2023-07

Development of dried African nightshade products for post-harvest loss reduction and shelf-life extension in Tanzania

Kazosi, Marynurce

NM-AIST

https://doi.org/10.58694/20.500.12479/2211

DEVELOPMENT OF DRIED AFRICAN NIGHTSHADE PRODUCTS FOR POST-HARVEST LOSS REDUCTION AND SHELF-LIFE EXTENSION IN TANZANIA

Marynurce Kazosi

A Dissertation Submitted in Partial Fulfillment of the Requirements for the Degree of Master's in Life Sciences of the Nelson Mandela African Institution of Science and Technology

Arusha, Tanzania

July, 2023

ABSTRACT

African nightshade (ANS) is a luminary food plant, considered a cheap and potential dietary source for micronutrients and bioactive compounds. Lack of value addition on ANS, results to high availability of ANS during peak season and shortage in off-season was the great demand for developing dried products. This study evaluated the effects of drying techniques on nutritional (minerals & vitamin C) and anti-nutritional (oxalate & phytate) contents of Solanum scabrum (SS) and S. villosum (SV). Three methods of drying namely indirect solar drying (ISD), mixed solar drying (MSD), and open sun drying (OSD) were employed. Furthermore, blanching (85°C, 2 min) with and without 3% salt (NaCl) were used as pre-treatments for ANS. The effect of pre-treatment methods on nutrient retention and anti-nutrients removal was also recorded. From the results ISD was the most effective method for vitamin C (14.76% 19.2%), Ca (92.90%, 96.57%), Fe (77.88%, 71.54%), and Zn (86.94%, 90.09%) retention for both SS and SV leaves, respectively. On the other hand, all drying methods significantly reduced levels of oxalate (4.46% to 35.24%) and phytate (52.12% to 85.55%). Pannelists rated dried ANS significantly ≤ 0.05 higher for texture, colour, taste, aroma, bitterness and overall acceptability. Shelf life studies of dried products were stable at ambient and refrigeration storage for a period of three months with no growth of bacteria, yeast and mold, with significance loss of Vitamin C under both conditions. The findings showed that the ISD best method for vitamin C, minerals retention and anti-nutritional reduction.

Keywords: African nightshade, Solanum sp., drying methods, vitamin C, minerals, anti-nutrients

DECLARATION

I, Marynurce Kazosi, do hereby declare to the Senate of the Nelson Mandela African Institution of Science and Technology that this dissertation is my own original work and that it has neither been submitted nor being concurrently submitted for degree award in any other institution.

23/06/2023

Marynurce Kazosi Date

The above declaration is confirmed by:

23/06/2023

Prof. Athanasia Matemu Date

23/6/2023

Dr. Haikael Martin Date

COPYRIGHT

CERTIFICATION

The undersigned certify that they have read and hereby recommend for acceptance the dissertation *entitled "Development of Dried African Nightshade Products for Post-harvest Loss Reduction and Shelf-life Extension in Tanzania"* in Partial Fulfillment of the Award of the Degree of Master's in Life Sciences of the Nelson Mandela African Institution of Science and Technology.

23/06/2023

Prof. Athanasia Matemu — Date

23/6/2023

Dr. Haikael Martin — Date

ACKNOWLEDGMENT

I would like to exalt and give glory to our almighty God for his favour and the gift of living He has granted me. For God glory, my warmth appreciation goes to my family, my lovely husband Fred Kivale who encouraged me despite the fact that my absence was felt by him and our children Florance, Francis and Godfrey. My gratitude goes to my supervisors Prof. Athanasia Matemu and Dr. Haikael Martin who worked hand in hand with me to make everything possible withouting leaving behind all academics of NM-AIST for their assistance during my studies. My sincere gratitude to my employer VETA for the permission to join studies. I acknowledge the financial support from both Centre for Reasearch, Agriculture advancement, Teaching Excelence and Sustainability in Food and Nutritional Security (CREATES-FNS) project under Prof. Hulda Swai and Fruit and Vegetable for all Season (FruVaSe) project hosted at NM-AIST engineered by Dr. Edna Makule. Furthermore, the technical assistance on my research project from FruVaSE team members including Dr. Edna Makule, Dr. Neema Kassim, Mr. Frank Sangija, Ms. Angela Aluko and Mr. Noel Dimoso is highly appreciated.

Sincerely, I wouldn’t reach this stage without receiving attention from NM-AIST and SUA laboratories. I am grateful to Mr. Damas Nyang’ali, Mr. Sylvester Temba and Ms. Irene Tesha from NM-AIST and Mr. Suleiman Amour from SUA for their Labaratory technical support.

DEDICATION

This research is dedicated to my lovely husband, Fred Leonard Kivale, my children (Florance Francis and Godfrey) for their permissiveness, prayers and encouragement

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APENDECIES

LIST OF ABBREVIATIONS AND SYMBOLS

ANS	African Nightshades
ANOVA	Analysis of Variance
SS	*Solunum scabrum*
SV	*Solanum villosum*
ISD	Indirect Solar Drier
M.A.S.L	Metres Above Sea Level
MSD	Mixed Solar Drier
OSD	Open Sun Dried
Mg	Magnesium
NaCl	Sodium Cloride
FAO	Food and Agriculture Organization
Fe	Iron
UnB	Unblanched samples
WB	Water blanched samples
WBS	Water blanched with NaCl samples
WHO	World Health Organization
Zn	Zinc

CHAPTER ONE

INTRODUCTION

1.1 Background of the Problem

African nightshade (ANS) is among the African indigenous vegetables, and they contribute substantially to nutritional and pharmacological benefits (Traoré *et al.,* 2017; Kamga *et al*., 2013). Amongst species of ANS includes *Solanum scabrum* and *Solanum villosum* which are commonly found in house gardens/farms (Gockowski *et al.*, 2003; Ojiewo *et al.*, 2013). The ANS leaves, and tender shoots are cooked to improve the organoleptic properties and reduce anti-nutrients. The preferable cooking methods are frying, steaming, or boiling (Ojiewo *et al.*, 2013; Yuan *et al.,* 2018). In Tanzania and Kenya, cereal staples such as Ugali are the main dishes which are oftenly taken in together with ANS (Ekesa *et al.*, 2009; Ochieng *et al.*, 2018; Oluoch *et al.*, 2012).

Fresh ANS are always containing higher moisture contents which creates favourable condition for microbial growth and senescence, and thus, accounts for post-harvest losses (Constant *et al*., 2016). The post-harvest losses of leafy vegetables are ranging from 30% to 50% in sub-Saharan Africa (Gustavsson *et al.*, 2011; Sagar *et al.*, 2010; Tumwet *et al.*, 2014) with small-scale farmers facing quantitative and qualitative losses in the value chain. Following high perishability rate of ANS, proper post-harvest handling is highly recommended to extend the shelf-life (Patricia *et al*., 2014). Although processing and preserving of ANS poses a challenge in sub-Saharan Africa, direct sun drying is reported as the standard preservation method, and in some cases it is being sumplemented with few fermentation techniques (Ofor & Ibeawuchi, 2010; Ukegbu & Okereke, 2013).

In addition to high chances of being contaminated, the ANS when exposed directly to sunlight in sun-drying method causes deterioration of micronutrients (Constant *et al*., 2016; James & Matemu, 2016). However, drying technology improves storage at low moisture content, organoleptic quality and extends shelf life. It also aids micronutrient retention, reduces food bulkiness, reduces transportation costs, and promotes food and nutrition security (Hasan *et al.*, 2019; Sagar *et al.,* 2010). Solar drying has been shown to retain micronutrients and decrease seasonality on raw vegetables (Chege *et al.*, 2014). Despite the fact that direct, indirect, and mixed solar driers are the typical modern drying techniques applied to ANS, their effect on nutrient retention and anti-nutrients removal is not well known (Pardhi *et al.*, 2013). Therefore, this study aimed to evaluate the effect of the open sun, indirect solar, and mixed solar drying methods in retaining vitamin C, minerals (Ca, Fe, Mg and Zn) and reducing anti-nutrients (oxalates and phytate) in *S. villosum* and *S. scabrum.*

1.2 Statement of the Problem

Worldwide, malnutrition rate is increasing due to lack or insufficient intake of micronutrients. In SSA, various types of leafy vegetables are edible (Remi *et al.,* 2005) though their consumption is said to be the lowest in the world (AVRDC, 2003). Also, the IFPRI (2001) reported that there is an increase of 18% of malnourished children in SSA from year 2001 to 2020 under the lowest supplies of vegetables of 43% (Keding &Yang, 2009). According to Van Rensburg *et al*. (2004), an increased intake of indigenous vegetable aids to relieve the malnutrition rate. Recently, it is reported that the post-harvest losses of African vegetable leaves in SSA are more than 50% due to various constraints along the farm to consumer chain (Tumwet *et al.*, 2014). Regardless of their importance, ANS are said to be highly perishable; they have limited shelf life, and thus they need proper post-harvest handling to keep stable their physical properties (Patricia *et al*., 2014). The high perishable rate of ANS is attributable to a number of factors such as high bruising rates, poor transportation, and lack of refrigerated facilities. With these factors, decomposition and wilting, in particular, during transportation, handling, marketing, and storage at the domestic level are highly favoured, and thus are the leading causes of postharvest loses of ASN. Therefore, development of efficient and cost-effective solutions to the farmers is needed to curb ANS post-harvest losses and thus preserving them for tremendous future use (Ayua *et al.*, 2017; Ochieng *et al.*, 2018).

1.3 Rationale of the Study

Currently, traditional African vegetables including African nightshade have been receiving considerable attention for their role in food and nutrition security and opportunities for enhancing smallholder livelihoods. Promoting the production and consumption of traditional vegetables is expected to enhance household nutrition among urban and rural households (Ochieng *et al*., 2018). Besides, the intake of African nightshade is increasing and is becoming a promising alternative cash crop locally and internationally. Considering their high nutritional value, medicinal and health benefits, their demand is at the top level in the community. More recently, the production of African nightshades is undertaking a revolutionary move from kitchen to market gardening (Agong *et al.*, 2013). Therefore, posthaverst handling and processing particularly through drying as a preservation technology not only will enhancing keeping their quality but also will assure off-season availability, product diversification, employment opportunity, food security and nutrition security and advanced household income.

1.4 Objectives

1.4.1 General Objective

To develop a dried African nightshade product (*Solanum scabrum* and *Solanum villosum*) for post-harvest loss reduction and shelf-life extension.

1.4.2 Specific Objectives

(i) To develop dried ANS products of *solanum scabrum* and *solanum villosum.*

(ii) To analyze the nutritional and anti-nutritional content of the raw and dried products.

(iii) To analyze sensory evaluation and acceptability of the dried ANS.

(iv) To evaluate the shelf life of the dried ANS.

1.5 Research Questions

(i) How can African nightshade vegetables be dried?

(ii) What are the moisture content, nutritional, anti-nutritional factors and microbial loads of raw and dried ANS vegetable?

(iii) What are the sensory characteristics of the dried ANS?

(iv) What is the shelf life of the dried ANS?

1.6 Significance of the Study

The study will foster awareness and promote the consumption and utilization of ANS, and improve food processing knowledge in Tanzanian societies. In addition, the dried product can add value to the food and nutritional security across the region and reduce post-harvest losses. Morever, the knowledge of drying technique can be transfered and created to the community to break seasonalities accross the year and add variety to food chain.

