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A REVIEW OF THE PROCESS, EFFECTS AND BENEFITS ON SOLAR DRYING OF AFRICAN LEAFY VEGETABLES

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ABSTRACT

Micronutrient deficiencies affect over two billion people globally, with Africa facing significant challenges in ensuring adequate nutrition for its growing population. African leafy vegetables (ALVs) are a traditional part of local diets and hold potential to combat hunger and micronutrient deficiencies if their availability and consumption are increased. Solar drying, a simple and sustainable post-harvest technology, can extend the shelf life and marketability of these vegetables and is also a cost-effective solution to improve food preservation and security. The objective of this review is to provide a comprehensive understanding of the solar drying process, as applied to ALVs, its effects and benefits. It is a structured narrative review of online sources including peer-reviewed articles, books, theses and various publications that focus on solar drying technologies, conditions, effects and challenges related to ALVs. A thorough search was carried out using search engines including Google search, Google Scholar and ResearchGate, with terms such as 'drying of indigenous leafy vegetable,' 'solar- drying,' 'solar dryers,' 'solar-dried African leafy vegetables,' 'effects of solar drying on ALVs,' 'nutritional value of dried ALVs' and 'bacterial load of solar-dried ALVs'. Solar drying methods include direct, indirect, mixed-mode, and hybrid technologies, with optimal conditions ranging from 10 - 30°C above ambient temperatures. Mixed-mode solar dryers offer several advantages over other methods which rely fully on solar energy. Drying takes 2 - 5 days depending on the dryer, the vegetable type and the prevailing weather conditions. While solar drying helps reduce microbial contamination, extends shelf life and antinutrients, it can also lead to nutrient loss – proximate, vitamins, minerals, phytochemicals and affect the sensory quality of the vegetables, depending on factors like drying method, vegetable type and environmental conditions. Other variables influencing the dried product's quality include the variety of vegetables, its maturity, climate during growth and the time between harvest and drying. Despite its challenges and limitations, solar drying preserves food, conserves resources, and promotes sustainable food systems, contributing to food security, environmental sustainability and economic efficiency.

Key words: Solar drying, African leafy vegetables, nutrients, shelf-life, safety, acceptability

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INTRODUCTION

Micronutrients, including essential vitamins and minerals, are crucial for various bodily functions such as growth, immune health and brain development. However, over two billion people globally suffer from micronutrient deficiencies, with Southeast Asia and sub-Saharan Africa being particularly affected [1, 2]. In Kenya, deficiencies in vitamins A, cobalamin B_{12}, folate B_9, iron, iodine and zinc are widespread, especially among pregnant women, children and the general population [3]. Addressing these deficiencies requires strategies like nutrition education, dietary diversity, food fortification and supplementation, aligned with Sustainable Development Goal 2 and the African Union's Agenda 2063 [4, 5].

Fruits and vegetables, particularly African leafy vegetables (ALVs), are vital sources of micronutrients, providing essential vitamins (like beta-carotene, vitamin C and E), minerals (iron, calcium and zinc), protein, fiber, and antioxidants [6]. African leafy vegetables help combat hidden hunger and food insecurity [7, 8]; but their availability is limited due to seasonality and post-harvest losses, which can reach up to 50% [5, 9, 10, 11]. Thus, preserving ALVs year-round is essential for improving nutrition and combating micronutrient malnutrition [12, 13].

Various processing techniques, such as washing, fermentation, blanching, freezing, canning, and pulverizing, can enhance the shelf life, nutritional value and marketability of ALVs. The choice of method depends on available resources, market demand and desired outcomes, with innovation potentially leading to new products [5]. One ancient, cost-effective method for preserving food is solar drying, particularly through sun drying, which uses solar energy to remove moisture from food while maintaining its nutritional value and flavor [14]. This method is especially beneficial in rural areas with abundant sunlight, offering an environmentally friendly, economically viable solution for improving food security by preserving surplus produce [15]. Solar drying not only ensures food availability during off-seasons but also reduces transportation costs by lowering bulk and weight and extends shelf life [16].

This review explores the role of solar drying in preserving ALVs, examining various methods and technologies, optimal drying conditions, impacts on nutritional content, shelf life, microbial safety, and economic and environmental benefits. It contributes to the development of solar drying technologies to address food security challenges.

MATERIALS AND METHODS

This paper provides a comprehensive and structured narrative review on solar drying of African leafy vegetables, synthesizing the current knowledge and contributing to the development of the field. The search encompassed online sources, peer-

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reviewed journal articles, books and other publications. Additionally, published literature from universities and national research institutions, including student theses, conference proceedings, working papers and project reports, were considered. A thorough search was carried out using the search engines Google Search, Google Scholar and ResearchGate, with terms such as 'drying of indigenous leafy vegetable,' 'solar- drying,' 'solar dryers,' 'solar-dried African leafy vegetables,' 'effects of solar drying on ALVs,' 'nutritional value of dried ALVs' and 'bacterial load of solar-dried ALVs.' Ninety-seven articles were downloaded and scrutinized for this review, during the second quarter of 2024. The title of the article and the abstract were used to sort the literature to be used for this review. Only literature highlighting the technologies, processing and drying conditions, effects of solar drying on ALVs, the benefits, challenges and those not very old were selected. The majority of the articles selected were published in the last 10 years with a few chosen which had specific data that had been published in earlier years.

RESULTS AND DISCUSSION

The different methods and technologies used for drying of ALVs using solar energy

Different methodologies and techniques are used in drying ALVs using solar energy. The objective is to optimize and standardize the drying process to ensure the production of high-quality products. Drying technologies are primarily assessed based on their ability to reduce water activity with low energy cost while maintaining the good sensory qualities of the dried products. Utilization of the proper drying techniques is the most important aspect of leafy vegetable preservation [17]. The methodology used determines the quality of the dried product in terms of nutrients retention, colour, taste, texture, duration of drying and exposure to contaminants.

Open sun drying involves vegetables being evenly spread on trays under direct exposure to sunlight or rays (29±5^{o}C) until the samples are brittle. Open sun drying not only takes longer to dry produce than solar dryers but is also prone to contamination from stray animals, flies, foreign matter and microbes. Aflatoxin-producing fungi can become a problem, especially when drying is slow and done without regard to good drying practices. Prolonged drying times result in products with inconsistent colour, taste and lower nutritional value [12,18-21].

