Response of Nutritional and Phytochemical Constituents of Bitter Leaf to Some Drying Methods

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Authors’ contributions:

This work was carried out in collaboration between all authors. Authors Johnson Odukoya and Julianah Odukoya designed the study, managed the literature searches, discussed the results and wrote the final draft of the manuscript. Authors Johnson Odukoya and UC managed the experimental analyses. Author UC wrote the protocol and performed the statistical analysis. All authors read and approved the final manuscript.

ABSTRACT

Aim: Food processing is one of the post-harvest factors that affect the quality of food products. This research was aimed at evaluating the impact of two drying methods (sun-drying and freeze-drying) on the nutritional and phytochemical contents of Vernonia amygdalina Del.

Study Design: Processed vegetables of V. amygdalina were subjected to the selected drying methods and the composition of the dried samples was thereafter compared.

Place and Duration of Study: The eight-month study was carried out at the Food Chemistry Research Laboratory, Chemistry Department, The Federal University of Technology, Akure, Ondo State, Nigeria.
Keywords: Food processing; freeze-drying; nutritional composition; phytochemicals; sun-drying; Vernonia amygdalina.

1. INTRODUCTION

Vernonia amygdalina Del., with English name bitter leaf, is a shrub with green leaves which have a characteristic odour and bitter taste [1,2,3]. It is a drought tolerant plant [3], belonging to the Compositae family [4, 5], which grows in tropical Africa [6] and other parts of Africa, essentially in Nigeria, Cameroon and Zimbabwe [2]. The plant has been given different local names in Nigeria such as: 'Kiriologbo' (in Ijaw), 'Onugbu' (in Igbo), 'Ewuro' (in Yoruba) and 'Shiwaka' (in Hausa).

According to Winifred and Alexander [7], several species of Vernonia including V. amygdalina are consumed as leafy vegetables. The leaves of this plant are used as an ingredient in Nigeria for the preparation of 'Ogbon' soup and 'Ndole' dish in Cameroon after the removal of its bitter taste via soaking in several changes of water or by boiling [5]. Several authors such as Georgewill and Georgewill [1], Ebong et al. [4] as well as Igile et al. [6], have also reported the use of V. amygdalina leaves, containing phytochemicals like alkaloid and flavonoids, in traditional medicine for the treatment of malaria, diabetes and inflammatory disease.

Ijeh and Ejike [3], however, identified V. amygdalina as one of the under-utilised plants as its application in the human diet is limited to those culture that consume the plant after the removal of its bitter taste. In some cases, the leaves of this plant are presented in the dried form (alongside its fresh form) for sale at the market [7] or dried, before soaking in different water condition to remove the bitter taste, in the course of its soup preparation.

Generally, processing has been noted by Ratti [8] as well as Ciurzynska and Lenart [9] to partially or completely affect the quality of food product. Among other potential benefits, the dried food products according to Ahmed et al. [10] have enhanced taste, nutrients, storability and reduced size. According to Hassan et al. [11], sun-drying is the most common drying method for drying farm produce in most of the developing countries of the tropical region. Meanwhile, Odukoya [12] identified temperature as one of the post-harvest factors that affect the phytochemical contents of fruits and vegetables. In line with this author and others like Gonzalez-Vallinas et al. [13] as well as Liu [14], these phytochemicals are the natural non-nutritive bioactive compounds present in plants which promote human health.

Consequently, as V. amygdalina has been noted to have both culinary and medicinal application, this research is aimed at comparing the impact of sun-drying and freeze-drying methods on the nutritional and phytochemical contents of the leaves of this vegetable. This is of immense importance as freeze-drying is currently regarded as a standard processing technique in the bio-sector as it helps in the production of high quality stable products [9]. Mohammadzadeh and Hatamipour [15] added that, most times, it is the
only suitable drying process that can be used to produce dried products of high quality.

2. MATERIALS AND METHODS

2.1 Collection and Preparation of Samples

The leaves of V. amygdalina used for the research were harvested fresh from a farm in Aba-Oyo village, Akure, Ondo State, Nigeria. They were identified as well as authenticated at the Crop Science and Pest Department of The Federal University of Technology, Akure, Ondo State, Nigeria. Thereafter, the leaves were rinsed with distilled water and divided into two portions to be dried by sun-drying and freeze-drying methods. The dried vegetable samples were then finely ground into powder and kept cool prior to analyses.