1.7 Delineation of the Study

The focus of this study was to evaluate the effect of the open sun, indirect solar, and mixed solar drying methods in retaining vitamin C, minerals (Ca, Fe, Mg and Zn) and reducing anti-nutrients (oxalates and phytate) in S. villosum and S. Scabrum. Also the study aimed at development of efficient and cost-effective solutions to the farmers so as to curb ANS post-harvest losses and thus preserving them for tremendous future use.

CHAPTER TWO

LITERATURE REVIEW

2.1 African Nightshade with their Species

African nightshade comprises of several species in the genus *Solanum,* in the section *Solanum,* also referred to as the *Solanum nigrum* complex (Ronoh *et al.,* 2018). These vegetables are among the largest and most variable groups in the genus *Solanum*, and are regionally distributed from temperate to tropical and sea level to altitudes above 3500 meters. The ANS grow well under high moisture conditions, 1500 mm rainfall and between a temperature of 20°C to 30°C (Mwai *et al.,* 2007). Also, ANS flourishes well in fertile soils rich in nitrogen, phosphorus, and with high organic matter content.

In addition, ANS is an annual herbaceous plant and may sometimes be perennial, reaching up to 100 cm in height. Their stem may be smooth or bear tiny hairs (trichomes). Also, the flowers are usually white in colour, have five regular parts and are up to 0.8 cm wide. The leaves are alternate and somewhat ovate with irregularly toothed wavy margins and can reach 10 cm in length and 5 cm in width (Akubugwo *et al*., 2007).

Nonetheless, the study done by Mwai *et al*. (2007) reported that there are various species of African nightshade including, *Solanum americanum, Solanum chenopodioides, Solanum grossidentatum, Solanum retroflexum, Solanum villosum, Solanum florulentum, Solanum nigrum,* and *Solanum scabrum.* The most common species found in Tanzania are *Solunum americanum*, *Solanum villosum*, *Solanum scabrum* and *solunum'eldoretii'* (Keller, 2004).
For the interest of this study, *Solanum villosum* and *Solanum scabrum* were used in optimizing the drying processing conditions.

2.2 Consumption of African Nightshades

To improve the palatability, texture and taste, vegetables have to be cooked before being eaten. This aids to alleviate potential pathogens and/or neutralize poisonous or irritating substances (Tumwet *et al.,* 2014). However, the cooking methods adopted are mainly due to convenience and taste preference instead of nutrient retention (Yuan *et al*., 2009).

Nightshades vegetables are important African leafy vegetables largely consumed in most parts of SSA (Ronoh *et al.,* 2018). The ANS leaves are being consumed in various ways depending on the resources in place. With enough resources, ANS can be boiled, fried with onions, tomatoes and other spices, salts and milk to enhance their taste. Mostly, indigenous consumers boil and add salts and milk only. Bitter dark varieties prepared by boiling and adding salts only for tasting are preferred by men mostly (Ontita *et al.*, 2016).

With this research, the dried product was prepared for sensory evaluation. To make it palatable, a standard method of cooking with tomatoes, onions and carrot was used to prepare dried ANS. The preparation method for the dried ANS, i.e., frying was a typical method used by local people to prepare fresh vegetables of nightshades.

2.3 Nutritional Composition of African Nightshade

The fresh leaves of most of the African leafy vegetables (ALVs) like vegetable amaranths (*Amaranthus*), slender leaf (*Crotalaria brevidens*), spider plant (*Chlorophytum comosum*), vegetable cowpeas (*Vigna*), pump-kin leaves (*cucurbits*) and jute mallow (*Corchorus*) contain more than 100% of the recommended daily allowances for vitamins and minerals and 40% proteins for growing children and lactating mothers (Oulai *et al.*, 2015).

Likewise, the African nightshade plays a vital role in the provision of nutritional needs of rural families. Particularly, they are rich in protein (methionine-amino acid, rarely available in plants), vitamin A, iron (Fe) and calcium (Ca) (Mwai *et al.*, 2007). Additionally, ANS is rich in bioactive compounds and their health benefits to humans.

2.4 Effect of Processing Technology on African Nightshade

The fresh leaves of green leafy vegetables are normally prepared by either boiling, frying or steaming method. The cooking time differs depending on the type of leaves and culture. Since the harvested leafy vegetables are highly perishable, they can be processed and preserved by partial cooking, blanching or drying. The drying and storing of vegetables guarantee ample supply during off-season or out of seasonal periods and to other areas where the vegetables are not grown (Van Rensburg *et al.*, 2004).

Conversely, African leafy vegetables are usually inexpensive or free and are, a rich source of nutrients, especially vitamins A and C, and minerals (Ca and Fe). Boiling the leaves may reduce the vitamin C content by up to 80%, while drying reduces the vitamin content by about 95%. The blanching process plays a role in the retention of nutrients, steam blanching, followed by dehydration is most effective in retaining ascorbic acid (Vorster *et al.*, 2002).

2.4.1 Blanching

Blanching or scalding is the process done physically with hot water or steam. It mainly aims to inactivate enzymes that cause off-flavor, which might occur during storage of frozen and dried products, omitting air from the tissue and controlling the product (Musa *et al.*, 2017). Hence, it is crucial to ensure heating for a sufficient time at a temperature range 91°C to 99°C (Musa, 2017). Although the range of temperature and time depends on the thickness of the product to be blanched, it may be 1 to 11 minutes.

2.4.2 Drying Techniques

Combating post-harvest losses in vegetables is imperative in facilitating food availability and food security throughout the time. The World Bank (2011) accounted that investment in post-harvest technology in the attainment of African food security is significant by limiting post-harvest losses of vegetables, fruits and grains.

Solar drying helps to preserve the product and sustain nutrient composition in the final product if practised properly (Ukegbu & Okereke, 2013a). Additionally, the studies done by James and Matemu (2016a) reported that, solar drying provides concentrated product, adds variety to the diet, simplifies easy means of transport and enhances accessibility of vegetable product throughout the year.

2.5 Anti-Nutritional Factors in African Nightshade

The oxalates and phytate content of dried leaves are higher than those of fresh leaves. The values ranged from 100 to 1261.26 mg/100 g and 46.45 to 66.96 mg/100 g after 3 days of sun drying for oxalates and phytate, respectively. The meaning is that, the increase in consumption of sun dried leaves pose no adverse effect in human nutrition since oxalates and phytates impair the bioavailability of calcium, magnesium, zinc, and iron (Zoro *et al*., 2015). The study conducted by Mosha *et al.* (1995a) stated that blanching reduces phytate and tannin levels in green leafy vegetables.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Description of the Study Areas

The study was conducted in Arusha Urban and Meru district of the Arusha region. The region was selected because of it is famous in the production of ANS, and the district also produces plenty of the ANS as compared to other districts wthin the Region. One ward from each district and one village/street from each ward were purposively selected for sample collection due to high African nightshades cultivation in the area. The villages/streets under the study were Moivaro street located in Moshono ward (Arusha urban) and Nkuanrua village located in Akheri ward (Meru district) (Fig. 1). Arusha region is located in Nothern zone (latitude 3°22^{i} 00^{ii}S, Longitde 36° 40^{i} 59^{ii} E at an altitude of 1415 m. a.s.l. The average annual rainfall amounts to 1100 mm and temperature averaging to 20°C as low and 30°C as high.

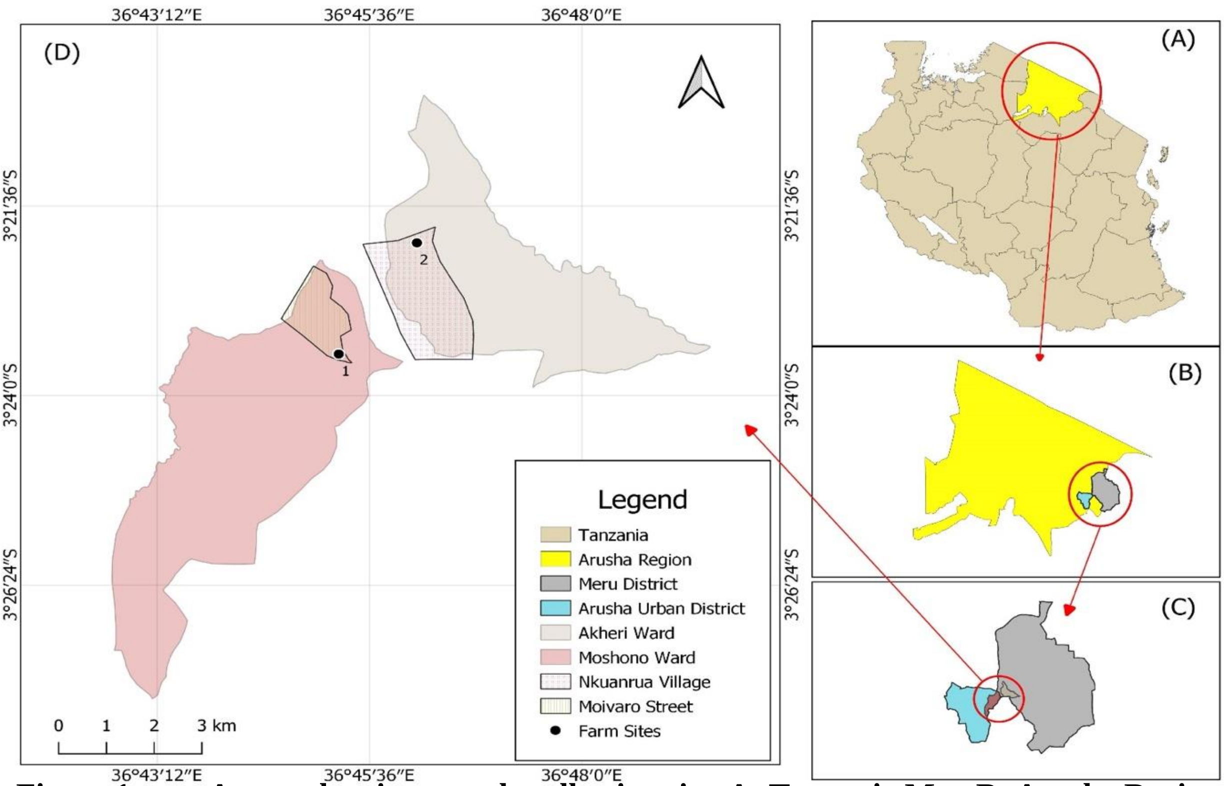

Figure 1: A map showing sample collection site A: Tanzania Map B: Arusha Region C: Arusha Uban and Meru District

3.2 Sample Collection

Fresh leaves of *S. scabrum* and *S. villosum* as shown in plate 1 were obtained from Arusha Urban and Meru districts. The ANS were harvested at their maturity stage during the fourth to fifth weeks after planting. The harvesting was conducted in the morning from 06:30 am to 08:00 am EAT, the harvested ANS leaves were packaged in the perforated plastic crates and immediately transported to the NM-AIST food processing unit for sorting, washing, and de-stalking (Plate 2).

