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Effects of Drying Techniques on Nutrient Retention and Phytochemicals in Selected Vegetables

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ABSTRACT

Vegetables are a rich source of bioactive compounds and functional constituents that are beneficial to human health. However, the short shelf life of these vegetables can be a major cause of bio unavailability of nutrients when they are out of season especially during dry season. Drying is one of the most convenient technologies for the production of shelf stable food products. However, drying can lead to considerable loss of the available bioactive compounds due to thermal degradation depending on the drying method and temperature conditions. This study investigated the effect of three drying methods (oven, open sun and indirect solar (sun drying) on the retention of nutrients and nutri-pharmaceutical compounds. Samples were dried up to ~10% moisture content. The fresh and dried samples were analyzed for nutrient composition and nutri-pharmaceutical compounds. The results showed that the retention of nutrients and nutri-pharmaceutical compound was not significantly ($p \geq 0.05$) affected by drying method and drying temperature with although differently affected. This study demonstrates that oven drying was the most effective in retaining the highest nutrients and bioactive compounds vegetables followed by indirect solar drying. Ethanol: Ethyl ether solvent was more effective in extraction for phytochemicals than n-Hexane. The effectiveness was based on their polarity of these solvents.

Keywords: Vegetables, Bioactive compounds, Phytochemicals, Drying, Nutrients, Polarity.

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I. Introduction

Vegetables are the major sources of micronutrients, especially among the rural poor. In particular, leafy vegetables can easily be accessible to every household with minimum effort and various studies have established them as a rich source of the highly needed body micronutrients [1]. Leafy vegetables have unique advantages within the farming systems, in that they grow quickly and many are disease and drought resistant because they are adapted to local conditions. More so, vegetables are important for human health because of their vitamins especially (vitamin A, vitamin C, and vitamin E), minerals, phytochemical compounds, and dietary fiber content with associated important roles in human health [2]. Adequate vegetable consumption can also be protective to several chronic diseases such as diabetes, cancer, obesity, metabolic syndrome, cardiovascular diseases, as well as improve on risk factors related with these diseases due to present phytochemical substances such as flavonoids, polyphenols and tannins [3]. The present phytochemicals in vegetables are not only useful for plant defense mechanism but do play a great role in both human and animal defense mechanisms though they are known to complex the nutritional composition in the vegetables such as proteins are chelated by tannins [4]. Also, nutrients and phytochemicals in foods play significant roles in human health [5]-[8]. Therefore, this requires for modifications in processing to maintain the required concentrations of both phytochemicals and nutrients and an improvement on preservation techniques for minimization of enzyme activities that render vegetable deteriorations. Unfortunately, vegetables face high postharvest losses (30–40%) leading to high nutritional and economic losses [9]. Postharvest handling techniques that have basically been used are drying based which involves sun drying, solar drying, oven drying and freeze-drying techniques to improve on vegetable shelf life. However, no information about nutrient retention for these techniques has been documented.

Despite the significance of the vegetable processing and preservation techniques, a lot remains to understand the nutritional retention of the vegetables that are subjected to different processing and preservation techniques that are employed by household farmers in rural areas in Uganda. In Uganda, agronomic institutions like NaCRRI- horticulture program has mainly focused on fostering new varieties that are resistant to drought, pests and diseases, poor soils and high yielding capacity. Therefore, it is also necessary to study and identify appropriate processing and preservation

techniques in order to minimize post-harvest losses. Understanding the effect of drying techniques on the retention of nutrients and phytochemicals in the selected vegetables is therefore vital in solving the problems of health-related diseases such as eye blindness, goiter and carcinogenic diseases.

The ultimate aim of this research is therefore, to help in understanding nutrient retention in vegetables subjected to different drying techniques and to explore the possibility of eliminating out the seasonality of vegetable availability so as to ensure a year-round supply of micronutrient-rich vegetables to mostly the rural poor who are in dire need of those nutrients. Vegetables are described as the cheapest sources of micro nutrients and macro nutrients that are highly associated with disease prevention in children under the age of 5 years and the elderly. However, during harvesting and postharvest handling of the vegetables about 20% to 50% vegetable loss majorly during transport chain. Therefore, this has substantially caused nutrient bio unavailability for body utilization leading to several healthy associated diseases and creating a gap between season of plenty and scarcity. This is found not to be in line with the 2030 Agenda for Sustainable Development Goal of part two of number two‘‘end hunger, achieve food security and improved nutrition and promote sustainable agriculture, by 2030, and end all forms of malnutrition by 2025. Therefore, providing information about the use of different drying techniques for both processing and preservation of vegetables and data collection about optimum nutrient retention could offer a better measure for solving the problems of malnutrition in rural and poor households of Uganda resulting from poor postharvest handling.

