 | 0.004 |
| 1.84 | 2.37 | -0.53 | 0.28 | 0.118 |
| 13.07 | 15.37 | -2.30 | 5.29 | 0.344 |
| 86.93 | 84.58 | 2.35 | 5.52 | 0.065 |
| 10.92 | 10.90 | 0.02 | 0.00 | 0.000 |
| 3.54 | 3.77 | -0.23 | 0.05 | 0.014 |
| 2.53 | 2.36 | 0.17 | 0.03 | 0.012 |
| 12.80 | 15.42 | -2.62 | 6.86 | 0.445 |
| 87.28 | 84.84 | 2.44 | 5.95 | 0.070 |
| 11.15 | 10.94 | 0.21 | 0.04 | 0.004 |
| 3.63 | 3.78 | -0.15 | 0.02 | 0.006 |
| 2.49 | 2.38 | 0.11 | 0.01 | 0.005 |

Total 3.1073

Table 5. Result of elemental analysis with each chi-square expected value.

| Sample state | Mg     | Ca      | Fe      | Cu      | Pb      | Total     |
|--------------|--------|---------|---------|---------|---------|-----------|
| Air-dried    | 40.29  | 71.16   | 2.95    | 0.29    | 0.06   | 114.75    |
| Sun-dried    | 43.04  | 69.28   | 3.12    | 0.28    | 0.05   | 115.77    |
| Oven-dried   | 41.87  | 67.43   | 2.73    | 0.26    | 0.04   | 112.33    |
| Solar-dried  | 42.46  | 67.08   | 2.81    | 0.24    | 0.04   | 92.64     |

Total 435.49

It is central to building strong tissue; maintain blood volume and producing energy in the cells. Yet, for all its critical importance, we don’t have much copper in our body. In foods we commonly eat, there are only very small amounts of copper so, the value of copper in VA leaf was higher for fresh (0.31 mg/100 g) and dried samples with a range of 0.24–0.29 mg/100 g. It showed that VA leaf was a low source of dietary copper. It also showed that none of the drying methods could improve the levels of copper in nutritive value of this vegetable. The recommended dietary allowance for copper is 1 mg for adults [24], dried VA can contribute 27% of copper to RDA while fresh can contribute 31%.

Lead serves no useful purpose in the human body, but its presence in the body can lead to toxic effects, regardless of exposure pathway. Lead toxicity can affect every organ system; the nervous system is the most sensitive target of lead exposure [23]. In children, lead affects particularly the development of the brain and nervous system while in adults, it increases the risk of high blood pressure and kidney damage. The values obtained for lead are: fresh (0.08 mg/100 g), sun-dried (0.05 mg/100 g), oven-dried (0.04 mg/100 g), solar-dried (0.04 mg/100 g) and air-dried (0.06 mg/100 g), showing a very minute content of lead, and drying shows to further reduce the quantity of lead. The risk of heavy metals like lead is associated with the consumption, showing...
that moderate consumption of bitter leaf has no risk of lead toxicity.

3.1. Statistical analysis using chi-square ($X^2$)

By using Chi-square $X^2$, i.e. the expected value is calculated using the formula:

$$X^2 = \sum \frac{(O_{ij} - E_{ij})^2}{E_{ij}},$$

where $O_{ij}$, observed frequency; $E_{ij}$, expected frequency; $ij$, one particular cell.

For hypothesis 1, from Table 1,

$$X^2 = \sum \frac{(O_{ij} - E_{ij})^2}{E_{ij}} = 3.1073. \quad (2)$$

To obtain the tabulated value, where, $r$, number of rows and $c$, number of columns:

$$(4 - 1)(5 - 1) = 3 \times 4 = 12.$$

Test at 1% level of significance (i.e. 99% confident limit):

$$X^2_{0.09, (12 \text{ df})} = 26.2.$$

3.1.1. Decision

Since $X^2 = 3.1073$ is less than the tabulated value (26.2), the null hypothesis ($H_0$) is accepted and the alternative hypothesis ($H_a$) is rejected.

Therefore, there is difference between the value of proximate content of the fresh bitter leaf (control) and the dried leaves at 1% significant level. This means that test at 1% level showed that the value of proximate content of dried bitter leaf is different from that of fresh bitter leaf.

For hypothesis 2, from Table 2,

$$X^2 = \sum \frac{(O_{ij} - E_{ij})^2}{E_{ij}} = 3.0553. \quad (3)$$

To obtain the tabulated value, where $r$, number of rows and $c$, number of columns:

$$(4 - 1)(5 - 1) = 3 \times 4 = 12.$$

Test at 1% level of significance (i.e. 99% confident limit):

$$X^2_{0.09, (12 \text{ df})} = 26.2.$$

3.1.2. Decision

Since $X^2 = 3.0553$ is less than the tabulated value, the null hypothesis ($H_0$) is accepted and the alternative hypothesis ($H_a$) is rejected.

Therefore, there is difference between the value of dietary elemental content of the fresh bitter leaf (control) and the dried leaves at 1% significant level. This means that test at 1% level showed that the value of dietary elemental content of dried bitter leaf is different from that of fresh bitter leaf.

4. Conclusion

This study shows how different drying methods can affect the dietary elemental composition of VA. The results of this study suggest that drying could improve the concentration of both organic and elemental constituents and oven–solar drying methods could be useful in preserving VA leaves in a more hygienic way and ensure its all-the-year round availability. This partly shows the uses of this plant in herbal medicine. As a rich source of minerals and beneficial elements, this plant can be seen as potential source of useful food and drugs. The result reveals that dried VA can contribute to the recommended dietary allowance about Fe (20%), Cu (27%), Mg (12%) and Ca (9%). VA is a good antianemic agent and antidiabetic agent because of the high contents of iron present in it. This information is useful in the pharmaceutical research industry and food industry particularly in the preservation of food.

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No potential conflict of interest was reported by the authors.

Author contributions

Designed and supervised the experiments: ZNG. Performed the experiments and analysed the data: SO.

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