A ©**Kazosi** B ©**Kazosi**

Plate 1: (a) and (b): Plants of *S. scabrum* and *S. villosum* leaves consecutively at the farm

Harvesting of ANS

Collection of ANS in perforated crates © Kazosi

Washing of ANS leaves

Weighing of sorted ANS leaves

Sorting of of ANS leaves

Plate 2: Processing of ANS leaves from harvesting, collection and preperation

3.3 Pre-treatments of Solanum sp

Before drying, SS and SV leaves were pre-treated by blanching with 3% NaCl (WBS) or without 3% NaCl (WB). Briefly, about 500 g of the fresh leaves were blanched at 85°C for 2 min with or without salt separately, followed by immediate cooling in ice water for both treatments (Xiao *et al*., 2017; Plate 3). Water was drained, and the pre-treated leaves were ready for drying (Plate 3). For control, no pre-treatment was done on fresh SS, and SV leaves, i.e., un-blanching (UnB).

Blanching of ANS leaves

Cooling of blanched ANS leaves

Draining of ice cooled ANS leaves

Plate 3: Pre-treatment of ANS leaves

3.4 Drying of Solanum sp Leaves

The SS and SV leaves (UnB, WB, and WBS) were dried using either an open sun (OSD), or mixed solar (MSD), or indirect solar driers (ISD) separately (plate 4). The drying started at 09:30 am to 5:30 pm EAT with an average drying rate of 28.43 g/h and 24.44 g/h-SS, and SV for OSD; 56.19 g/h-SS, 60.01 g/h-SV for MSD, and 23.83 g/h-SS and 24.31 g/h-SV for ISD, respectively. Frequently turning of the leaves was done to allow an even heat distribution and equal drying time. The temperature and relative humidity were recorded using a temperature and relative humidity data logger (PCE HT 71N, China). For ODS, samples were removed from the driers at night to avoid moisture pick-up as the relative humidity increases. The dried SS and SV leaves were collected after reaching the set limit for moisture contents measured using the Oven drying method (AOAC, 1990). The samples from each category of the dried leaves were stored in a dark, cool place for further analyses while others were packed, labeled and stored in the processing unit for display as shown in Plate 5.

The drying time for each drying technique were different due to the different heated air circulated in the product. Their drying time ranged from 9.5-10.8 hours for OSD; 4.8-5.8 hours for MSD and 12-15.3 hours for ISD. In connection to this, the higher temperature for OSD, MSD and ISD were 33.90℃, 62.36℃ and 46.30℃, consecutively.

Open sun drier

Mixed solar drier

Indirect solar drier

Plate 4: Different types of driers used in the study

Sample of Unblanched dried ANS product

Sample of Blanched and dried ANS product

Packaged and labelled ANS Products

Plate 5: Pictorate of packaged and labeled products of ANS

3.5 Moisture Content Determination

The Oven drying method determined the moisture content of fresh and dried SS and SV leaves (AOAC, 2000). A 5 g of fresh and dried samples were placed on dry and labeled moisture dishes. The samples were heated in Oven (DIN EN60529-IP 20, Germany) at 105°C for 24 h. The samples were removed and cooled in a desiccator before being re-weighed. The moisture content was calculated as per the formula:

$$\text{Moisture contents} = \frac{W_1 - W2_2}{W_1} \times 100$$

Where: W_1 = Weight (g) of SS or SV before oven drying

W_2 = Weight (g) of SS or SV after oven drying

3.6 Vitamin C Determination

The vitamin C from the fresh and dried SS and SV leaves was evaluated as total ascorbic acid (Kapur *et al.*, 2012). Five grams of fresh or dried leaves were homogenized with 25 mL of 3% Meta-phosphoric acid-8% acetic acid solution (Loba Chemie Pvt. Ltd, India). The mixture was centrifuged at 4000 rpm for 15 min (Eppendorf. AG, Germany) and filtered with Whatman paper no. 1 (Johnson Test Papers Ltd, UK). Four milliliters of the extract were added in 0.23 mL of 3% Bromine water (Bio-Chem Laboratory, USA), followed by 0.13 mL of 10% Thiourea (Loba Chemie Pvt. Ltd, India). After that, 1 mL of 2,4-Dinitrophenylhydrazine solution (BDH Lab. Chem. Group, England) was added. The mixture was heated at 37°C for 3 h in a water bath (Constant thermostat water tank, XMTE-205, China), cooled in an ice bath (Icemaker S/N14728341, China) for 30 min. Then 5 mL of chilled 85% Sulphuric acid solution (Loba Chemie Pvt. Ltd, India) was added to a cooled mixture. The resulting red solution's absorbance was measured at 521 nm (UNICO Spectrophotometer, USA). The total ascorbic acid content was calculated from the calibration curve of the Ascorbic acid standard (Merck Chemicals, USA) and expressed as mg/100 g (dry basis).

$$\text{Vitamin C} = \frac{\text{Co - DF}}{\text{Ws} \times 10}$$

Where	Co	=	Concentration from the graph;
	Df	=	Dilution factor;
	Ws	=	Weight (g) of sample.

3.7 Minerals Determination

Dry ashing at 600°C was performed in a Muffle furnace (Thermal Scientific, Germany) for 5 h using 5 g of fresh and dried SS and SV leaves placed on a clean porcelain crucible (AOAC, 1990). The starting temperature was 550°C and gradually increased to 600°C at a rate of 50°C/h. The ash obtained was digested with 10% Hydrochloric acid (Loba Chemie Pvt. Ltd, India) and filtered with Whatman filter paper no. 41 (Fisher Scientific, UK) into a 25 mL flask, and the volume made to the mark using distilled water. The mineral (Ca, Fe, Mg, and Zn) content was determined using Atomic Absorption Spectrophotometer (Thermo Scientific iCE 3300, UK). The absorption wavelengths for Ca, Fe, Mg, and Zn were set at 422.6, 248.1, 285.1, and 213.6 nm, respectively. The minerals in each sample were calculated by the formula:

$$\text{Mineral conc. (mg/100g)} = \frac{\text{Graph conc} \times \text{Dilusion factor}}{\text{Weight of sample} \times 10}$$

3.8 Anti-Nutrients Determination

3.8.1 Oxalate Content

The oxalate content was evaluated according to Kandonga *et al*. (2019) with some modifications. Briefly, 1 g of fresh or dried leaves was mixed with 75 mL of 3 M Sulphuric acid solution (Loba Chemie Pvt. Ltd, India) and stirred (MR Hel-Standard, Germany) for 1 h. The mixture was centrifuged at 4000 rpm for 15 min (Eppendorf. AG, Germany) and filtered using Whatman filter paper no. 1 (Fisher Scientific, UK). Twenty-five milliliters of the filtrate were titrated against 0.05 M of Potassium permanganate (Dentex Industry Ltd, Kenya), while hot (90°C) until pale pink colour appeared and persisted for at least 30 secs. The oxalate content was calculated and expressed in mg/100g (dry basis) by considering 1 mL of 0.05 M Potassium permanganate equivalent to 2.2 mg of oxalate (Agbaire & Management, 2011; Jonathan & Funmilola, 2014).

3.8.2 Phytate Content

The phytate quantification in fresh or dried SS and SV was done according to *Mwanri et al*. (2018), with slight modifications. Concisely, 0.5 g of grounded leaves was added in 12.5 mL 3% Tri-chloroacetic acid (Loba Chemie Pvt. Ltd, India), stirred by orbital shaker (Thermo Scientific, USA) for 45 min, and centrifuged at 4000 rpm for 15 min (Eppendorf AG, Germany). To a 10 mL of the supernatant, 4 mL of Ferrous chloride solution (Loba Chemie Pvt. Ltd, India) were added by lowering rapidly from the pipette. The content was then heated in a boiling water bath (WBH-200, Germany) for 45 min, cooled, and centrifuged at 2000 rpm for 15 min (Eppendorf AG, Germany). The precipitate was washed twice by dispensing well in 12.5 mL of 3% Tri-chloroacetic acid solution, heated in boiling water bath for 10 min, centrifuged, and washed with water repeatedly. The precipitate was dispersed in 5 mL of water and 3 mL of 1.5 N Sodium hydroxide (Loba Chemie Pvt. Ltd, India) with mixing. The volume was brought to approximately 30 mL with distilled water and then heated in a boiling water bath (WBH-200, Germany) for 30 min. The precipitate was filtered through a moderately retentive Whatman filter paper no. 2 (Fisher Scientific, UK). The residue was washed with 70 mL hot water, and filtrate discarded; dissolved the precipitate from the paper with 40 mL hot 3.2 N Nitric acids (Loba Chemie Pvt. Ltd, India). The filter paper was washed with several portions of distilled water and collected in the same flask taking care not to exceed 100 mL. The flask was cooled at ambient temperature and diluted to volume with water. An aliquot of 5 mL was diluted to 100 mL mark and withdrawing 0.5 mL of the diluted sample, added with 7.5 mL distilled water and 2 mL of 1.5 M Potassium thiocyanate (Loba Chemie Pvt. Ltd, India).

The absorbance was taken at 470 nm within 1 min; phytate content calculated using the formula:

$$\text{Phytate content in. mg/100 g} = \frac{C*E*DF}{S*Av} \times 100$$

Where:	C	=	Phytate c oncentration from sta Qdard graph (mg/mL);
	E	=	Total extraction volume (12.5 mL);
	D.F	=	Dilution factor (0.05);
	S	=	Analytical sample taken (g);
	Av	=	Analytical volume (10 mL).

3.9 Sensory Evaluation: Consumer Acceptability Test

The consumer test was carried out in the Department of Training under section of Culinary Art, at VETA Hotel and Tourism Training Institute-Arusha using a 9-point hedonic scale (where 9-Like extremely, 5-Neither like nor dislike 1-Dislike extremely) by untrained panelists as described by Lawless and Heyman (2003). The prepared samples were randomly coded with three digit numbers using statistical random tables and served to the panelist at 11:30 am with clean drinking water, in a randomized manner. The untrained panelists were instructed to rate the colour, texture, taste, appearance, aroma and general acceptability attributes indicating the degree of liking or disliking by putting a number as provided in the hedonic scale according to their preferences. The test was done in two days and each assessed four samples in a day. This test was completely voluntary and it involved participants of 21 to 48 years of age.

3.10 Shelf Life Studies

The shelf life studies were carried after obtaining the results on the contents of vitamin C retained from the three driers. The investigation were done to assess the effect of storage on vitamin C, and mirobial quality (total bacteria and yeast and moulds) to the stored samples under ambient and refrigeration temperature. The dried products of African nightshade (SS & SV) packaged in polyethylene laminated aluminium bags were stored at ambient temperature at 26 ± 1°C and refrigeration (4°C). The packaged samples were stored for three months. The analyses were performed at an interval of 0, 30, 60 and 90 days (three monthly) for total bacteria count, yeast and moulds.

3.11 Data Analysis

The data of fresh and dried SS and SV samples were organized by Microsoft excel 2010 for descriptive statistics. The data were analyzed using the R statistical package (R Development Core Team, Version 3.0.6, Vienna, Austria) for two-way analysis of variance (ANOVA) to determine the differences and interactions between the processing methods with treatments (Means were separated by post hoc pair-wise test (Turkey's Honest Significant Difference) at $p<0.05$. The differences were considered statistically significant at $p < 0.05$.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Drying Rate, Time, Temperature and Relative Humidity of African Nightshade

The temperature variations in open sun, mixed and indirect solar dryer's drying chamber were as shown in Fig. 2. The average open sun drying temperature increased from 25.8°C (Rh 21.2 at 10:00 am, EAT) to 41.8°C (Rh 16.5 at 14:00 EAT) and decreased thereafter to 27.6°C (Rh 22.4 at 17:00 pm EAT). Similarly, temperature of the drying chamber within the mixed solar dryer increased from an average of 53.2°C (Rh 12.7 at 10:00 am) to 69.2°C (Rh 3.5 at 14:00 EAT) and decreased afterwards to average of 41.5°C (Rh 10.2 at 17:00 EAT). However, for indirect solar dryer the temperature increased from an average of 33.3°C (Rh 36. at 10:00) to 45.8°C (Rh 12.2 at 14:00 EAT) and decreased to an average of 41.1°C (Rh 315.5a t 17:00 EAT). 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 different from the temperature in indirect and open sun drying methods. The study done by Ayua *et al.* (2017) reported that mixed mode solar dryer had highest temperature as compared to other dryers.