Solar dryers: A solar dryer converts solar energy into heat and helps to reduce or remove the moisture content of a substance to be dried by boosting the dehydrating temperature and reducing the relative humidity. The high air temperature in the solar dryer significantly reduces the drying time of raw materials by 2.5-4.5 times compared to traditional drying in the sun [22].

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Solar dryers have a structure that regulates the drying process and protects the product from damage by dust, rain and insects [23]. Therefore, the quality of the product resulting from solar-drying is better than the sun-dried products in terms of colour, taste and nutritional value [12, 18 - 21].

There are many versions of solar dryers, depending on how they are constructed, the materials used and drying modes. Solar dryers have been classified according to (i) nature of airflow, (ii) mode of heat transfer from the sun to the product, and (iii) nature of the drying chamber [24]. They have also been categorised as direct dryers, indirect dryers, mixed-type dryers, which can have natural air circulation (passive dryers) or forced air circulation (active dryers). In their construction, they can either be box-type, cabinet or tunnel dryers, as shown in Figure 1.

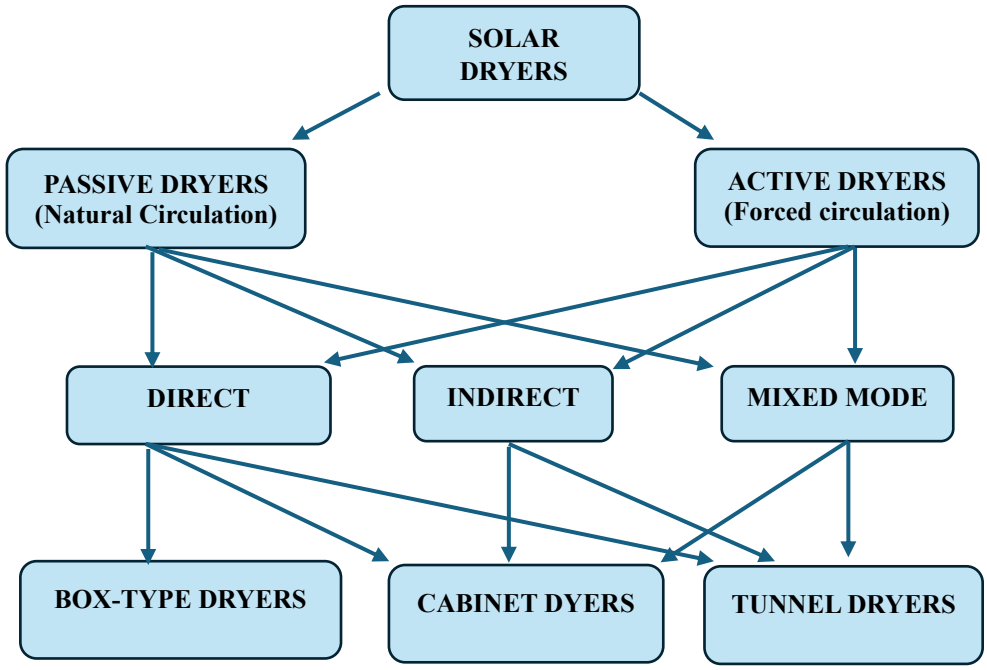

Figure 1: Classification of solar dryers

A **direct solar dryer** is the conventional method for drying agricultural and food products. It uses a transparent cover (such as glass or polyethylene) to minimize heat loss, protect the food from contamination, and capture solar radiation. The dryer has insulated side walls and enclosures where heat builds up to dry the food [15, 18-20, 25]. Sunlight and heat from the surrounding air evaporate moisture from the product. Unlike open sun drying, direct solar dryers protect food from rain, snow and debris. However, they have drawbacks, including excessive internal heat that can degrade product quality, slow drying due to low vapor removal, potential color changes from direct sunlight exposure, and reduced transmissivity from moisture condensation inside the cover [26].

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An **indirect solar dryer** consists of two main parts: an enclosure for drying food and a separate solar radiation collector that preheats the air before it enters the drying area. These dryers are classified into natural and forced-convection systems based on how air is moved over the product. The drying process occurs as hot air transfers heat to the product, causing moisture to evaporate [26]. Compared to direct solar dryers, indirect ones offer advantages like better control over the drying process and product quality, protection from localized heat, suitability for drying thick layers and photosensitive crops, and greater drying efficiency.

A **mixed-mode type solar dryer** combines direct and indirect solar drying techniques. It features two heat sources: solar radiation that directly heats the product through a transparent cover, and preheated air from a solar thermal collector [20]. The design also includes a chimney to improve airflow. This type of dryer offers several benefits: reduced drying time, improved product quality, and decreased pungency.

A **hybrid Solar Dryer** uses both solar energy and another energy source (like electricity or biomass) to dry agricultural products efficiently, even in unfavorable weather. These dryers combine solar energy with thermal backup systems, where thermal energy is stored in materials like solids or liquids. This energy is used when solar power is unavailable, ensuring continuous drying at a consistent air temperature, which prevents microbial degradation. Benefits include reliability (consistent drying even without sunlight), efficiency (low operational costs with reliable energy sources), and improved product quality (preserved nutritional content, color, and flavor). Solar-assisted drying is commonly used in developing countries due to abundant solar radiation and increasing fossil fuel costs [26].

The optimal conditions (temperature and timelines) for solar drying ALVs

The optimal conditions applicable for solar drying are difficult to ascertain as the process has many variables, including type of solar dryer, the weather conditions and vegetable species being dried. This section outlines a few examples of reported optimal solar drying conditions.