2.2 Determination of Proximate Composition

The methods of Association of Official Analytical Chemists, AOAC [16], were used for the determination of the proximate composition (dry matter, ash, crude fat, crude fibre and crude protein contents) of the sun-dried and freeze-dried V. amygdalina samples. The dry matter content of the samples was evaluated by oven-drying a known weight of the homogenized sample at 105°C for three hours until a constant weight was obtained. For the determination of the ash content, the muffle furnace temperature was gradually increased to 550°C in order to achieve complete ashing. Soxhlet apparatus with extraction under reflux with n-hexane was used for the assessment of the crude fat content of the vegetable samples. The crude fibre content determination of the samples was achieved with the use of 0.125 M H₂SO₄ and 1.25% NaOH and filtration using a Buckner funnel as well as a muslin cloth at an appropriate time. Kjeldhal method was carefully followed for the determination of the crude protein content while the total carbohydrate content of the samples was obtained by difference.

The total energy value in kcal/100 g present in the V. amygdalina sample was determined using the method described by FAO [17] and Adinortey et al. [18] given as:

\[
\text{Energy value} = (\% \text{ Crude protein} \times 4) + (\% \text{ Crude fat} \times 9) + (\% \text{ Carbohydrate} \times 4)
\]

2.3 Determination of Minerals Contents

Aside from the use of a Flame Photometer (FP 902 model) for the determination of sodium and potassium contents, the assessment of the distribution of the major and minor dietary minerals as well as the mineral contaminants was done using Atomic Absorption Spectrophotometer (Buck Scientific 210 VGP Model).

2.4 Phytochemicals Screening

The phytochemical constituents of the aqueous and ethanolic extract of the powdered samples were preliminary assessed using the methods of: Harborne [19], Trease and Evans [20] and Sofowora [21]. The phytochemicals tested were: saponin, tannin, alkaloid, cardiac glycosides (Keller-Killani test), terpenoids (Sallowski test), sterols, phlobatannins and flavonoid.

2.5 Quantification of Phytochemicals

2.5.1 Determination of total phenols content

The modified method of Singleton et al. [22] was used for the determination of total phenols content of the powdered vegetables’ samples. In this, 0.2 ml of the vegetable extract was mixed with 2.5 ml of 10% Folin and Ciocalteu’s phenol reagent and 2 ml of 7.5% sodium carbonate. The reaction mixture was then incubated at 45°C for 40 mins and the absorbance was measured at 700 nm using a spectrophotometer with gallic acid as the standard.

2.5.2 Determination of total flavonoids content

The determination of the total flavonoids content of the powdered vegetables’ samples involved the use of the modified method of Bao et al. [23]. Extract (0.2 ml) was added to 0.3 ml of 5% NaNO₃. After five mins of this addition, 0.6 ml of 10% AlCl₃ was added and after six mins, 2 ml of 1 M NaOH was added to the mixture followed by the addition of 2.1 ml of distilled water. Absorbance was read at 510 nm against the reagent blank and the total flavonoids content was expressed as mg rutin equivalent.

2.5.3 Determination of vitamin A content

A weighed quantity of the sample containing not more than one gram fat and at least 240 unit of
vitamin A was mixed with 30 ml absolute alcohol and 3 ml of 5% potassium hydroxide boiled gently under reflux. After rapid cooling, 30 ml of water was added before the transfer to the separator. Washing with ether was done followed by extraction of vitamin A by shaking for one min. The residue obtained from the complete separation, washing as well as evaporation of washed extract was then dissolved in sufficient isopropyl alcohol to give a solution containing 9 – 15 units per ml. The extinctions at appropriate wavelengths (300, 310, 325 and 334 nm) were measured accordingly [24].

2.5.4 Determination of vitamin C content

For the vitamin C (ascorbic acid) content determination, 200 μl of the aqueous extract was pipetted and mixed with 300 ml of 13.3% of trichloroacetic acid (TCA) and 75 μl of DNPH (2 g dinitrophenyl hydrazine, 230 mg thiourea and 270 mg CuSO$_4$·5H$_2$O in 100 ml of 5 M H$_2$SO$_4$). The mixture was incubated at 37°C for 3 h and H$_2$SO$_4$ was added. Thereafter, the absorbance was read at 520 nm and the vitamin C content of the extract was consequently calculated using ascorbic acid as the standard [25].