Currently, in many countries, rural household farmers utilize vegetables only in the plenty periods and few subject vegetables to limited processing techniques to bridge the gap between the plenty and scarcity periods specially to targeted vegetables like cassava leaves in West Nile. However; little is known about the nutritional composition that remains in the processed vegetables. This has considerably led to nutritional healthy associated effects to the rural household group. Therefore, it is imperative to obtain nutrient retention data from different processing and preservation techniques of vegetables so as to create a medium of nutrient conservation and supply in right quantities that do not deviate from the fresh vegetables. This measure will enhance efficient healthy so as to improve on agricultural work force that mediates food security and income among the household groups in Uganda. The measure is therefore inconformity with the 2030 Agenda for Sustainable Development Goal of part two of number three ‟ensure healthy lives and promote well-being for all at all ages by 2030, end preventable deaths of newborns and children under 5 years of age ”. The study has helped in understanding the deviation between nutrient retention levels in processed and preserved vegetables from fresh vegetables. The study also helped in obtaining data about an elite drying technique that would solve the problem of vegetable nutrient losses of 20% to 50%. The study obtained data on nutri-pharmaceutical levels that mediate defense against pathogens in vegetables and carcinogenic cancer-causing cells in human beings.

II. Materials and Methods

A. Sample Collection and Preparation

The study involved the harvest and analysis of mature vegetables from already established fields at the agronomical research institute National Crops Resources Research Institute- Namulonge set by the Horticulture programme. National Crops Resources Research Institute (NaCRRI)-Namulonge located within the Lake Victoria crescent at 32°37’36.0”E and 0°31’13.7”N, 1134 m above sea level in Central Uganda. A total of 7 varieties of selected mature vegetables were harvested in the morning hours of 8:00 to 10:00 am to avoid enzyme activities that induce deterioration on both nutrients and vegetables. The vegetables were collected under cold conditions and transported to the bio-analytical and nutrition laboratory in bioscience section at NaCRRI-Namulonge for preparation and laboratory analysis of nutri-pharmacueticals and bioactive compounds. After sample collection, drying techniques such as oven drying method, direct and indirect solar drying techniques were used for treatment of the samples and the fresh samples was kept at -80 ºC. Dried samples were ground into a fine powder using a gridding machine. The powder was passed through a 2mm double sieve to obtain fine flour. For both fresh and powdered sample, 5 g were extracted with 25 ml 80% of n-Hexane, and ethanol: ethyl ether solvents. The extracts were centrifuged at 6000 rpm for 25 min at 4 °C and the supernatant taken for quantitative phytochemical. The experiment in the laboratory for both extraction and analysis was carried out in triplicate.

B. Drying Processes

Drying is a longstanding, fairly easy method of food preservation which does not improve food quality but increase its shelf life. Effective and sufficient drying produces safe food with good flavor, texture, color and nutritional properties.

1. Sun drying (direct solar drying)

Vegetables were evenly spread on trays in a dust, rubbish and insect free environment to avoid contamination and left to dry under direct exposure to sunlight or rays (29±5 ºC) until when the samples were brittle (3 days).

2. Indirect solar drying.

A closed solar structure was constructed with strong heat absorbing materials where 100g of each sample were dried on a pre-weighed and labelled silver plate, but carrots were sliced before drying.

3. Oven drying

This drying was carried out at a temperature of 50 ºC for 24 h in an oven drier (fissta modle). 100 g of each sample was weighed on a pre-weighed and labelled silver plate, but carrots were sliced before drying.

C. Determination of Nutrient Composition of Selected Dried and Fresh Vegetables

Fresh vegetable and dried sample obtained from drying techniques were used for the determination of nutrient composition. Standard procedures were followed for the determination of nutrient composition including total carbohydrates, reducing sugars, proteins, vitamin C and total carotene.

1. Determination of total carotenoids content

The iCheck analytical kit developed by BioAnalyt Laboratory was used for measuring TCC (Total carotenoid content) with modifications as described by [10]. Briefly, 5 g of the vegetable flour and fresh sample were homogenized in 20 ml of distilled water and transferred into a 50 ml calibrated falcon tube. The 50 ml falcon tube content was shaken thoroughly left to stand for 8 min and 0.4 ml of the solution injected into the iExTM CAROTENE vial using the syringe and needle provided with the kit. Vials were placed on a solid-flat surface for approximately 5 min, shaken again and allowed to stand until two solution phases appear inside the vial (clear upper phase and a turbid lower phase). At this point, the absorbance of the vial content (the upper solution phase) was measured using the iCheckTM CAROTENE device. The experiment was done in triplicate.

$$\text{TCC (Ppm)} = \frac{\text{Ws}}{\text{Vs}} \times \text{A}$$

where Vs = volume of solution transferred to the falcon tube, Ws = weight of a sample, and A = absorbance of the iExTM CAROTENE vial content at a wavelength of 450 nm.