A solar dryer that had black polythene sheet covering its exterior and opposite ends, recorded the highest mean temperature of 30.13°C to 47.32°C in various panels in Mampong, Ghana during drying depending on the weather conditions, time of day and construction material. The drying period ranged between 3 and 5 days for all samples of cocoyam leaves (*Xanthosoma sagittifolia*), bitter leaf (*Vernonia amygdalina*), ayoyo leaf, moringa (*Moringa aleofera*) and waterleaf (*Talinum triangulare)* in various dryers [27]. These results are supported by other researchers who reported that the temperatures of vegetables during sun drying are usually 10

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– 30°C above ambient temperatures (in Baringo County, Kenya) and the time for drying African nightshade (*Solanum scabrum)* and the spider plant (*Cleome gynandra)* was three to four days [25]. In another experiment, using the mixed modes solar drier, leaves and flowers of the spider plant (*Cleome gynandra*) had drying time of 270 ± 6 min with their moisture content meeting the industry standard for dehydrated vegetables of ≤8.4% (in Eldoret, Kenya) [20]. In this experiment, the highest temperatures recorded were 69.2°C, 45.1°C and 41.8°C for mixed, indirect and open sun drying methods, respectively. Hence, the drying temperature in mixed solar dryer was significantly higher than the temperature in indirect and open sun drying methods. Finally, researchers in Arusha, Tanzania reported that the mixed mode solar drier used an average of 5.3 hrs, the indirect solar dryer used an average of 12.6 hrs while the open sun drying used an average of 10.2 hrs to dry African nightshade samples [27]. These dryers were found to differ in their drying rates, where the mixed mode solar dryer dried the vegetables very fast. Leafy vegetables such as amaranth and African nightshade will dry within a day. Simple solar dryers maintain temperatures of 15-35°C higher than open sun-drying conditions; too high temperatures (above 60°C) can result in low quality products (discoloured, loss of critical nutrients and antioxidants).

The effects of solar drying on the nutritional content of ALVs

Research in indigenous leafy vegetables often concentrates on levels of vitamin C, beta-carotene, iron, calcium and zinc. These nutrients are essential for human health and are often deficient in many populations, especially in developing countries. They are often in bioavailable forms in indigenous leafy vegetables, making them effective sources for addressing nutritional deficiencies. Ensuring an adequate intake of these nutrients can help address common deficiencies and improve overall health. In recent years, more researchers are studying phytochemicals in indigenous leafy vegetables. This can uncover valuable information about their health benefits, validate traditional uses, and promote their inclusion in modern diets for improved health outcomes. Drying ALVs can lead to considerable loss of the available bioactive compounds due to thermal degradation depending on the drying method and temperature conditions [15, 28, 29].

Effects on proximate composition

It has been reported that dehydration methods have little effect on the proximate composition of dried ALVs [30]. However, some researchers have shown some reduction in the levels of protein with a range of 28-43% as shown in Table 1 [31]. Others indicated that there was concentration of the proximate components due to the removal of water [32]. From the data used in this review, the mean decrease in protein after solar drying is 13.1% (Range: -21.2 to 43%), for lipids is 0.61% (Range: -11 to 7%) and an increase of 1.65% (Range: -0.66 to 2.58%) for fiber.

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Effects on vitamins

Though drying leads to loss of a proportion of water-soluble vitamins like vitamin C (ascorbic acid), fat soluble vitamins like beta-carotene are well-retained [33]. Several researches undertaken in solar drying of ALVs support this assertion as shown in Table 2. It is evident that the range of percentage loss in both vitamin C and beta-carotene in experiments conducted by different researchers and for different vegetables varies greatly. There are many factors which contribute to this as outlined below. From the data used in this review, the mean decrease in vitamin C after solar drying is 66.2% (Range: 26 to 97%), and 33.3% (Range: -91 to 76%) for beta-carotene. It is evident that there is interest in many ALVs, though the favorites are amaranth leaves, African nightshade and cowpea leaf.

In recent years, extensive efforts have been directed towards enhancing nutrient retention in dried products through modifications in processing methods and/or pretreatment [30]. One of these modifications is the adoption of blanching leafy vegetables. Blanching for 2-3 min at 95-100^{o}C before drying results in better retention of beta-carotene and vitamin C [34]. Blanching cowpea leaves improved beta-carotene and vitamin C retention by 15% and 7.5%, respectively [18].

Despite the losses, a significant amount of vitamins remain in the dried vegetables. It was been reported that a 100 g portion of relish made from solar-dried vegetables contributed between 120% and 275% of the recommended vitamin A level. Hence, consuming a 100 g portion of solar-dried vegetable relish could meet the recommended daily intake of vitamin A [35].

Effects on minerals

Several studies have assessed the impact of solar drying on minerals in ALVs (Table 3). It is evident that the range of percentage loss in iron, calcium and zinc in experiments by different researchers and for different vegetables greatly varies. There are many factors which contribute to this as outlined below. From the data used in this review, the mean decrease in iron after solar drying is 44.2% (Range: -10 to 97%), for calcium is 36.8% (Range: 6 to 98%) and 41.6% (Range: -3 to 93%) for zinc. There is interest in many ALVs, though amaranth leaves, African nightshade and cowpea leaf are commonly researched.

Blanching usually causes significant reduction in mineral content of ALVs. However, solar drying does not cause significant change in the mineral content of vegetables [5, 36]. Some researchers have reported an increase in the level of vitamins and minerals after solar drying [37]. Possible explanation is failure to consider the lost water during calculations, or failure to calculate values on dry weight basis.

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Effects on phytochemicals

It has been reported that the levels of phytochemical components such as flavonoids, alkaloids, phenols, tannins and antioxidants, are significantly lower ($P < 0.05$) in dried vegetables than in the fresh ones [9]. Table 4 gives the percent loss of phytochemicals in blanched solar dried ALVs by various authors. More research has been done on phenols compared to other phytochemicals, while cowpea and solanum varieties are the favorite vegetables. The range of percentage loss in phytochemicals by the different researchers and for different vegetables greatly varies. There are many factors which contribute to this as outlined below. From the data used in this review, the mean decrease in flavonoids after solar drying is 42.5% (Range: 23 to 69%), for phenols is 41.3% (Range: 8 to 80%) and 47% (Range: 37 to 57%) for antioxidants.