2.6 Statistical Analyses

All data represent means of triplicate determinations and are expressed as mean±standard deviation. The IBM Statistical Package for Social Scientists (Version 20) was used to carry out the Independent-samples t-test where applicable.

3. RESULTS AND DISCUSSION

3.1 Proximate Analysis

Moisture content determination is commonly used in the processing and testing of food [26]. The moisture content of the powdered vegetable samples obtained from the two drying methods are shown in Table 1 (in percentage) and 2 (in g/100 g DW). The latter, i.e. Table 2, gives the proximate analysis result of the powdered vegetable samples in terms of their dry weight equivalence.

The outcome of the moisture content test revealed that the freeze-dried vegetable samples had significantly lower moisture content (p < 0.05). This indicates that the freeze-drying process had better drying action on the vegetables than sun-drying. Hence, the freeze-dried vegetable samples with lower moisture content would have a higher shelf life and present more hindrance to the growth of microorganism [27,28].

Meanwhile, the proximate composition of the dried leaves as shown in Table 1 and 2, revealed that the two drying methods had no significant effect on the crude fibre content of V. amygdalina leaves.

Aliero and Abdullahi [29] attributed the significantly higher concentration of ash in sun-dried samples to the uncontrollable exposure of the vegetables to dust during sun-drying. Meanwhile, in line with the work of Reis et al. [30], the difference in the lipid content observed in this study suggest that the freeze-drying process led to fat degradation in the course of drying. The outcome of the crude protein analysis in which the sun-dried samples had lesser crude protein content supports the work of Clement et al. [31] where the least protein content of Moringa oleifera leaves was recorded at the highest drying temperature. It is also similar to that of Duan et al. [32]. According to these authors (i.e. Duan et al. [32]), the reduced crude protein content recorded in the sun-dried sample could be attributed to the long drying time at normal temperature during sun-drying in which the crude protein may have become decomposed or transformed.

Generally, as noted in Andzouana and Mombouli [26], the rich level of protein recorded in the leaves of V. amygdalina makes it good for consumption as a source of vegetable protein. It also suggests the presence of a high amount of essential amino acids in the leaves which can act as an alternative source of energy when carbohydrate metabolism is impaired via gluconeogenesis [26,33]. Based on the crude protein contents, the leaves of this plant can help in the provision of important body constituents, maintenance of fluid balance, the formation of hormones and enzymes as well as contributing to immune function [26].

According to Onyeike et al. [34], dietary carbohydrate is the main source of energy for the brain and essential for the maintenance of glycemic homeostasis as well as gastrointestinal function. As noted in Ciurzynska and Lenart [9] as well as Odukoya et al. [35], that processing gives rise to changes in the physical, chemical and/or biological characteristics of food, the carbohydrate content of the sun-dried samples, calculated by difference, was found to be higher than that of the freeze-dried samples while the
latter (i.e. the freeze-dried samples) had higher energy content (Table 2). Notwithstanding, the low amount of carbohydrate found in the V. *amygdalina* leaves support the findings in the literature, such as Andzouana and Mombouli [28] as well as Adjatin et al. [36], that most vegetables are not rich in carbohydrate.

### 3.2 Minerals Content

Dietary minerals are the other elements aside from carbon, hydrogen, oxygen and nitrogen that are present in foods [12,37,38] while the total mineral content of foods is a function of the ash value [12,39]. The statistical analysis of the experimental outcome on the minerals’ distribution in the powdered vegetable samples showed that sodium and manganese were the only dietary minerals not affected by the drying methods. Aside from zinc and lead, the powdered samples obtained via freeze-drying method had significantly (p < 0.05) higher concentration of all the minerals tested in this study. The observed differences in the concentration of most of the minerals in the vegetable samples from the two drying methods further support the view of Ciurzynska and Lenart [9], including Odukoya et al. [35], as earlier noted in Section 3.1 that processing affects food attributes.