In comparison with the performance of the dryers used, the mixed mode was also found to have low drying times as compared to indirect and open sun drying dryers. The mixed mode used shorter time (4.8 h to 5.8 h) than the indirect solar dryer that used 12 h to 13.3 h and 9.5 h to 10.8 h for the open sun drying method for SS and SV samples as presented in Fig. 3. These dryers were found to differ in their drying rates, where mixed solar dryer dried the vegetables very fast at a rate of 51.4 g/h to 63.1 g/h than indirect solar drier (drying rate 22.5 to 25 g/h) and open sun drying method (drying rate 27.7 to 32.1 g/h). This describe that the drying temperature is directly proportional to the performance of the dryer. Hence the relative humidity is lower when the temperature increases. Thus, the higher the temperature, the higher the drying rate of the respective dryer in drying the samples as tabulated in Table 1. Similar finding was reported by Bolaji and Olalusi (2008) on performance evaluation of a mixed mode dryer that low relative humidity with higher drying temperature guarantees adequate drying of foods.

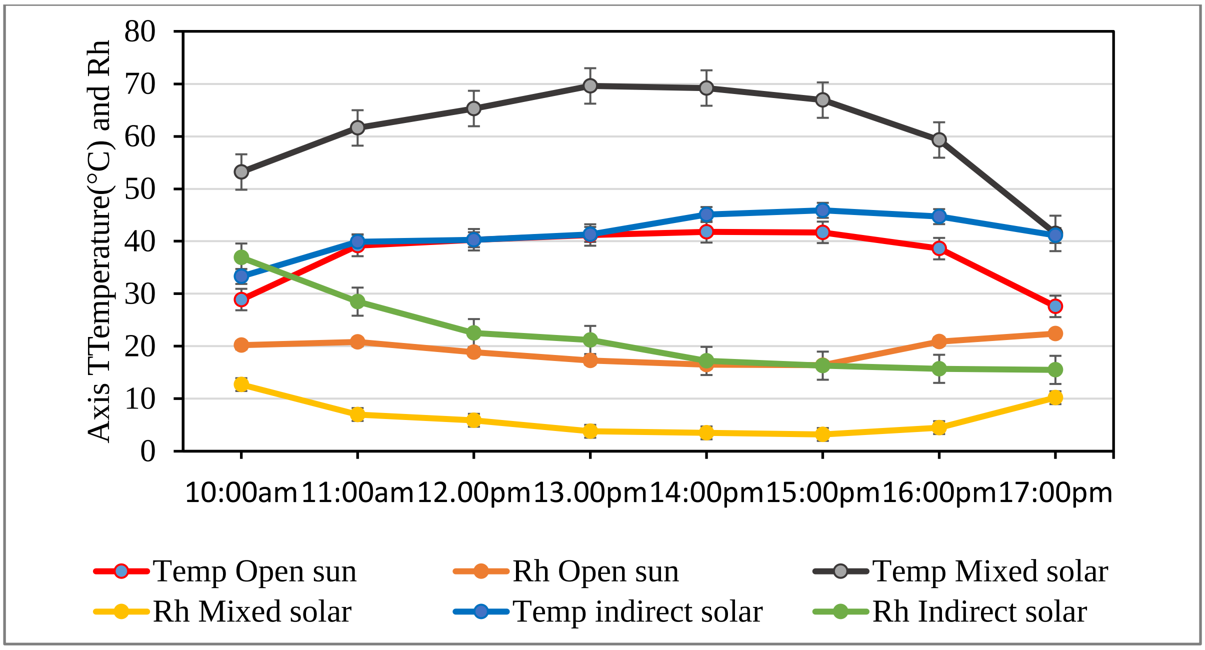

Figure 2: Temperature (°C) and relative humidity of open and solar drying methods

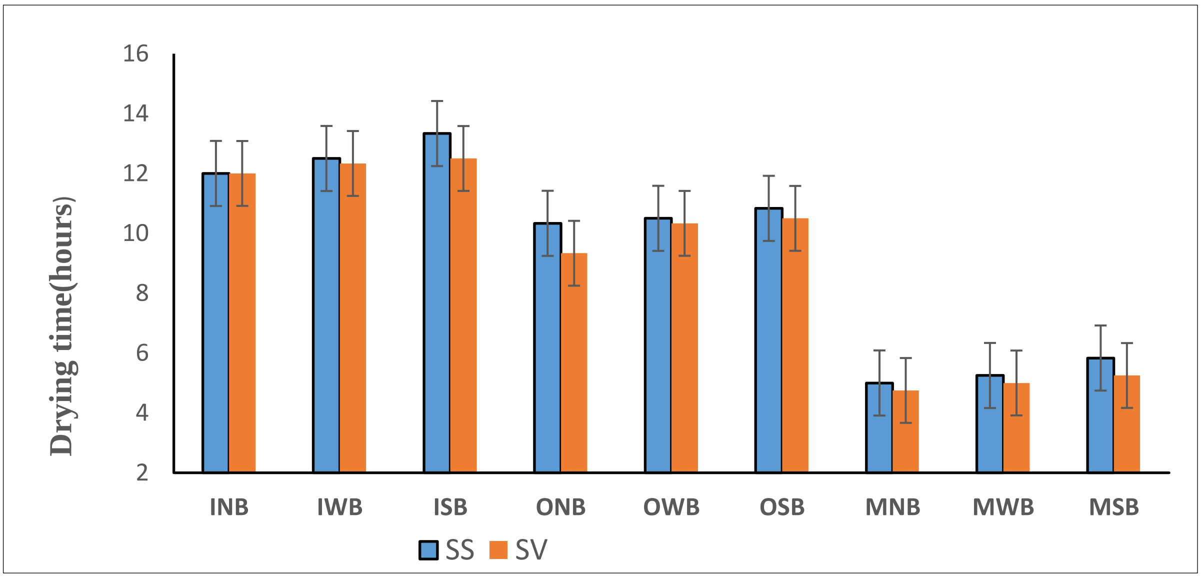

Figure 3: Drying times (hours) of open sun, mixed and indirect solar dryer of *S. scabrum* and *S. villosum*

Table 1: Summary of temperatures (°C), drying times and drying rate recorded during ANS drying

Vegetable	Description	Indirect Sun		Open Sun		Mixed Solar	
		Min	Max	Max	Min	Min	Max
SS	Temperature(°C)	33.3	45.9	25.8	43.2	41.5	69.2
	Drying times (hours)	12.0	13.3	10.3	10.8	5.0	5.8
	Drying rate (g/hour)	22.5	25	27.7	29	51.4	60
SV	Temperature(°C)	33.3	45.9	25.8	43.2	41.5	69.2
	Drying times (hours)	12.0	12.5	9.3	10.5	4.8	5.3
	Drying rate (g/hour)	24.0	25.0	28.6	32.1	57.1	63.2

4.2 Effect of Drying Methods on the Moisture Content

Drying of vegetables removes the moisture to extend shelf life, and hence leads to the preservation effect. Table 2 presents the moisture content of both fresh (FO) and dried SS and SV leaves. Fresh SS and SV leaves had the highest moisture content (87.03% ± 0.17 and 84.06% ± 0.4, respectively). This moisture content amount agreed to the studies done by Nnamani *et al*. (2009) and Traoré *et al.* (2017) on *S. scabrum* Mill which reported the moisture contents to be 87.13 ± 1.39%. A significant moisture content reduction was recorded in both dried SS and SV leaves. Conversely, all drying methods substantially reduced moisture content with ISD recording a range of 8.58% to 11.96% for SS and 8.61% to 10.69% for SV, respectively. Further, for MSD, the moisture content ranged from 7.64 to 10.13% for SS and 6.37% to 9.16% for SV, respectively. Also, for OSD, the moisture content was from 7.96% to 8.98% in SS and 8.38% to 9.96% in SV. Generally, all dried samples, regardless of pre-treatment and drying methods; they attained a recommended percent of moisture content (for drying rate, time, temperature and relative humidity of ANS) for safe storage of leafy vegetables. Similarly, Traoré *et al.* (2017) reported a reduction in moisture content of black nightshade to 11.82 ± 3.5% under shade drying, 6.47 ± 1.24% under cabin drying (60°C), and 7.38 ± 3.84 under cabin drying (50°C), which agrees to the findings from this study.

Also, Yakubu *et al*. (2012) reported higher moisture content of *Vernonia amygdalina* blanched with salt. Nevertheless, variation in moisture content might have been contributed by differences in leaf size such that with large and broader leaves in SS and with thin and small size leaves in SV. Furthermore, farming location, fertilizers use, and abuse within the varieties may contribute to the differences. According to Uusiku *et al.* (2010), agronomic reasons, including differences in the vegetables' harvesting time and maturity stages, may result in moisture content variations. The moisture content of all dried SS and SV leaves was < 13% of the recommended for safe storage of dried vegetables for six months and above without deteriorating at ambient temperature (Sahar *et al.*, 2015; Seidu *et al.*, 2012).

Table 2: Effect of drying methods on the moisture content of SS and SV leaves

African nightshade	Drying methods	Pre-treatment methods	Moisture (%)
S. scabrum (SS)		**FO**	**87.03 ± 0.17**
	ISD	UnB	8.58 ± 0.00
		WB	9.52 ± 0.00
		WBS	11.96 ± 0.00
	MSD	UnB	7.64 ± 0.00
		WB	9.74 ± 0.11
		WBS	10.13 ± 0.11
	OSD	UnB	7.96 ± 0.00
		WB	8.63 ± 0.00
		WBS	8.98 ± 0.01
		FO	**84.06 ± 0.40**
	ISD	UnB	8.61 ± 0.00
S. villosum (SV)		WB	9.82 ± 0.00
		WBS	10.69 ± 0.00
	MSD	UnB	6.70 ± 0.00
		WB	9.16 ± 0.01
		WBS	6.37 ± 0.00
	OSD	UnB	8.38 ± 0.10
		WB	9.96 ± 0.00
		WBS	8.98 ± 0.01

Means ±SD (n=3). UnB: Unblanched sample; WB: Water blanched; WBS: Water blanched with NaCl

4.3 Effect of Drying Methods on Vitamin C Retention

Vitamin C content of both fresh and dried SS and SV leaves are as presented in Table 3. The vitamin C content of fresh SS and SV leaves was 118.36 ± 2.97 mg/100 g and 92.58 ± 2.49 mg/100g, respectively. Fresh SS leaves contained significantly higher levels of vitamin C than fresh SV leaves. Both pre-treatment and drying methods had a significant effect on vitamin C reduction. A marked decrease in vitamin C was observed in untreated (UnB) and pre-treated (WB and WBS) dried SS and SV leaves in contrast to the fresh leaves.