Effects on anti-nutrients

Anti-nutrients are compounds found in food that can interfere with the absorption or utilization of essential nutrients. While anti-nutrients can reduce the bioavailability of certain nutrients such as iron and zinc, they often do not completely prevent nutrient absorption. Moreover, many anti-nutrients have potential health benefits. The content of anti-nutrients is altered by various processing methods including solar drying [16]. Table 5 gives the percent reduction in antinutrients in blanched solar dried ALVs as summarized for various authors. Much research has been done in oxalates compared to other antinutrients and great interest is in solanum species and cowpea leaf. It is evident that the percentage loss in antinutrients in studies by the different researchers and for different vegetables greatly varies and many factors contribute to this as outlined below. From the data used in this review, the mean reduction in nitrates after solar drying is 76.8% (Range: 54 to 95%), for oxalates is 40.3% (Range: 1 to 78%), for phytates is16% (Range: 15 to 17%) and 61% (Range: 18 to 83%) for tannins.

How solar drying affects the sensory attributes (colour, flavour and texture) of ALVs

The quality of the dried product is evident not just in its texture, flavour and colour, but also in its capacity to rehydrate to a state that closely resembles the original raw material. The effectiveness of rehydration depends on the preparation and the drying method used [16].

Table 6 shows that cooked solar-dried samples of ALVs are organoleptically less acceptable compared to fresh cooked leaves in all the sensory attributes. Colour change to grey green is due to degradation of chlorophyll and conversion to pheophytins due to thermal treatments like drying [19]. Changes in flavour and texture are due to several factors including moisture loss, high temperature during

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blanching and drying, oxidation, nutrient degradation and environmental factors. From the data used in this review, on average the panelists 'liked slightly' the colour, flavour and texture of solar dried leafy vegetables, which is usually above average, that is 5 in a 7- Hedonic rating scale.

How solar drying affects the bacterial load of ALVs

In recent times, there has been growing attention to the microbiological quality and safety aspects of dried products [38]. Research has shown that blanching and solar drying of leafy vegetables results in significantly lower bacterial and mold load in the final products compared to the fresh ones [31, 38] (Table 7). From the data used in this review, the mean decrease in total viable count after solar drying is 34% (Range: 30 - 36%, for yeast and mold is 32% (Range: 13 to 51%) and 24.3% (Range: -7 to 53%) for coliform count. An increase in bacterial load in dried ALVs could be due to cross-contamination. It has also been observed that samples preserved only by solar-drying have higher microbial load compared with samples that are blanched before solar-drying [39]. Clearly, blanching contributes to lowering the microbial population.

How solar drying affects the shelf life of ALVs

Blanching and solar drying treatments have proven to be effective for producing stable and highly acceptable vegetables during storage, making them suitable for market distribution. After such treatments, vegetables are stored in air-tight polythene sacks, further enclosed in brown envelopes, and can be kept under room temperature for six months [34]. Another researcher suggests packaging dried vegetables for sale or consumption in the dry season, highlighting that they can be stored for up to a year in paper or sealable bags [40]. Additionally, it has been emphasized that drying vegetables to less than 10% moisture content is a simple preservation method that ensures vegetables remain in good condition for over six months when properly packed and stored. More than half of the respondents in a study conducted in Morogoro Region, Tanzania, indicated that they could store dried vegetables for more than a year [9].

Factors affecting the variation in the reported composition/quality of the solar dried ALVs

Type of solar dryer affects the drying temperatures and the drying period, consequently, the levels of micronutrients, bacterial load, keeping quality, colour and texture [20, 28, 41].

Analytical method used for determination of nutrients in leafy vegetables (fresh or dried), could result in significantly different results. Different analytical methods have different accuracies and sensitivities, hence giving different results as shown by Singh and Harshal [42] when investigating the best method to estimate levels of

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vitamin C in green leafy vegetables. Also, while comparing different chlorophyll determination methods for leafy vegetables, a researcher concluded that a higher correlation between non – destructive methods and biochemical analyses was observed in radish and mustard leaf vegetables. Whereas lower correlation was obtained for cabbage seedlings. The non-destructive determination methods are better suited for green leafed vegetables [43].

Maturity level of harvested and dried vegetables affects the level of nutrients in the final product. In one experiment, stinging nettle, amaranth leaves and African nightshade vegetables harvested at 5 weeks and 10 weeks after planting, were dried. The results indicated that the mature vegetables had significantly higher levels in crude fiber, beta carotene, vitamin C, total phenols, total flavonoids and antioxidant activity than the younger ones [44]. These results agree with findings by researchers working on amaranth leaves harvested at different growth stages [45]. It established that various components vary differently as the plant grows older.

The Variety of the vegetable can influence the levels of nutrients. Muriuki reported results of the most popular varieties of amaranth leaves after drying. *A. cruentus* had significantly higher levels in protein, zinc, beta carotene and total phenols than the other varieties, while calcium and iron were significantly higher in *A. dubius* [46]. The antinutrient content in all the species was not significantly different ($p<0.05$) Nyonje [45] reported that there were significant differences ($P\leq0.05$) in the nutrient content among ten amaranth varieties. Similarly, there was also significant variation ($P\leq0.05$) in antinutrient and phytochemicals among the amaranth varieties.

Processing procedures through which the vegetable is dried can result in significantly different levels of nutrients in the final product. These include whether the vegetables are sliced or not, time and temperature of blanching, and whether the blanching water has salt or not [29, 44, 46].

Calculations are done in different ways to determine the levels of nutrients remaining in dried ALVs. It is advisable to indicate whether the values are on dry weight basis or wet weight basis, otherwise the values could be misleading. Examples are Constant *et al*. [32] and Asante *et al*. [37] who reported that sun drying of ALVs was concentrating (increasing) the nutrients, unlike most researchers who report the reduction (decrease) of nutrients after drying.

Time taken before the samples are analysed after harvesting is a factor to consider. Leafy vegetables should take minimum time after harvesting before they are processed and dried**.** Research has shown that ALVs which are processed and dried immediately after harvesting result in higher levels of nutrients than those which take longer. Ahmed *et al*. [9] processed and dried both freshly harvested and

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wilted ALVs. The results indicated that the levels of moisture content, beta-carotene, ascorbic acid and antioxidant activity were significantly higher in the freshly harvested samples than the wilted ones.