Although the sun-dried vegetable samples would contribute more to the synthesis of metallothionein as a result of its higher zinc concentration [40], the consumption of the freeze-dried vegetables in relation to its higher magnesium, calcium, potassium, copper and iron contents would contribute more to the: (1) preventive action against circulatory diseases [36], (2) blood clotting and nerves functions [41], (3) maintenance of body fluid volume and osmotic equilibrium [28], (4) stimulation of body defence system [41], and (5) haemoglobin formation, normal functioning of the central nervous system as well as oxidation of carbohydrate, protein and fats [36,41,42,43], respectively.

Analysis of undesirable mineral contaminants revealed that lead contents of the samples from the two drying methods were below the FAO/WHO Codex maximum level of 0.30 mg/kg [44] indicating that the inclusion of these dried vegetables in the human diet would not give rise to lead contamination. Although the cadmium content of the freeze-dried samples was found above the FAO/WHO Codex maximum level of 0.20 mg/kg [44], they were still lower than the maximum permissible concentration of the element (1 mg/kg DW) in vegetables for human consumption as noted in Samara [45].

#### Table 1. Proximate composition (%) of the dried *V. amygdalina* leaves

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Sun-dried sample</th>
<th>Freeze-dried sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture content</td>
<td>11.21±0.39a</td>
<td>7.62±0.59a</td>
</tr>
<tr>
<td>Ash content</td>
<td>13.94±2.35a</td>
<td>9.75±0.34b</td>
</tr>
<tr>
<td>Lipid content</td>
<td>6.77±0.50a</td>
<td>5.02±0.70b</td>
</tr>
<tr>
<td>Crude Fibre content</td>
<td>10.62±0.31a</td>
<td>10.15±0.49a</td>
</tr>
<tr>
<td>Crude Protein content</td>
<td>38.97±3.99b</td>
<td>57.41±1.69a</td>
</tr>
<tr>
<td>Total Carbohydrate content</td>
<td>18.49±5.12a</td>
<td>10.05±1.35b</td>
</tr>
</tbody>
</table>

Values are means of three replicates; standard deviation.

Means followed by different letters are significantly different (p < 0.05).

#### Table 2. Proximate composition g/100g DW of the dried *V. amygdalina* leaves

(Energy measured in kcals/100 g)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Sun-dried sample</th>
<th>Freeze-dried sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry weight</td>
<td>88.79±0.34a</td>
<td>92.38±0.59a</td>
</tr>
<tr>
<td>Ash content</td>
<td>15.79±2.65a</td>
<td>10.56±0.37b</td>
</tr>
<tr>
<td>Lipid content</td>
<td>7.62±0.56a</td>
<td>5.44±0.75b</td>
</tr>
<tr>
<td>Crude fibre content</td>
<td>11.96±0.35a</td>
<td>10.98±0.53c</td>
</tr>
<tr>
<td>Crude protein content</td>
<td>43.89±4.49b</td>
<td>62.15±1.82c</td>
</tr>
<tr>
<td>Total carbohydrate content</td>
<td>20.83±5.77a</td>
<td>10.88±1.46d</td>
</tr>
<tr>
<td>Energy (kcals/100 g)</td>
<td>327.48±14.72b</td>
<td>341.02±2.31a</td>
</tr>
</tbody>
</table>

Values are means of three replicates; standard deviation.

Means followed by different letters are significantly different (p < 0.05).
Flavonoids, phlobatannins, sterols, terpenoids, cardiac glycosides, alkaloids, tannins, and saponins are phytochemicals found in plants. These compounds are present in relatively small amounts in plants. Flavonoids, for instance, have been found to have the potential to reduce the risk of major chronic diseases like heart disease, cancer, stroke, diabetes, Alzheimer’s disease and cataracts. Steroids, as indicated in Adeniyi et al. [51], have antibacterial properties and relationship with compounds such as sex hormones. These authors, i.e. Adeniyi et al. [51], also recorded that terpenoids play key roles in the healing of wounds and scars while it was noted in Ojieh et al. [52] that glycosides lower blood pressure.

Nonetheless, as indicated in Nieman et al. [46] and Odukoya [12,47], only the vegetable samples obtained via the freeze-dried method with Na/K ratio < 0.6 would not contribute to high blood pressure.