The vitamin C retention in SS dried was in between 9.10% and 14.76% (ISD), 6.03% and 12.94% (MSD), and 5.47% and12.08% (OSD), respectively. For dried SV, vitamin C retention was in between 13.33% and 19.23% (OSD), 11.5% and 17.79% (MSD) and 11.5% and 15.69% (OSD), respectively. Generally, the average loss in vitamin C during drying ranged from 81.36% to 94.53%. Likewise, Kandoga *et al*. (2019) reported a 99.51% loss in vitamin C in blanched and dried false sesame and common bean leaves. Ndawula *et al*. (2004) reported 84.54% loss in vitamin C when fruits and cowpea leaves were open sun-dried. Furthermore, Babalola *et al*. (2010) reported a significant loss of vitamin C in sun dried-blanched samples, thus open sun had a tremendous impact compared to other drying methods.

The vitamin C loss was significantly affected by blanching. Blanching with salt (WBS) negatively affected vitamin C retention regardless of the drying methods. Comparably, slightly higher vitamin C was retained in untreated (UnB) than pre-treated (WB and WBS). Further losses occurred in WBS, suggesting that salt negatively affected vitamin C levels. Therefore, pre-treatment with WB and WBS was not practical in retaining vitamin C. As a whole, vitamin C retention was more significant in dried SV than SS (Table 3).

Noteworthy, all drying methods had a tremendous decrease in vitamin C. The vitamin C loss trend was in the order of ISD < MSD < OSD. The indirect exposure to sunlight might have contributed to the variation in levels of vitamin C in MSD or ISD. Hence, less oxidation, mainly in the open sun, accelerated vitamin C losses due to oxidation, oxygen, and ultraviolet rays (Constant *et al.*, 2016). According to Constant *et al.* (2016), the loss of vitamin C by sun-drying in different five-leafy vegetables was 85.12% to 96.42%. Besides, the drying temperature in ISD (39.9°C) and MSD (47.2°C) may also affect the drying rate and vitamin C levels.

Furthermore, less vitamin C retention resulted from the pre-treatments and drying process. Blanching causes leaching as vitamin C is water-soluble and sensitive to heat and light (Lee *et al.*, 2000). This is consistent with Kandonga *et al*. (2019) findings of 70.62 to 91.24% vitamin C losses due to blanching and sun-drying of false sesame and common bean leaves. Negi *et al.* (2000) and Ndawula *et al*. (2004) reported 7.5% retention of vitamin C in blanched solar-dried cowpeas leaves. Hence, drying un-blanched SS and SV leaves with ISD can be an alternative method to avoid more vitamin C losses regardless of the *Solanum* sp.

Table 3: Effect of drying methods on vitamin C content of SS and SV

African nightshade	Drying methods	Pre-treatment Methods	Vitamin C (mg/100g (db))
S. scabrum (SC)	ISD	**FO**	**118.36 ± 2.97[a]**
		UnB	17.47 ± 1.04[b]
		WB	11.67 ± 0.39[d]
		WBS	10.77 ± 0.58[de]
	MSD	UnB	15.31 ± 1.04[c]
		WB	9.57 ± 0.06[e]
		WBS	7.14 ± 0.86[f]
	OSD	UnB	14.30 ± 0.59[c]
		WB	9.34 ± 0.29[e]
		WBS	6.48 ± 0.40[f]
S. villosum (SV)	ISD	**FO**	**92.58 ± 2.49[a]**
		UnB	17.79 ± 0.20[b]
		WB	17.26 ± 0.23[bc]
		WBS	12.35 ± 0.20[de]
	MSD	UnB	16.47 ± 0.82[bc]
		WB	12.79 ± 0.03[de]
		WBS	10.65 ± 0.57[e]
	OSD	UnB	14.53 ± 0.66[cd]
		WB	12.65 ± 0.79[e]
		WBS	10.65 ± 0.61[e]

Means ± SD (n=3). The means in columns with different superscript letters are significantly other (p<0.05); ISD: Indirect solar drier, MSD: Mixed solar drier; OSD: Open solar drier; UnB: Un-blanched; WB: Water blanched; WBS: Water blanched with NaCl

4.4 Effect of Drying Methods on Mineral Content

Table 4 presents mineral content (Ca, Fe, Mg, and Zn) retained in the fresh, and dried leaves. Fresh SS and SV leaves displayed significantly higher mineral values than dried ones. Therefore, different drying methods significantly lowered the mineral content of SS and SV leaves. Notably, much higher mineral levels were retained in untreated (UnB) than pre-treated (WB and WBS) dried leaves. Therefore, pre-treatment with WBS resulted in a further reduction in mineral content (Table 4), thus the trend of mineral retention in both SS and SV followed the following sequence; UnB> WB>WBS.

Table 4: Effect of drying methods on minerals retention in dried SS and SV leaves (mg/100 g dry basis)

African nightshade	Drying Method	Pre-treatment	Ca	Fe	Mg	Zn
S. scabrum (SC)		**FO**	**1392.02±18.60^{a}**	**152.01 ± 4.96^{a}**	**253.56 ±3.08^{a}**	**6.05±0.20^{a}**
	ISD	UnB	1289.01 ± 5.29^{b}	118.39 ± 0.47^{b}	191.08 ± 7.78^{b}	5.26±0.36^{b}
		WB	1157.06 ± 1.94^{cd}	79.22 ± 0.63^{d}	188.11 ± 0.69^{b}	4.56±0.10^{c}
		WBS	1106.24 ± 6.67e	78.20 ± 0.30^{d}	175.90 ±0.92^{de}	3.15±0.06^{d}
	MSD	UnB	1157.03 ± 7.54^{cd}	79.49 ± 10.96^{d}	185.29 ±1.26^{bc}	3.56± 0.19^{d}
		WB	1115.29 ± 10.92^{e}	62.00 ± 0.36^{e}	171.84 ±1.39^{de}	3.17±0.11^{d}
		WBS	982.59 ± 1.85^{g}	60.27 ± 0.42^{e}	159.54±14.98^{f}	2.41±0.08^{e}
	OSD	UnB	1179.88 ± 5.72^{c}	90.16 ± 1.14^{c}	178.63±4.78^{cd}	2.64±0.21^{e}
		WB	1141.87 ± 3.91^{d}	78.39 ± 0.19^{d}	167.01±0.15^{ef}	2.39±0.10^{e}
		WBS	1076.35 ± 8.29^{f}	62.03 ± 2.99^{e}	148.42±0.83^{g}	2.30±0.03^{e}
S. villosum (SV)		**FO**	**1243.95± 22.35^{a}**	**158.23±1.74^{a}**	**223.16±4.13^{a}**	**4.24±0.00^{a}**
	ISD	UnB	1201.38± 24.98^{a}	113.48 ± 0.19^{b}	180.45±0.62^{b}	3.82±0.31^{b}
		WB	1146.18 ± 4.75^{a}	71.71 ± 0.49^{de}	163.22±0.66^{f}	3.42±0.12^{cd}
		WBS	1117.38 ± 17.67^{a}	71.63 ± 5.35^{de}	147.81±0.97^{de}	3.27±0.02^{d}
	MSD	UnB	1135.60 ± 10.26^{a}	80.60 ± 0.26^{c}	156.57±9.06^{c}	3.66±0.01^{bc}
		WB	1115.45 ± 22.50^{a}	69.65 ± 1.33^{e}	155.62±0.50^{cd}	3.31±0.11^{d}
		WBS	1099.34 ± 5.60^{a}	68.97 ± 0.33^{e}	135.35±1.12^{f}	2.89±0.04^{ef}
	OSD	UnB	1163.59 ± 12.88^{a}	78.75 ± 0.02^{cd}	157.69±0.29^{c}	3.16±0.10^{de}
		WB	1125.40 ± 3.81^{a}	69.67 ± 5.41^{e}	141.58±1.59^{ef}	2.87±0.03^{ef}
		WBS	1109.87 ± 1.52^{a}	55.32 ± 4.93^{f}	115.47±0.58^{g}	2.79±0.01^{f}

Means ± SD (n=3). The means in columns and rows with different superscript letters are significantly different ($p<0.05$); ISD: Indirect solar drier, MSD: Mixed solar drier; OSD: Open solar drier; UnB: Un-blanched; WB: Water blanched; WBS: Water blanched with the addition of NaCl

According to Saltzman et al. (2014), mostly Fe and Zn are minerals of public health concerns needed in small quantities despite their importance for disease prevention, development, and human well-being. The amount obtained from the dried samples is enough to supply the body with the required amount per daily recommended allowances.

For Ca, fresh (FO), SS, and SV leaves recorded 1392.02 ± 18.00 and 1243.95 ± 22.35 mg/100 g, respectively (Table 4). All drying methods reduced Ca levels in SS leaves by 7.4 to 20.53%, 16.88 to 29.41%, and 15.24 to 22.68% for ISD, MSD and OSD, respectively. In SV, Ca losses ranged from 3.14 to 10.17% (ISD), 8.71 to 11.63% (MSD), and 6.46 to 10.78% (OSD). However, much higher Ca levels were retained in UnB than WB and WBS, respectively. Kamga *et al.* (2013) reported Ca reduction in *S. scabrum* and *Corchorus olitorius* (Jute mallow), respectively. Generally, Ca reduction in this study was significantly higher with a range between 3.14% to 22.68%, irrespective of the drying method. Regardless of the reduced levels, the reported amount is still within the recommended dietary allowance (RDA), ranging from 1000 to 3000 mg/100 g. Oni *et al*. (2015) reported a significant decrease in Ca concentration in sun-dried edible botanicals ranging from 1.23 ± 0.42% to 1.62 ± 1.70%. Also, blanching resulted into further Ca reduction, especially when blanched with salt. Therefore, the trend for Ca retention considering both pre-treatment and drying methods was ISD > OSD > MSD.

Generally, a similar trend in Fe, Mg, and Zn retention was observed (Table 4). The Fe content in fresh SS was 152.01 ± 4.96 and 158.23 ± 1.74 mg/100 g in SV, respectively. The pre-treatment and drying methods employed showed less retention effect on Fe in both SS and SV leaves. The UnB retained a higher Fe level, with WB and WBS significantly reducing Fe levels. Furthermore, WBS treated dried leaves presented the lowest Fe values. For dried SS leaves, Fe retention was between 51.44% to 77.77%, 39.65% to 52.29%, and 40.81% to 59.31% for ISD, MSD, and OSD, respectively. On the other hand, Fe retention in dried SV leaves was in the range of 45.26% to 71.72% (ISD), 43.59% to 50.94% (MSD), and 34.96% to 49.77% (OSD), respectively. Generally, Fe losses were in a range of 22.23% to 60.35% for SS and 28.28% to 65.04% for SV regardless of the drying methods. Considering the drying, both MSD and OSD had the lowest Fe values ($p < 0.05$) compared to ISD. Therefore, Fe retention was in the order of ISD> MSD> OSD. Kamga *et al*. (2013) reported Fe contents in *S. scabrum* to be 14.74 ± 1.69 and 38.74 ± 13.61 mg/100 g, lower than values from this study.

Table 4 shows Mg concentration in both fresh and dried SS and SV leaves. Like in Ca and Fe, Mg concentration was higher in UnB than WB and WBS. Magnesium retention in dried SS was in a range of 69.37% to 75.34%, 62.92% to 73.06%, and 58.53% to 70.49% for ISD, MSD, and OSD, respectively, while, for dried SV, it was 66.15% to 80.76% for ISD, MSD (60.57% to 70.67%), and OSD (51.67% to 70.57%), respectively. To sum up, both drying methods influenced the Mg retention levels, with WB and WBS causing further losses. The decline might be due to the effects of water-soluble minerals that reduce their contents; moreover, the effect increases as the blanching time increases (Babalola & Alabi, 2015; Bamidele *et al.*, 2017; Yakubu *et al.*, 2012). The effect of drying methods on the Mg retention was in the trend ISD > ISD > OSD. The findings of this study show that ISD method was the best in Mg retention under both treatments.