Climatic conditions, soil varieties and light intensity under which the vegetables grow contribute significantly to the level of nutrients in the vegetables. As reported by Colonna *et al*. [47], the nutritional composition and quality traits of ten leafy vegetables in relation to the light intensity at time of harvest were determined. When leafy vegetables were harvested at low as opposed to high Photosynthetically Active Radiation (PAR), the leaf content was higher in dry matter, protein, potassium, calcium, magnesium and antioxidant activity. Whereas, the highest values in total phenols for most of the vegetables were observed under high PAR.

The economic and environmental impact of solar drying of ALVs

Solar drying is a preferred method of preserving vegetables owing to its minimum cost of production and high-quality product, making ALVs available in the market even during the off-season [17, 33]. This technique offers a solution to reducing post-harvest losses of ALVs, as excess vegetables can be dried and used to prepare sauces with acceptable quality [31].

The significance of this approach becomes evident when considering the potential losses associated with food waste. As outlined by Ahmed *et al*.[9], describing the multifaceted impacts of such losses: (i) agricultural resources are affected as investments in time, labor and resources by farmers may not yield returns, leading to decreased income and food security; (ii) natural resources like fertile land and water are used inefficiently, contributing to resource depletion and environmental degradation; (iii) economic resources suffer due to decreased efficiency in the food system, impacting production, transportation, and storage costs; (iv) food resources diminish, causing price hikes and reduced food security; (v) nutritional resources decline, affecting the availability of essential vitamins and minerals found in leafy vegetables; and (vi) environmental pollution increases through waste generation, contributing to greenhouse gas emissions such as methane.

The challenges and limitations of solar drying of ALVs, and how they can be addressed

Solar drying presents a valuable method for preserving ALVs, yet it comes with its own set of challenges and limitations including health, environmental and chemical hazards, that can impact its efficiency and effectiveness [30]. Key issues include dependency on climatic conditions, potential for uneven drying, risk of contamination and limitations in scale.

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Firstly, solar drying heavily depends on favorable weather conditions, and consistent, strong sunlight is essential for effective drying. This reliance can be problematic in regions experiencing frequent cloudy or rainy weather, leading to prolonged drying times or spoilage of the produce. To mitigate this, technological innovations in dryer design and hybrid drying systems can be implemented that combine solar energy with other energy sources, such as biomass heating, to maintain a consistent drying process regardless of weather variations.

Another challenge is the potential for uneven drying, where some parts of the vegetables dry faster than others, resulting in a product that is inconsistently dried. This can affect both the quality and safety of dried vegetables. Slow drying processes under uncontrolled conditions can lead to the growth of aflatoxin-producing fungi, particularly when drying practices are not meticulously followed. Moreover, addressing the susceptibility of dried foods to spoilage from microbial, biological, chemical and physical reactions is crucial. To address this, improved solar dryer designs that ensure more uniform air flow and heat distribution can be developed. Regular turning and rearranging of vegetables during the drying process also help achieve more uniform results.

Contamination is also a concern, as open solar drying exposes vegetables to direct sunlight rays, dust, insects and other pollutants, which can degrade the quality and safety of the produce as discussed by Wanjiku *et al.* [48]. Enclosed solar dryers, which protect the vegetables from direct exposure to these contaminants, offer a solution. Additionally, proper pre-drying treatment and handling practices can further reduce the risk of contamination. After drying, the type of packaging material used can also impact on the product's longevity due to varying moisture retention capacities.

An additional concern is that dried products generally require longer cooking times than fresh or canned counterparts and often do not retain their original flavour, which can deter their use [16]. Soaking the vegetables in warm water before cooking helps in rehydration of the dried vegetables.

The scalability of solar drying operations can be limited, making it challenging to process large quantities of vegetables efficiently. This limitation can be particularly problematic for larger farming operations or for communities needing to process significant amounts of produce. Scaling up involves not only larger or more solar dryers but also possibly integrating mechanization to handle larger volumes of vegetables.

Lastly, awareness and consumer education are pivotal, as demonstrated by Yegon *et al*. [12], where most respondents in their study were not aware of solar-dried ALVs,

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significantly affecting their consumption choices [12]. Creating consumer awareness not only stimulates interest but also drives demand for high-quality solar-dried ALVs. This is crucial since perceptions and attitudes significantly influence consumption habits [21].

To address these multifaceted challenges, adopting improved handling procedures, using appropriate solar drying methods, hybrid drying systems and selecting suitable packaging materials are recommended to enhance the shelf life and safety of dried ALVs. Additionally, strategies to boost information access and consumer awareness about the benefits and quality of solar-dried ALVs can help overcome barriers to their adoption and consumption [31]. These improvements can make solar drying a more viable and sustainable option for preserving ALVs, thus contributing positively to food security and safety.

CONCLUSION AND RECOMMENDATIONS FOR DEVELOPMENT

Solar drying of vegetables is a technique that can benefit farmers as it offers a cost-effective method to preserve surplus vegetables that might otherwise perish. By extending the shelf life of their produce, farmers can reduce waste, increase their income by selling dried products during the off-season, and improve food security in their communities. Solar dried vegetables retain most of their nutrients, are lighter and require less storage space, making them ideal for consumers in areas with limited access to fresh produce. They are also beneficial for use in emergency food supplies or for outdoor activities like camping. The technique can be used as a tool for enhancing food security, improving nutritional intake, and developing local economies through small-scale agribusinesses.

Promoting and supporting solar drying technologies by governments and policy makers can help stabilize local markets, reduce post-harvest losses, enhance food preservation and contribute to agricultural sustainability. Finally, the technique is a sustainable method that utilizes renewable energy, thereby reducing reliance on fossil fuels and decreasing greenhouse gas emissions associated with traditional drying methods or the transportation of fresh produce over long distances. By adopting solar drying technologies, stakeholders can achieve economic benefits while also contributing to environmental sustainability and improved health outcomes.