### 3.3 Phytochemical Screening

Phytochemical screening is a vital step in the evaluation of some biological components in plants [35,48]. Although these bioactive compounds (referred to as phytochemicals) are found in relatively small amounts in plants, they have human health benefits [12,13,14].

The outcome of the phytochemical screening of the vegetable samples from the two drying methods as shown in Table 4 revealed that both the aqueous and ethanolic extracts of the sample indicated the presence of tannin, alkaloid, cardiac glycoside, terpenoid, steroid and flavonoid. Saponin was only detected in the aqueous extract while phlobatannins were not detected in the aqueous and ethanolic extracts of the dried samples.

The medicinal advantages of the *V. amygdalina* can be attributed to the presence of some phytochemicals in these powdered samples [50] which have human health benefits. Flavonoids, for instance, have been found to have the potential to reduce the risk of major chronic diseases like heart disease, cancer, stroke, diabetes, Alzheimer’s disease and cataracts [12,14]. Steroids, as indicated in Adeniyi et al. [51], have antibacterial properties and relationship with compounds such as sex hormones. These authors, i.e. Adeniyi et al. [51], also recorded that terpenoids play key roles in the healing of wounds and scars while it was noted in Ojieh et al. [52] that glycosides lower blood pressure.

However, the presence of some antinutrients (e.g. tannins and saponins) shows the tendency for interference with nutrient utilization. Tannins inhibit the bioavailability of proteins and minerals [35,42] while some of the characteristics of saponins as noted in Ojieh et al. [52], include the formation of foams in aqueous solution, hemolytic activity, cholesterol binding properties and bitterness.

### 3.4 Total Phenols and Total Flavonoids Contents

Among the groups of polyphenols, flavonoids have attracted most research interest [12,35,53]. This can be attributed to the findings of Liu [14] that they have the potential to reduce the risk of chronic diseases like heart disease, cancer, stroke, diabetes, Alzheimer’s disease, and cataracts. Following the result of the phytochemical screening in which flavonoid was detected to be present in the dried vegetable samples, the total flavonoids and total phenols were evaluated with the experimental outcome provided in Table 5.

### Table 3. Minerals distribution (mg/kg DW) in the dried V. amygdalina leaves

<table>
<thead>
<tr>
<th>Minerals</th>
<th>Sun-dried sample</th>
<th>Freeze-dried sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Na</td>
<td>15.25±0.05</td>
<td>16.50±2.90</td>
</tr>
<tr>
<td>Mg</td>
<td>3.81±0.91</td>
<td>5.75±0.66</td>
</tr>
<tr>
<td>Ca</td>
<td>45.35±0.65</td>
<td>105.33±2.89</td>
</tr>
<tr>
<td>K</td>
<td>13.60±0.10</td>
<td>161.50±11.50</td>
</tr>
<tr>
<td>Fe</td>
<td>2.07±0.01</td>
<td>4.29±0.16</td>
</tr>
<tr>
<td>Cu</td>
<td>0.60±0.01</td>
<td>0.78±0.00</td>
</tr>
<tr>
<td>Zn</td>
<td>0.59±0.12</td>
<td>0.42±0.01</td>
</tr>
<tr>
<td>Mn</td>
<td>0.34±0.00</td>
<td>0.35±0.01</td>
</tr>
<tr>
<td>Cd*</td>
<td>0.01±0.00</td>
<td>0.72±0.00</td>
</tr>
<tr>
<td>Pb*</td>
<td>0.18±0.00</td>
<td>0.13±0.00</td>
</tr>
<tr>
<td>Na/K</td>
<td>1.12±0.01</td>
<td>0.10±0.01</td>
</tr>
</tbody>
</table>

*Selected undesirable mineral contaminants analysed in the samples; Values are means of three replicates ± standard deviation; Means followed by different letters are significantly different (p < 0.05).*

### Table 4. Phytochemical screening of the dried *V. amygdalina* leaves’ extract

<table>
<thead>
<tr>
<th>Phytochemicals</th>
<th>Sun-dried sample</th>
<th>Freeze-dried sample</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Aqueous extract</td>
<td>Ethanolic extract</td>
</tr>
<tr>
<td>Saponins</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Tannins</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Alkaloids</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Cardiac glycoside</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Terpenoids</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Sterols</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Phlobatannins</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Flavonoids</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