Zinc content in fresh SS and SV leaves was 6.05 ± 0.20 and 4.24 mg/100 g, respectively (Table 3). Zinc is a micronutrient essential for proper human immune functioning and required for body growth (Black, 2003). Hotz and Brown (2004) reported an estimated 20% of the world population to be at risk of inadequate intake of Zn. The standard RDA for Zn is between 4 to

40 mg/100 g. The pre-treatment and drying methods reduced the amount of Zn in both SS and SV leaves. Zinc retention in dried SS was 50.07% to 86.94%, 39.83% to 58.84% and 38.02% to 43.64% for ISD, MSD, and OSD respectively. On the other hand, the amount of Zn retained in dried SV ranges from 77.12% to 90.09%, 68.16% to 86.32%, and 65.80% to 74.53% for ISD, MSD, and OSD, respectively. Like other minerals, both pre-treatment and drying methods negatively affected Zn content in SS and SV. Specifically, WB caused a further decrease in Zn content from UnB, with the least retention in WBS. This indicates that the drying methods caused more destruction of these minerals, especially OSD. Despite the decrease, ISD was the best method for Zn retention in the dried SS. Therefore, the effect of the drying method on Zn retention was in trend of ISD > MSD > OSD.

Kamga *et al*. (2015) reported that the quantity of Zn in *S. scabrum* ranges from 3.89 ±3.07 to 4.18 ± 1.56 mg/100 g, which was a little bit lower than fresh SS but similar to fresh SV leaves. Iron and Zn as trace elements were significantly reduced in vegetables dried by the open sun (Abiodun *et al*., 2010). However, the decrease in minerals concentration in the blanched leaves was due to disruption of cell walls as minerals are also found in plant cell walls; hence blanching results in the leaching of minerals (Babalola & Alabi, 2015; Bamidele *et al.*, 2017; Yakubu *et al.*, 2012).

Generally, Ca and Mg work together to reduce hypertension and blood pressure in the human body. Still, also they are the potential for good healthy teeth, strong bones and provide healthy muscles (Oni *et al.*, 2015; Wardlaw *et al.*, 2004). Iron produces hemoglobin, and its deficiency can result in anemia in children and women (Kumar *et al*., 2020). The shortage of Zn results in malfunctioning of the immune system and gastrointestinal tract (Welch, 1993).

4.5 Effect of Drying Methods on Oxalate and Phytate Removal

Anti-nutritional factors in foods reduce the bioavailability of nutrients by impairing the body to utilize nutrients absorbed from the diet (Danso *et al.*, 2019). Figure 9A and B presented percentage oxalate and phytate reduction in fresh SS and SV and dried leaves. Significant decrease ($p<0.05$) in oxalate and phytate levels was observed in both pre-treatment and drying methods (Fig. 9A & B). Similarly, pre-treatment with WB and WBS positively impacted oxalate removal, compared to UnB in the sequence WBS > WB > UnB. These findings suggest that WB significantly reduced oxalate. Besides, the highest oxalate removal was attained in WBS (Fig. 4A).

By comparing drying methods in OSD, oxalate reduction ranged from 14.48% to 26.92%, 22.78% to 30.55% (MSD) and 27.98% to 35.24% (ISD) for dried SS, respectively. For dried

SV, oxalate removal ranged from 4.66% to 10.21% (OSD) through 12.07% to 17.94% (MSD) and 12.61% to 20.79% (ISD), respectively. The oxalate removal followed the trend of ISD > MSD > OSD. Generally, the ISD method combined with WBS pre-treatment was the best in oxalate reduction.

Likewise, Mwanri *et al*. (2018) reported similar oxalate values in *S. villosum*, although some were higher due to differences in the maturity stage. Various studies also reported oxalate reduction in different vegetables during drying (Abiodun *et al*., 2010; Kandonga *et al*., 2019; Matazu & Haroun, 2004; Oni *et al.*, 2015). Kandonga *et al*. (2019) reported a reduction of oxalate (27.18% to 43.36%) to unblanched sun dried leaves of common beans, which were either covered with black or white clother or uncovered. The higher reduction of oxalate (88.79% to 95.74%) was found when the same common bean leaves were blanched. Similarly, other processing methods, including ressure cooking, open pan cooking, blanching, boiling and drying, had shown a tremendous effect in oxalate reduction in vegetables (Babalola & Alabi, 2015; Essack *et al.*, 2017; Mosha *et al.*, 1995; Mwanri *et al.*, 2011; Virginia *et al.*, 2012).

For phytates, both fresh SS and SV recorded 0.90 ± 0.06 mg/100 g and 0.94 ± 0.02 mg/100 g, respectively (Fig. 9B) higher than that recorded by Mwanri *et al.* (2018) for the ANS, spider plant, and amaranths, respectively.

On the other hand, phytate removal in dried SS was 82.22% to 85.55% (ISD), 74.44% to 76.66% (MSD) and 70% to 73.33% (OSD), while in dried SV, phytate removed ranged from 76.6% to 82.99% (ISD), 62.77% to 73.4% (MSD) and 52.12% to 57.45% (OSD), respectively. Further, both pre-treatment and drying methods significantly affected phytate reduction. In addition, pre-treatment with WBS and WB resulted in more phytate removal than in UnB. A substantial reduction of phytates was observed in all drying methods (Fig. 8B); However, the highest removal was recorded in ISD (82.22% to 85.55%). Generally, the ISD was the most efficient method in reducing phytates. Therefore, the trend for phytate removal was ISD > MSD > OSD. Thus, the ISD can be recommended as the best method for removing phytates in ANS. Blanching, sun, and solar drying were also reported to reduce phytates in bitter leafy vegetables (Elisha *et al.*, 2016; Ilelaboye *et al.*, 2013; Natesh *et al.*, 2017; Yakubu *et al*., 2012).

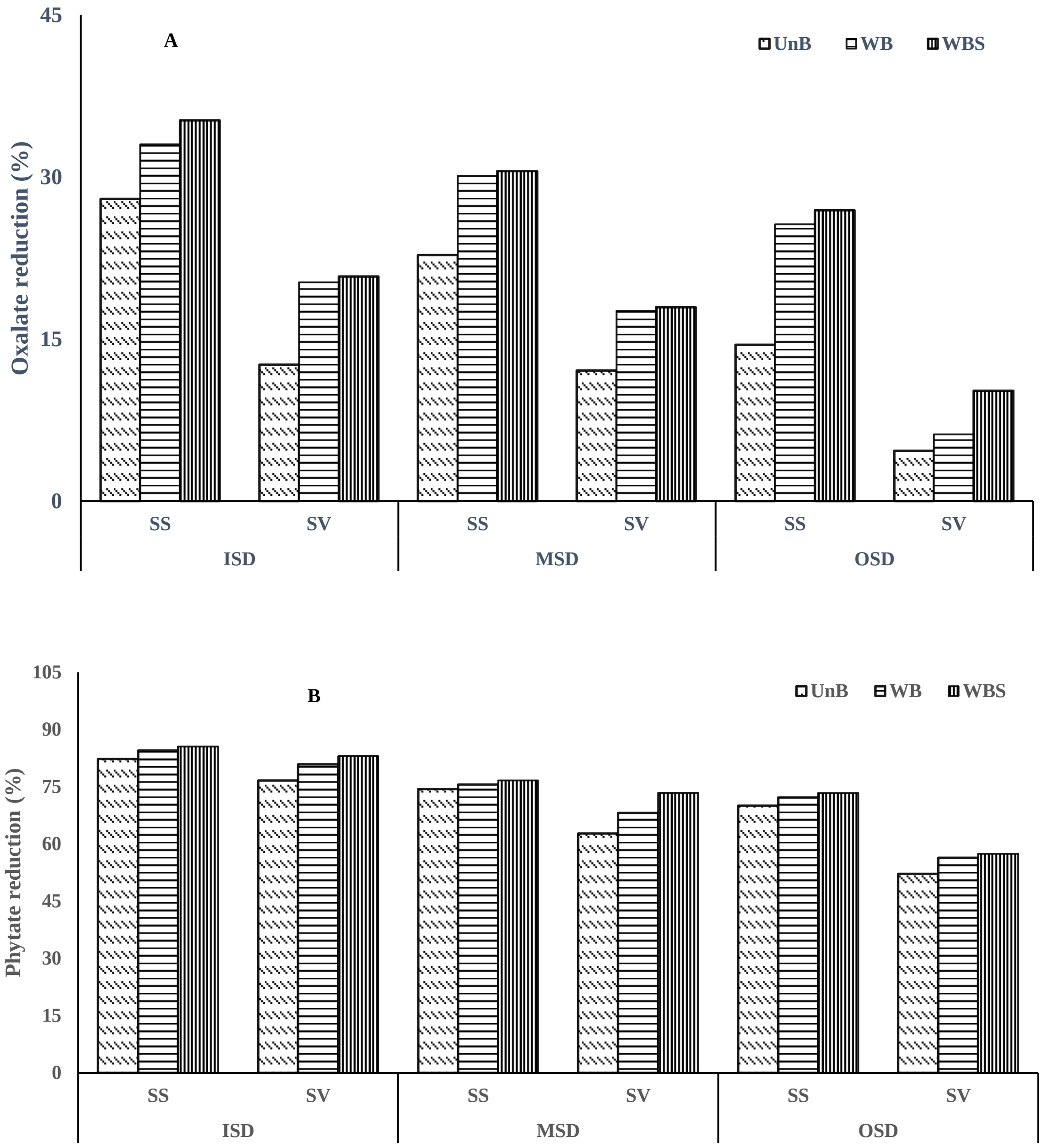

Figure 4: **Effect of drying methods on oxalate (A) and phytate (B) reduction in *Solanum scabrum* (SS) and *Solanum villosum* (SV). ISD: Indirect solar drier, MSD: Mixed solar drier; OSD: Open solar drier; UnB: Un-blanched; WB: Water blanched; WBS: Water blanched with the addition of 3% NaCl**

4.6 Consumer Acceptability Test Scores of the Dried African Nightshades

The test scores for consumer's acceptability of the sensory attributies are presented in Table 5. The test scores showed that the dried products were generally accepted with minimum score being 8.60. Significant ($p<0.05$) differences were observed on the colour, texture and bitterness attributes between fresh, pre-treated and un-blanched products for both SS and SV. The sensory analyses were not significantly different in colour intensity between FO and UnB samples (7.45; 7.33) in SS; (7.95; 8.33) in SV respectively. However, their significance differences

($p<0.05$) in colour were exhibited between FO and UnB with WB and WBS in SS but also between FO and UnB with WB and WBS in SV. Thus, consumers liked very much WB and WBS dried colours preferably than UnB and FO. The significant differences ($p<0.05$) in colour between pre-treated SS and SV samples were attributed to the tendency of blanching to inactivate enzymes and fixation of green colours (Negi & Roy, 2000).