Conflict of interest

None

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Table 1: Percentage loss in proximate composition of blanched and dried leafy vegetables according to the literature

Vegetable	% loss in Crude Protein	% loss in Crude Fiber	% loss in Lipids	Reference
Cowpea leaf	31	7	ND	[31]
Spider plant	43	(2)	ND	[31]
Slender leaf	28	(11)	ND	[31]
Xanthosoma sagittifolia	1.99	3.26	2.58	[27]
Talinum triangulare	(4.15)	(0.88)	(0.66)	[27]
Moringa oleifera	(21.24)	(6.26)	(0.09)	[27]

NB: The values in parenthesis show an increase in the component content. ND means Not Determined

Table 2: Percentage loss of vitamins in blanched solar dried leafy vegetables according to the literature

Vegetable	% Loss of Vitamin C[a]	% Loss of Beta-carotene	Reference
Amaranth leaves	-	23	[33]
Amaranth leaves	82	22	[49]
Amaranthus hybridus	69	76	[50]
Amaranthus cruentus	41	72	[50]
African nightshade	51	(91)	[9]
African nightshade	64	29	[49]
Solanum scabrum	93	-	[41]
Solanum villosum	97	45	[29]
Solanum villosum	89	-	[41]
Common bean leaf	28	-	[36]
Cleome gynandra	95	47	[29]
Corchorus olitorius	96	46	[29]
Crotalaria ochroleuca	92	42	[29]
Cowpea leaf	86	42	[13]
Cowpea leaf	29	52	[31]
Cowpea leaf	48	9	[10]
Cowpea leaf	76	25	[17]
False sesame leaves	26	-	[36]
Fig-leaf	51.3	10.1	[5]
Pumpkin leaf	57.3	10.3	[5]
Slender leaf	61	59	[31]
Spider plant	53	64	[31]
Stinging nettle	62	33	[5]
Stinging nettle	83	25	[49]
Sweetpotato leaves	60	59	[52]

NB: The values in parenthesis show an increase in the vitamin content
[a]Vitamin C was measured as ascorbic acid

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Table 3: Percentage loss of minerals in blanched solar dried leafy vegetables according to the literature

Vegetable	% Loss of Iron	% Loss of Calcium	% Loss of Zinc	Reference
Amaranth leaves	74	9	88	[49]
A. hybridus	39	8	-	[50]
A. cruentus	11	7	-	[50]
Common bean leaf	62	-	70	[36]
Cowpea leaf	94	97	-	[31]
Cowpea leaf	41	32	-	[13]
Cowpea leaf	(1)	57	(3)	[53]
Solanum scabrum	45	16	36	[41]
Solanum villosum	54	6	20	[41]
African nightshade	75	9	93	[49]
False sesame leaf	40	-	41	[36]
Fig-leaf	1.2	-	5.5	[5]
Pumpkin	4.5	-	7	[5]
Slender leaf	97	98	-	[31]
Spider plant	96	98	-	[31]
Stinging nettle	4.1	-	13	[5]
Stinging nettle	68	6	87	[49]
Sweetpotato leaves	(10)	35	-	[52]

NB: The values in parenthesis show an increase in the mineral content

Table 4: Percentage loss of phytochemicals in blanched solar dried leafy vegetables according to the literature

Vegetable	% Loss in Flavonoids	% Loss in Phenols	% Loss in Antioxidant	Reference
African nightshade	-	53	-	[49]
African nightshade	-	-	37	[9]
Solanum scabrum	69	29	-	[51]
Amaranth leaves	-	47	-	[49]
Cleome gynandra	26	45	-	[51]
Corchorus olitorius	23	30	-	[51]
Crotalaria ochroleuca	52	33	-	[51]
Cowpea leaf	-	30	-	[54]
Cowpea leaf	-	8	-	[53]
Cowpea leaf	-	-	57	[9]
Stinging nettle	-	80	-	[52]
Sweet potato leaves	-	58	-	[52]

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Table 5: Percentage reduction of anti-nutrients in blanched solar dried leafy vegetables according to the literature

Vegetable	% Reduction of Nitrates	% Reduction of Oxalates	% Reduction of Phytates	% Reduction of Tannins	Reference
Common bean leaf	-	59	-	83	[36]
Cowpea leaf	54	3	-	-	[54]
Cowpea leaf	71	1	-	-	[53]
Cowpea leaf	95	-	-	-	[10]
Cleome gynandra	-	-	-	41	[29]
Corchorus olitorius	-	-	-	79	[29]
Crotalaria ochroleuca	-	-	-	72	[29]
False Sesame leaf	-	61	-	18	[36]
Solanum scabrum	-	66	15	-	[41]
Solanum scabrum	-	-	-	73	[29]
Solanum villosum	-	78	17	-	[41]
African nightshade	87	-	-	-	[9]
Sweetpotato leaves	-	14	-	-	[52]

Table 6: Sensory attributes of blanched, solar dried and cooked leafy vegetables according to the literature

Vegetable	Colour	Flavour	Texture	Reference
Cowpea leaf	Like slightly	Like slightly	Like slightly	[13]
Cowpea leaf	Like slightly	Like moderately	Like slightly	[34]
Cowpea leaf	Like moderately	Like moderately	Like slightly	[10]
Pumkin leaves	Like slightly	Neither like nor dislike	Dislike moderately	[5]
Fig leaf	Like moderately	Neither like nor dislike	Dislike slightly	[5]
Stinging nettle	Like moderately	Like slightly	Like slightly	[5]
African nightshade	Like slightly	Like slightly	Like slightly	[9]

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Table 7: Percentage reduction of bacterial load of blanched and dried leafy vegetables according to the literature

Vegetable	% reduction in Total viable count	% reduction in Yeast and molds	% reduction in Coliform Counts	Reference
Cowpea leaf	30	32	53	[31]
Spider plant	36	51	27	[31]
Slender leaf	36	13	(7)	[31]

NB: The values in parenthesis show increase in the bacterial load

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REFERENCES

1. **Beal T, Massiot E, Arsenault JE, Smith MR and RJ Hijmans** Global trends in dietary micronutrient supplies and estimated prevalence of inadequate intakes. *PLoS One.* 2017; **12(4):** e0175554.

2. **Sharma P, Dwivedi S and D Singh** Global poverty, hunger, and malnutrition: A situational analysis. **In**: Singh U, Praharaj C, Singh S and S Singh (Eds). Biofortification of food crops. *Springer.* 2016: 47–66. https://doi.org/10.1007/978-81-322-2716-8_2

3. **Ministry of Health.** The Kenya national micronutrient survey. 2011. http://www.nutritionhealth.or.ke/wp-content/uploads/Downloads/TheKenyaNationalMicronutrientSurvey202011.pdf *Accessed on 29th May 2024.*

4. **Irakoze ML, Wafula EN and E Owaga** Potential role of African fermented indigenous vegetables in maternal and child nutrition in sub-Saharan Africa. *Int J Food Sci.* 2021; **1:** 3400329.