Key: (+) = Detected, (-) = Not Detected
The result as shown in Table 5 showed that the freeze-dried vegetable leaves have a significantly lower concentration of total phenols and total flavonoids. In a way, this is similar to the outcome of the investigation of Leong and Oey [54] on food processing conditions in which the freeze-dried samples had lower phytochemicals content. According to these authors (i.e. Leong and Oey, [54]), although freeze-drying is effective for the preservation of sensory and nutritional qualities, the phytochemicals in freeze-dried samples are more prone to degradation as a result of the large surface area of the samples exposed during processing. This brings about fast oxidation of most of the labile phytochemicals as water molecules, acting as a protecting film on the sample surface, are also evaporated [54].

Table 5. Total phenols and total flavonoids contents of the dried V. Amygdalina leaves

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Sun-dried sample</th>
<th>Freeze-dried sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Phenols (mg/g)</td>
<td>4.75±0.08a</td>
<td>2.87±0.11b</td>
</tr>
<tr>
<td>Total Flavonoids (mg/g)</td>
<td>4.03±0.12a</td>
<td>2.14±0.87b</td>
</tr>
</tbody>
</table>

Values are means of three replicates±standard deviation; Means followed by different letters are significantly different (p < 0.05).

### 3.5 Vitamins Content

Vitamins are essential micronutrients and their concentrations in plants are influenced by variety, growing conditions, postharvest storage conditions as well as processing [12,38]. In this research, attention was focused on two of the most important vitamins in food science and technology (vitamin A and C – the former being a fat-soluble vitamin and the latter, a water-soluble vitamin) [12,37]. These two vitamins are antioxidants [43,55].

The experimental results as shown in Table 6 revealed that the freeze-dried V. amygdalina samples had significantly (p < 0.05) higher concentration of vitamin A and C than samples obtained via sun-drying.

This outcome supports the previous finding that processing affects the vitamin contents of plants [12,38] and that vitamin can be best preserved by freezing [12,37]. More specifically, it is in line with the work of Clement et al. [31] where the least vitamin A and C contents were recorded at the highest drying temperature used in their experiment. The results of the vitamins analysis in this study further suggests that the consumption of the freeze-dried sample with higher vitamin A content would assist in the regulation of gene expression and cell differentiation [43]. These samples with a higher concentration of vitamin C would also help more in: (1) strengthening the body immunity against infection, collagen and thyroxine synthesis, iron absorption [12,43,55], (2) maintaining a healthy lifestyle and preventing diseases [36], as well as (3) healthy formation of bones, gums and teeth [42,50].

Table 6. Vitamins content of the dried V. amygdalina leaves

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Sun-dried sample</th>
<th>Freeze-dried sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vitamin A</td>
<td>6732.60±1.80</td>
<td>10233.90±55.40</td>
</tr>
<tr>
<td>Vitamin C</td>
<td>49.91±0.05</td>
<td>83.31±2.98</td>
</tr>
</tbody>
</table>

Values are means of three replicates±standard deviation; Means followed by different letters are significantly different (p < 0.05).

### 4. CONCLUSION

Principally, the experimental results revealed that freeze-drying method is more appropriate for the drying of vegetable samples where the main focus is on the concentration of crude protein, major dietary minerals, vitamin A and C. Following the view of Mensah et al. [55], it further shows that the leaves of V. amygdalina can be recommended for patients suffering from protein deficiency diseases. The results obtained from the sun-drying of vegetable samples in which some of the parameters tested (such as the ash, lipid, carbohydrate, zinc, cadmium, total phenols and total flavonoids contents) were favoured by sun-drying, support the view of Hassan et al. [11] that the application of heat can have both beneficial and detrimental effect on the nutritional composition of foods. Although to a large extent the freeze-dried samples were found to be of higher quality, the high operating cost of freeze-drying as a result of the slow sublimation rate at very low temperature and pressure [15] makes the drying method only economical for commercial drying of vegetables. Further work is needed to determine the impact of selected drying methods as considered in this study on the level of antinutrients in food samples.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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