The pre - treatment (WB and WBS) also caused alteration in the texture of dried ANS, thus leading to lower rating by pannelists with the minimal scores being 7.73-SS and 7.93-SV. Other attributes including taste and aroma were ranked high by the consumers with no significance differences among SS and SV to UnB, WB and WBS (Table 5). Nevertheless, the consumers rated high on bitterness attribute of the products (WB and WBS) in SS and SV products and ranked lower to FO and UnB (Table 5). This significant difference was contributed by the pre-treatment subjected to the sample before drying, which decreased the bitterness in the ANS due to inactivation of the enzymes (Mepba *et al.*, 2007; Sangija *et al.*, 2021).

Table 5: Consumer acceptability test scores of dried African nightshade products

African nightshade	Drying Method	Pre-treatment		Colour	Texture	Appearance	Taste	Aroma	Bitterness	Overall acceptability
S. scabrum	ISD	FO	Mean	7.45[c]	8.98[a]	8.71[a]	8.23 [a]	8.34[a]	8.33[b]	8.69[a]
			SD	0.42	1.46	0.02	0.45	0.56	0.67	0.03
		UnB	Mean	7.33[c]	8.80[a]	8.88[a]	8.00[a]	7.67[a]	7.73[b]	8.65[a]
			SD	0.58	0.81	1.23	0.10	0.68	0.74	0.01
		WB	Mean	7.94[b]	7.73[b]	8.62[a]	8.47[a]	8.33[a]	8.83[a]	8.60[a]
			SD	0.65	0.57	0.01	0.02	1.00	0.57	1.00
		WBS	Mean	8.06[b]	7.67[b]	8.67[a]	8.16[a]	8.33[a]	9.00[a]	8.73[a]
			SD	0.51	0.58	0.46	0.00	0.58	0.00	0.13
S. villosum	ISD	FO	Mean	7.95[b]	8.85[a]	8.80[a]	8.10[a]	8.00[a]	7.67[b]	8.84[b]
			SD	0.03	0.06	1.00	1.00	0.00	0.56	1.16
		UnB	Mean	8.33[b]	8.90[a]	8.77[a]	8.22[a]	8.33[a]	8.00[b]	8.00[b]
			SD	0.58	1.31	0.67	0.57	0.07	0.67	0.09
		WB	Mean	8.84[a]	7.93[b]	8.67[a]	8.41[a]	8.00[a]	8.80[a]	8.96[a]
			SD	0.32	0.13	0.56	0.85	0.58	0.00	0.76
		WBS	Mean	8.96[a]	8.00[b]	8.50[a]	8.39[a]	8.33[a]	8.67[a]	8.75[a]
			SD	0.69	0.03	0.01	1.09	0.58	0.83	1.13

Means with different superscript letters within a column are significantly different $p < 0.05$, n=50). 1 = dislike extremely, 5 = Neither like nor dislike, 9 = like extremely; ISD: Indirect solar drier, UnB: Un-blanched; WB: Water blanched; WBS: Water blanched with the addition of NaCl

4.7 Stability of Dried ANS During Storage at Ambient and Refrigeration Temperature

The results on the stability of the stored dried ANS at ambient and refrigeration were as tabulated in Tables 6 and 7. The results revealed that there were no bacterial, mould and yeast growths in the analyzed samples for all three months of storage at ambient and refrigeration temperatures for both SS and SV (Tables 6 and 7).

Even though, the results revealed an effect on vitamin C content from the first to the third month of storage at both conditions. There were higher significant losses of the Vitamin C under ambient storage (Table 6) than refrigeration storage (Table 7). The percentage ranged from 22% to 43% for SS and 19% to 41% for SV products under ambient storage (27°C), where percent losses were 2% to 13% to SS and 3% to 12% in refrigeration storage (4°C). The significance loss of vitamin C of dried ANS stored under ambient temperatiure was facilitated by transparent polyethylene laminated bag, which permits penetration of light intensity and amount of temperature, hence more loss of vitamin C (Araújo *et al.*, 2017; Sangija *et al.*, 2021). The lower loss of vitamin C in refrigeration storage was contributed by lower temperature (4°C) of storage with no light intensity.

Table 6: The shelf life of Dried African nightshade products stored at ambient temperature (27°C). The Vitamin C presented in dry basis (mg/100 g)

Drying Method	ISD																							
Months	**0**						**1**						**2**						**3**					
African Nightshade	**Ss**			**Sv**			**Ss**			**Sv**			**Ss**			**Sv**			**Ss**			**Sv**		
Pre-treatment	**UnB**	**WB**	**WBS**	**UnB**	**WB**	**WBS**	**UnB**	**WB**	**WBS**	**UnB**	**WB**	**WBS**	**UnB**	**WB**	**WBS**	**UnB**	**WB**	**WBS**	**UnB**	**WB**	**WBS**	**UnB**	**WB**	**WBS**
Total bacteria	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Yeast & Mold	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Vitamin C	17.47	11.67	10.77	17.79	17.26	12.35	13.60	8.87	8.69	14.23	13.88	9.88	11.53	7.47	7.00	13.16	12.60	9.14	10.13	6.65	6.25	11.03	10.70	7.29
% Loss Vit.C	0	0	0	0	0	0	22	24	25	20	19	20	34	36	35	26	27	26	42	43	42	38	38	41

Means ± SD (n=3). The means in columns with different superscript letters are significantly different at $p < 0.05$; Ss: *S. scabrum*; Sv: *S. villosum;* ISD: Indirect solar drier; UnB: Un-blanched; WB: Water blanched; WBS: Water blanched with NaCl

Table 7: The shelf life of dried African nightshade products stored under refrigeration temperature (4°C). The Vitamin C were presented in dry basis (mg/100 g)

Drying Method	ISD																							
Months	**0**						**1**						**2**						**3**					
African Nightshade	**Ss**			**Sv**			**Ss**			**Sv**			**Ss**			**Sv**			**Ss**			**Sv**		
Pre-treatment	**UnB**	**WB**	**WBS**	**UnB**	**WB**	**WBS**	**UnB**	**WB**	**WBS**	**UnB**	**WB**	**WBS**	**UnB**	**WB**	**WBS**	**UnB**	**WB**	**WBS**	**UnB**	**WB**	**WBS**	**UnB**	**WB**	**WBS**
Total bacteria	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Yeast & Mold	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Vitamin C	17.47	11.67	10.77	17.79	17.26	12.35	16.77	11.44	0.45	17.26	16.57	11.98	16.60	12.37	10.23	16.72	15.88	11.49	15.55	10.27	9.59	16.01	15.19	10.99
% Loss Vit.C	0	0	0	0	0	0	4	2	3	3	4	3	5	6	5	6	8	7	11	13	11	10	12	11

Means ± SD (n=3). The means in columns with different superscript letters are significantly different at $p < 0.05$; Ss: *S. scabrum*; Sv: *S. villosum;* ISD: Indirect solar drier; UnB: Un-blanched; WB: Water blanched; WBS: Water blanched with NaCl

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The nutritional quality of *Solanum* sp. is essential for the health benefits and well-being of human. All drying methods affected the vitamin C, mineral, oxalate, and phytate levels in *Solanum* sp. A substantial loss of vitamin C was evident, with a reduction in mineral content. Interestingly, oxalate and phytate as anti-nutrients were reduced by all drying methods. Nonetheless, pre-drying treatments employed had a considerable impact on the quality of the final dried products compared to the untreated. Among the drying methods used, ISD was the most effective method for nutrient retention; and oxalates and phytates reduction in *Solanum* sp. Therefore, ISD can be recommended as an effective method for *Solanum* sp. processing and preservation. Howerver, to enhance its usability due to uncontrolled environmental conditions, there is a need of employing a mechanism where an indirect solar dryer can be directed connected with heater and temperature instrument to control the amount of heat generated and allow to get into the tunnel. This can shorten the drying time and enhance the drying rate to be minimized hence nutrient retention in the dried vegetables and more production. Morever, since the dried ANS were stable for three months with no growth of total bacteria, yeast and mould, there is a need of miximizing this technology so that these vegetables can be made available throughout the year and minimizing post-harvest losses due to their perishability.

5.2 Recommendations

Since drying techniques are more affordable as compared to other food processing techniques, knowledge need to be transfered and more awareness created to the community on ANS drying processing techniques. This will suffice food securiy, add value to the food and improve nutrition across the regions. Together with this it will reduce post-harvest losses as ANS are more perishable.

REFERENCES

Abiodun, A., Aletor, O., & Aladesanwa, R. (2012). The influence of freeze and sun-drying on the nutrient and the anti-nutrient constituents of scent and basil leaves. *International Journal of Chemistry*, *22*(3), 197-205.

Agbaire, P. O. (2011). Nutritional and anti-nutritional levels of some local vegetables (*Vernomia anydalira, Manihot esculenta, Teiferia occidentalis, Talinum triangulare, Amaranthus spinosus*) from Delta State, Nigeria. *Journal of Applied Sciences and Environmental Management*, *15*(4), 625-628.

AOAC. (1990). *Official Methods of Analysis of the Association of Official Analytical Chemists*. Arlington VA, USA: Association of Official Analytical Chemists, Inc.

Bamidele, O. P., Fasogbon, M. B., Adebowale, O. J., & Adeyanju, A. A. (2017). Effect of blanching time on total phenolic, antioxidant activities and mineral content of selected green leafy vegetables. *Current Journal of Applied Science and Technology*, *24*(4), 1-8.

Chege, P. M., Kuria, E. N., Kimiywe, J. O., & Nyambaka, H. N. (2014). Changes in nutrient content for β-carotene, iron and zinc in solar dried and stored *Amaranthus cruentus* vegetables. *International Journal of Agriculture Innovations and Research*, *3*(3), 880-882.

Constant, A., Lessoy, Z., Niamkey, A., & Sebastian, N. (2016). Effect of sun drying on nutritive and antioxidant properties of five leafy vegetables consumed in Southern Côte D'ivoire. *Food and Environment Safety Journal*, 14(3), 1-13.

Danso, J., Alemawor, F., Boateng, R., Barimah, J., & Kumah, D. (2019). Effect of drying on the nutrient and anti-nutrient composition of *Bombax buonopozense* sepals. *African Journal of Food Science*, *13*(1), 21-29.

Ekesa, B., Walingo, M. K., Onyango, M. (2009). Accessibility to and consumption of indigenous vegetables and fruits by rural households in Matungu division, western Kenya. *Agriculture, Nutrition, & Development, 9*(8), 1-14.

Elisha, G. O., Arnold, O. M., Christian, U., & Huyskens-Keil, S. (2016). Postharvest treatments of African leafy vegetables for food security in Kenya: A review. *African Journal of Horticultural Science*, *9,* 1-10.

Erdman, J. W. (1979). Oilseed phytates: Nutritional implications. *Journal of the American Oil Chemists' Society*, *56*(8), 736-741.

Essack, H., Odhav, B., & Mellem, J. J. (2017). Screening of traditional South African leafy vegetables for specific anti-nutritional factors before and after processing. *Journal of Food Science and Technology, 37*, 462-471

Garba, Z. N., & Oviosa, S. (2019). The effect of different drying methods on the elemental and nutritional composition of Vernonia amygdalina (bitter leaf). *Journal of Taibah University for Science*, *13*(1), 396-401.

Gockowski, J., Mbazo'o, J., Mbah, G., & Moulende, T. F. (2003). African traditional leafy vegetables and the urban and peri-urban poor. *Food Policy*, *28*(3), 221-235.