5. **Muniu GJ** Nutrient retention and sensory acceptability of solar dried African leafy vegetables among women of reproductive age, Kiambu County, Kenya [master's thesis]. Kenyatta University; 2020.

6. **World Health Organization (WHO**). Increasing fruit and vegetable consumption to reduce the risk of noncommunicable diseases. e-Library of Evidence for Nutrition Actions (eLENA); 2023.

7. **Beal T and F Ortenzi** Priority micronutrient density in foods. *Front Nutr.* 2022; **9**:806566.

8. **Ball J, Collar D, Diazgranados M, Douglas R, Forest F, Hawkins J, Howes M, Ulian T, Vaitla B and S Pironon** Global plant diversity as a reservoir of micronutrients for humanity. *Nat Plants*. 2022; **8(3):** 225-32. https://doi.org/10.1038/s41477-022-01100-6

9. **Ahmed A, Almas S, Kissaka K and R Suleiman** Effect of sun-dry on nutritional and sensory acceptability of wilted African leafy vegetables: a case study of Morogoro Region, Tanzania. *Frontiers in Sustainable Food Systems*. 2023; **7**:1161961.

10. **Ridolfi C, Hoffmann V and S Baral** Post-harvest losses in fruits and vegetables: The Kenyan context. *Intl Food Policy Res Inst*. 2018; Mar 16.

11. **Kirigia D, Kasili R and H Mibus** African leafy vegetables pre-harvest and post-harvest constraints and Technologies for losses reduction along the field to consumer chain. *African Journal of Horticultural Science.* 2017; **12**: 51- 60.

12. **Muchoki CN, Imungi JK and PO Lamuka** Changes in beta-carotene, ascorbic acid and sensory properties in fermented, solar-dried and stored cowpea leaf vegetables. *Afr J Food Agric Nutr Dev.* 2007;**7(3):**1–20.

13. **Adeyeye SA, Ashaolu TJ and AS Babu** Food drying: A review. *Agricultural reviews*. 2022;**1(8**).

14. **Natumanya P, Twinomuhwezi H, Igwe VS, Maryam S and CG Awuchi** Effects of drying techniques on nutrient retention and phytochemicals in selected vegetables. *Eur J Agric Food Sci*. 202; **3(2):** 5-14.

15. **Gogo EO, Opiyo A, Ulrichs C and S Huyskens-Keil** Postharvest treatments of African leafy vegetables for food security in Kenya: A review. *Afr J Hortic Sci*. 2016; **9**: 32–40.

16. **Singh P, Singh S, Singh K, Singh BR and J Singh** The drying characteristics of amaranth leaves under greenhouse type solar dryer and open sun. *Greener J Agric Sci.* 2014; **4(6):** 281–7.

17. **Ndawula J, Kabasa JD and YB Byaruhanga** Alterations in fruit and vegetable β-carotene and vitamin C content caused by open-sun drying, visqueen-covered and polyethylene-covered solar dryers. *Afr Health Sci.* 2004; **4(2):** 125–30.

18. **Berinyuy JE, Tangka JK and GM Weka Fotso** Enhancing natural convection solar drying of high moisture vegetables with heat storage. *Agric Eng Int: CIGR J*. 2012; **14(1):** 141-148.

19. **Ayua E, Mugalavai V, Simon J, Weller S, Obura P and N Nyabinda** Comparison of a mixed modes solar dryer to a direct mode solar dryer for African indigenous vegetable and chili processing. *J Food Process Preserv.* 2017; **41(6):** e13216.

20. **Kessy R, Ochieng J, Afari-Sefa V, Chagomoka T and N Nenguwo** Solar-dried traditional African vegetables in rural Tanzania: Awareness, perceptions and factors affecting purchase decisions. *Econ Bot*. 2018;**72(4):**367–79. https://doi.org/10.1007/s12231-018-9434-2

21. **Archvadze K, Chachava I, Liparteliani R, Khotenashvili N, Chubinishvili Z and Z Tabukashvili**. On the issue of creating solar drying plants for the purpose of obtaining dried agricultural products. *World science*. 2022; **4(76):** 33-40.

22. **Rao TSB and S Murugan** Solar drying of medicinal herbs: A review. *Solar Energy*. 2021; **223**:415–36.

23. **Jin W, Mujumdar AS, Zhang M and CL Law** Novel drying techniques for spices and herbs: A review. Food Eng Rev. 2018; **10(1):** 34–45. https://doi.org/10.1007/s12393-017-9165-7

24. **Chelanga JK, Tonui JK and SC Limo** Evaluation of performance of a solar tunnel crop dryer in drying of two African indigenous vegetables (AIVs). *Kabarak J Res Innov*. 2018; **5(2):** 100–14.

25. **Visavale GL** Principles, classification, and selection of solar dryers. **In**: Hii CL, Ong SP, Jangam SV and AS Mujumdar (Eds). Solar drying: Fundamentals, applications, and innovations. Mujumdar Press; 2012: 1–50.

26. **El Hage H, Herez A, Ramadan M, Bazzi H and M Khaled** An investigation on solar drying: A review with economic and environmental assessment. *Energy*. 2018; **157**: 815–29.

27. **Seidu JM, Bobobee EYH, Kwenin W KJ, Frimpong R, Kubge SD, Tevor WJ and AA Mahama** Preservation of indigenous vegetables by solar drying. *ARPN J Agric Biol Sci*. 2012; **7(6):** 333–40.

28. **Kazosi M** Development of dried African nightshade products for post-harvest loss reduction and shelf-life extension in Tanzania [master's thesis]. Nelson Mandela African Institution of Science and Technology; 2023.

29. **Mibei EK and NK Ojijo** Effects of processing on chemical composition of four African leafy vegetables. *Electron J Environ Agric Food Chem*. 2011; **10(11**): 3121–31.

30. **Gupta S, Gowri BS, Lakshmi AJ and J Prakash** Retention of nutrients in green leafy vegetables on dehydration. *J Food Sci Technol.* 2013; **50(5):** 918–25. https://doi.org/10.1007/s13197-011-0407-z

31. **Njoroge EW, Matofari JW, Mulwa RMS and JO Anyango** Effects of blanching time/temperature combination coupled with solar drying on the nutritional and microbial quality of indigenous leafy vegetables in Kenya. *Afr J Food Sci Technol.* 2015; **6(7):** 209–19.

32. **Constant ACHO, Lessoy ZOUE, Niamkey ADOM and S Niamke** Effect of sun drying on nutritive and antioxidant properties of five leafy vegetables consumed in Southern Côte D'ivoire. *Food Environ Saf J*. 2016; **14(3).**

33. **Chege P, Kuria E, Kimiywe J and H Nyambaka** Retention of ß-Carotene, iron and zinc in solar dried amaranth leaves in Kajiado County, Kenya. *Int J Sci Basic Appl Res*. 2014; **13**: 329–38.

34. **Natabirwa H, Mukiibi J, Zziwa E and J Kabirizi** Nutritional and physicochemical properties of stored solar-dried cowpea leafy vegetables. *Uganda J Agric Sci.* 2016; **17(1):** 1–10.

35. **Mulokozi G and U Svanberg** Effect of traditional open sun-drying and solar cabinet drying on carotene content and vitamin A activity of green leafy vegetables. *Plants Food Hum Nutr*. 2003; **58**:1–15.

36. **Kandonga A** Effect of blanching and drying on micronutrients and anti-nutritional factors in false sesame and common bean leaves [master's thesis]. Nelson Mandela African Institution of Science and Technology; 2019. https://doi.org/10.58694/20.500.12479/1031

37. **Asante JM, Amaglo N and PK Tandoh** Effect of different drying methods on the mineral composition of three indigenous leafy vegetables. *Int J Plant Soil Sci.* 2024; **36(5):** 621–32.

38. **Bourdoux S, Li D, Rajkovic A, Devlieghere F and M Uyttendaele** Performance of drying technologies to ensure microbial safety of dried fruits and vegetables. *Compr Rev Food Sci Food Saf*. 2016; **15(6):** 1056–66.

39. **Jega BG, Iormanger M, Sani AM, Idris AA, Femi AO and AM Olaitan** Effect of blanching and sun-drying on the nutritional and microbiological qualities of vegetables in Ilorin Metropolis, Nigeria. *Int J Innovative Approaches Sci Res*. 2021; **5(4):** 207–19.

40. **Henze J, Abukutsa-Onyango M and A Opiyo** Production and marketing of African indigenous leafy vegetables: Training manual for extension officers and practitioners. Berlin: Humboldt-Universität zu Berlin; 2020.

41. **Kazosi ME, Martin HD and A Matemu** Effect of drying methods on the nutritional and anti-nutritional quality of African nightshade (Solanum sp.). *Int J Biosci.* 2022; **21(3):** 223–34.

42. **Singh RR and A Harshal** Effects of cooking on content of vitamin C in green leafy vegetables. *Scholars J Agric Vet Sci*. 2016; **3(6):** 416–23.

43. **Alsiņa I, Dūma M, Dubova L, Šenberga A and S Daģis** Comparison of different chlorophylls determination methods for leafy vegetables. *Agron Res*. 2016; **14(2):** 309–16.

44. **Cheptoo G, Owino W and G Kenji** Nutritional quality, bioactive compounds and antioxidant activity of selected African indigenous leafy vegetables as influenced by maturity and minimal processing. *Afr J Food Agric Nutr Dev*. 2019; **19(3):** 14769–89.

45. **Nyonje WA** Nutrients, anti-nutrients and phytochemical evaluation of ten vegetable amaranth (Amaranthus spp.) varieties at two stages of growth [master's thesis]. Jomo Kenyatta University of Agriculture and Technology; 2015.

46. **Muriuki EN** Nutritional diversity of leafy amaranth (Amaranthus) species grown in Kenya [master's thesis]. Jomo Kenyatta University of Agriculture and Technology; 2015.

47. **Colonna E, Rouphael Y, Barbieri G and S De Pascale** Nutritional quality ten leafy vegetables harvested at two light intensities. *Food Chem.* 2016; **199**: 702–10.

48. **Wanjiku GJ, Kingori GG and KJ Kirim** Effect of harvesting time, drying method and packaging of cowpea leaves on microbial contamination. *J Adv Microbiol.* 2024; **24(2):** 59–73. https://doi.org/10.9734/jamb/2024/v24i2796

49. **Kosgey GC** Nutritional quality and antioxidant properties of minimally processed African indigenous leafy vegetables [master's thesis]. Jomo Kenyatta University of Agriculture and Technology; 2021.

50. **Kiremire BT, Musinguzi E, Kikafunda JK and FB Lukwago** Effects of vegetable drying techniques on nutrient content: A case study of south-western Uganda. *Afr J Food Agric Nutr Dev*. 2010;**10(5):** 2587-2600. https://doi.org/10.4314/ajfand.v10i5.56341

51. **Mibei EK, Ojijo NK, Karanja SM and JK Kinyua** Compositional attributes of the leaves of some indigenous African leafy vegetables commonly consumed in Kenya. *Ann Food Sci Technol*. 2011;**12(2):**146–54.

52. **Mwanri AW, Kogi-Makau W and HS Laswai** Nutrients and antinutrients composition of raw, cooked and sun-dried sweet potato leaves. *Afr J Food Agric Nutr Dev.* 2011; **11(5):** 5142–56. https://doi.org/10.4314/ajfand.v11i5.70442

53. **Owade JO, Abong' GO, Okoth MW and AW Mwang'ombe** Comparative characterization of trends and patterns of physical and chemical attributes of optimal and traditional processed cowpea leaves. *J Food Qual.* 2022; **2022(1):**1503221. https://doi.org/10.1155/2022/1503221

54. **Muchoki CN, Lamuka PO and JK Imungi** Reduction of nitrates, oxalates and phenols in fermented solar-dried stored cowpea (*Vigna unguiculata*) leaf vegetables. *Afr J Food Agric Nutr Dev*. 2010; **10(11):** 4398–4412. https://doi.org/10.4314/ajfand.v10i11.64284