Gustavsson, J., Cederberg, C., Sonesson, U., Van-Otterdijk, R., & Meybeck, A. (2011). *Global Food Losses and Food Waste*: FAO Rome. https://scholar.google.com/

Hasan, M. U., Malik, A. U., Ali, S., Imtiaz, A., Munir, A., Amjad, W., & Anwar, R. (2019). Modern drying techniques in fruits and vegetables to overcome postharvest losses: A review. *Journal of Food Processing and Preservation*, *43*(12), e14280.

Ilelaboye, N., Amoo, I., & Pikuda, O. (2013). Effect of cooking methods on mineral and anti nutrient composition of some green leafy vegetables. *Archives of Applied Science Research*, *5*(3), 254-260.

James, A., & Matemu, A. (2016). Solar-drying of vegetables for micronutrients retention and product diversification. *American Journal of Research Communication,* 4(8), 1-13. 2325-4076.

Jonathan, A. A., & Funmilola, A. S. (2014). Nutritional and anti-nutritional composition of Bridelia ferruginea Benth (Euphorbiaceae) stem bark sample. *International Journal of Scientific Research in Knowledge, 2*(2), 92-104.

John, O. B., & Opeyemi, O. A. (2015). Effect of processing methods on nutritional composition, phytochemicals, and anti-nutrient properties of chaya leaf (*Cnidoscolus aconitifolius*). *African Journal of Food Science*, *9*(12), 560-565.

Kessy, R. F., Ochieng, J., Afari-Sefa, V., Chagomoka, T., & Nenguwo, N. (2018). Solar-dried traditional African vegetables in rural Tanzania: Awareness, perceptions, and factors affecting purchase decisions. *Economic Botany*, *72*(4), 367-379.

Kumar, D., Kumar, S., & Shekhar, C. (2020). Nutritional components in green leafy vegetables: A review. *Journal of Pharmacognosy and Phytochemistry*, *9*(5), 2498-2502.

Lee, S. K., & Kader, A. A. (2000). Preharvest and postharvest factors influencing vitamin C content of horticultural crops. *Postharvest Biology and Technology*, *20*(3), 207-220.

Morris, A., Barnett, A., & Burrows, O. (2004). Effect of processing on nutrient content of foods. *Cajanus*, *37*(3), 160-164.

Mosha, T. C., Gaga, H. E., Pace, R. D., Laswai, H. S., & Mtebe, K. (1995). Effect of blanching on the content of antinutritional factors in selected vegetables. *Plant Foods for Human Nutrition*, 47, 361-367.

Mwanri, A. W., Kogi-Makau, W., & Laswai, H. S. (2011). Nutrients and antinutrients composition of raw, cooked and sun-dried sweet potato leaves. *African Journal of Food, Agriculture, Nutrition and Development*, *11*(5), 5142-5156.

Natesh, H. N., Abbey, L., & Asiedu, S. K. (2017). An overview of nutritional and antinutritional factors in green leafy vegetables. *Horticulture International Journal*, *1*(2), 58-65.

Nnamani, C., Oselebe, H., & Agbatutu, A. (2009). Assessment of nutritional values of three underutilized indigenous leafy vegetables of Ebonyi State, Nigeria. *African Journal of Biotechnology*, 8 (9), 2321-2324.

Ochieng, J., Afari-Sefa, V., Karanja, D., Kessy, R., Rajendran, S., & Samali, S. (2018). How promoting consumption of traditional African vegetables affects household nutrition security in Tanzania. *Renewable Agriculture and Food Systems*, *33*(2), 105-115.

Ofor, M., & Ibeawuchi, I. (2010). Sun-drying: A low cost technology for reducing postharvest losses. *Academia Arena*, *2*(1), 56-59.

Ojiewo, C. O., Mwai, G. N., Abukutsa-Onyango, M. O., Agong, S. G., & Nono-Womdim, R. (2013). Exploiting the genetic diversity of vegetable African nightshades. *Bioremediation, Biodiversity and Bioavailability*, *7*(1), 6-13.

Oluoch, M. O., Habwe, F. O., Ngegba, J. B., Koskei, K. R., & Yang, R. (2012). Food preparation and processing methods on nutrient retention and accessibility in selected indigenous vegetables from East Africa. *Maseno University, Institutional Repository*. *15*, 233-241.

Oni, M. O., Ogungbite, O. C., & Akindele, A. K. (2015). The effect of different drying methods on some common Nigerian edible botanicals. *International Journal of Advanced Research in Botany*, *1*(1), 1-8.

Ontita, E. G., Onyango, C. M., & Nyamongo, D. (2017). Indigenous Knowledge on the Uses of African Nightshades *Solanum nigram* L. Species among Three Kenyan Communities. *Asian Journal of Agricultural Extension, Economics & Sociology*,14(3), 1-8.

Pardhi, C. B., & Bhagoria, J. L. (2013). Development and performance evaluation of mixed-mode solar dryer with forced convection. *International Journal of Energy and Environmental Engineering*, *4*, 1-8.

Patricia, O., Zoue, L., Megnanou, R. M., Doue, R., & Niamke, S. (2014). Proximate composition and nutritive value of leafy vegetables consumed in Northern Cote d'Ivoire. *European Scientific Journal*, *10*(6), 212-227.

Sagar, V. R., & Suresh, K. P. (2010). Recent advances in drying and dehydration of fruits and vegetables: A review. *Journal of Food Science and Technology*, *47*, 15-26.

Sahar, N., Arif, S., Iqbal, S., Afzal, Q. U. A., Aman, S., Ara, J., & Ahmed, M. (2015). Moisture content and its impact on aflatoxin levels in ready-to-use red chillies. *Food Additives & Contaminants: Part B*, 8(1), 67-72.

Sangija, F., Martin, H., & Matemu, A. (2021). African nightshades (*Solanum nigrum complex*): The potential contribution to human nutrition and livelihoods in sub-Saharan Africa. *Comprehensive Reviews in Food Science and Food Safety*, 20(4), 3284-3318.

Seidu, J. M., Bobobee, E. Y. H., Kwenin, W. K. J., Frimpong, R., Kubge, S. D., Tevor, W. J., & Mahama, A. A. (2012). Preservation of indigenous vegetables by solar drying. *Journal Agricultural Biologic Sciences*, *7*(6), 407-415.

Traoré, K., Parkouda, C., Savadogo, A., Ba/Hama, F., Kamga, R., & Traoré, Y. (2017). Effect of processing methods on the nutritional content of three traditional vegetables leaves: Amaranth, black nightshade and jute mallow. *Food Science & Nutrition*, *5*(6), 1139-1144.

Tumwet, T., Kang'ethe, E., Kogi-Makau, W., & Mwangi, A. (2014). Diversity and immune boosting claims of some African indigenous leafy vegetables in western Kenya. *Agriculture, Nutrition, & Development*, *14*(1), 8529-8544.

Ukegbu, P. O., & Okereke, C. J. (2013). Effect of solar and sun drying methods on the nutrient composition and microbial load in selected vegetables, African spinach (*Amaranthus hybridus*), fluted pumpkin (*Telferia occidentalis*), and okra (*Hibiscus esculentus*). *Sky Journal of Food Science*, *2*(5), 35-40.

Uusiku, N. P., Oelofse, A., Duodu, K. G., Bester, M. J., & Faber, M. (2010). Nutritional value of leafy vegetables of sub-Saharan Africa and their potential contribution to human health: A review. *Journal of Food Composition and Analysis*, *23*(6), 499-509.

Virginia, P., Swati, V., & Ajit, P. (2012). Effect of cooking and processing methods on oxalate content of green leafy vegetables and pulses. *Asian Journal of Food and Agro-Industry*, *5*(4), 311-314.

Von-Grebmer, K., Saltzman, A., Birol, E., Wiesman, D., Prasai, N., Yin, S., Yohannes, Y., Menon, P., Thompson, J., & Sonntag, A. (2014). *Synopsis: The 2014 Global Hunger Index: The Challenge of Hidden Hunger (Vol. 83). The International Food Policy Research Institute*. https://scholar.google.com

Wafula, E. N. (2017). *Effects of Postharvest-Processing Technologies on the Safety and Quality of African Indigenous Leafy Vegetables (Doctorate Thesis)*. The University of Hamburg. https://ediss.sub. uni-hamburg.de/handle/ediss/7392

Welch, R. M. (1993). Zinc concentrations and forms in plants for humans and animals. *Zinc in Soils and Plants: Proceedings of the International Symposium on 'Zinc in Soils and Plants' held at The University of Western Australia, 27–28 September, 1993* (pp. 183-195). Springer Netherlands.

Xiao, H.W., Pan, Z., Deng, L. Z., El-Mashad, H. M., Yang, X. H., Mujumdar, A. S., Gao, Z. J., & Zhang, Q. (2017). Recent developments and trends in thermal blanching: A comprehensive review. *Information Processing in Agriculture*, *4*(2), 101-127.

Yakubu, N., Amuzat, A., & Hamza, R. (2012). Effect of processing methods on the nutritional contents of bitter leaf (*Vernonia amygdalina*). *American Journal of Food and Nutrition. 2*(1), 26-30.

Yuan, B., Byrnes, D., Giurleo, D., Villani, T., Simon, J. E., & Wu, Q. (2018). Rapid screening of toxic glycoalkaloids and micronutrients in edible nightshades (*Solanum spp.*). *Journal of Food and Drug Analysis*, *26*(2), 751-760.

APPENDICES

Appendix 1: Exhibition at Nanenane 2020

I Participated at Nane nane Exhibition "Farmers' Day" a National day for Agriculture. It was Conducted at Njiro Arusha 1st August to 10 August 2020. I presented African nightshades dried products at prototype section from the Institute where NM-AIST worn a Trophy for the first award in the category of Institutions.

Team of participant with our products

A dried ANS displayed for the exhibition

Team of FRUVASE project with our vegetables and fruit products

Appendix 2: Dissemination programme

Participated in preparation of the dissemination manual for processing of African nightshades including drying and fermentation. I worked with FRUVASE Project team under Principal In-chage Dr. Edna Makule and Work Package II Supervisor Prof. Athanasia Matemu to disseminate the knowledge on African nightshade to two Regions (Kilimanjaro and Morogoro) specifically Morogoro Rural District and Moshi Rural District. The dissemination was conducted in March, 2021 intended to create knowledge to the community member on the importance of processing vegetables specifically ANS as they are prent available in these locations. Hence to avoid post harvest losses, they can process them and store them for future use, adding value and minimize the losses as they are perishable. Also the dissemination broadened their knowledge on utilization of processed products of ANS.

RESEARCH OUTPUTS

(i) Publication

Kazosi, M. E., Martin, H. D., Sangija, F., & Matemu, A. (2022). Effect of Drying Methods on the Nutrients and Anti-nutrients Composition of African Nightshade. *International Journal of Biosciences,* 21(3), 223-234.

(ii) Conference Presentation

Kazosi, M. E., Martin, H. D., Sangija, F., & Matemu, A. (2021). *Effect of Drying Methods on the Nutritional and Anti nutritional Content of African Nightshade (Solanum sp) Poster presentation at Tropentag, September 15-17, 2021, Toward shifting Agriculture hybrid conference.*

(iii) Poster Presentation

Conference Presentation

Effect of Drying Methods on the Nutritional and Anti nutritional Content of African Nightshade (Solanum sp) Poster presentation at Tropentag, September 15-17, 2021, Toward shifting Agriculture hybrid conference.

Kazosi, M. E., Martin, H. D., Sangija, F., & Matemu, A.