Each sample was extracted and technically measured for TCC in triplicate and all procedures for carotenoid quantification were performed in a dark room.

2. Determination of total protein content

The Bradford assay was conducted according to the method described by [11]. Briefly, 100 mg Coomassie Brilliant Blue G-250 were dissolved in 50 mL 95% ethanol (C_2H_5OH). Thereafter, 100 mL of 85% phosphoric acid (H_3PO_4) were carefully added under stirring, followed by distilled H_2O to a total volume of 1 L (liter) and the solution was filtered. For the measurements, 100 µL extract and 5 mL Bradford solution were mixed and incubated for 5 min. A standard curve was made of BSA (Bouvine Serum Albumen) (0, 0.0625, 0.125, 0.25, 0.5 and 1 g L^{-1}) and absorbance was read at 595 nM [12].

3. Determination of total carbohydrate content

0.5 g of the fresh sample was weighed, homogenized with 10 ml of 80% ethanol and vortexed at 6000 rpm, for 10 min at 4 °C. Following the modified colorimetric assay method for carbohydrate determination by Dubois et al. [13]. 0.5 ml aliquot was pipetted into a clean test tube in triplicate diluted with 1 ml of distilled water and dehydrated using 1 ml of concentrated sulphuric acid. The resulting furfural compound was estimated by adding 0.5 ml of 5% (w/v) phenol to form coloured complexes. The resulting compounds were then quantified spectrophotometrically by measuring absorbance at a wave length of 490 nm, against standard D-glucose [13].

4. Determination of total sugars content

Total reducing sugars were determined using Colorimetric method the procedure described by [14] with modifications. 0.1 g of the sample was hydrolyzed in 1 ml of 0.5 M H_2SO_4, then heated 0.5 ml of aliquot over boiling water bath for 30 min. After cooling under running water, two drops of phenolphthalein indicator were added. Later, 0.5 M NaOH were also added drop by drop to neutralize the acid in the hydrolysate till it developed pink colour. Further, 0.5 M H_2SO_4 was added to make it colorless. Then reducing sugars were analyzed using the phenol-sulphuric acid method. A glucose standard curve was used to estimate the reducing sugars [14].

5. Determination of vitamin C content

5.1. Chemical and Reagent required

5% Metaphosphoric acid-10% acetic acid

15 g of solid metaphosphoric acid (E. Merck) were dissolved in a mixture of 40 ml of glacial acetic acid (BDH) and 450 ml of distilled water in a 500 ml volumetric flask. The solution was filtered and collected.

10% Thiourea solution, 2,4-Dinitrophenylhydrazine solution, 85% Sulphuric acid

Standard vitamin C (ascorbic acid) solution

Stock standard solution containing 0.5 mg/ml of ascorbic was prepared in water by dissolving 0.05 g of AA in 100 ml of water and stored in a glass stoppered bottle. Solutions of variable concentrations were prepared by diluting the stock solution in water.

5.2. Sample preparation

10 g blended sample was homogenized with about 50 ml of 5% metaphosphoric acid- 10% acetic acid solution. Then it was quantitatively transferred into a 100 ml volumetric flask and was shaken gently until a homogeneous dispersion was obtained. Then it was diluted up to the mark by the 5% metaphosphoric aceid-10% acetic acid solution. Then the solution was filtered and the clear filtrate was collected for the determination of vitamin C in that sample.

5.3. Estimation of vitamin C. Procedure

To the filtered sample solution, Bromine water were added until the solution became colored (to confirm the completion of the oxidation of the ascorbic acid to dehydroascorbic acid. Then a few drops of thiourea was added to it to remove the excess bromine and thus the clear solution was obtained. Standard solutions of ascorbic acid (5 ppm, 10 ppm, 15 ppm, 20 ppm and 25 ppm) were prepared from 500-ppm stock solution of ascorbic acid by proper dilution. Then 1 ml of 2,4-DNPH solution was added thoroughly with all standards and also with the oxidized ascorbic acid. For the completion of the reaction, all the standards, samples and blank solution were kept at 37 ºC temperature for 3 hours in a water bath (thermostatic).

After this incubation all of those were cooled in an ice bath and treated with 5 ml of 85% H_2SO_4 with constant stirring. As a result, a coloured solution was obtained whose absorbance was taken at 521 nm.

D. Determination of Nutri-Pharmaceutical Compounds in Selected Vegetable Samples

1. Determination of lignin content

Lignin content was determined according to [15] with modifications to the vegetable samples. Vegetable samples were ground into flour with particles of mess sieve 40 as extractive free biomass sample while fresh sample was weighed and used fresh. From the sample, the lignin content was determined using the oven method and spectrophotometric method. 5 g fresh and dried samples was weighed in digestion tubes (50 ml falcon tubes). 10 ml of 72% sulphuric acid were added to the 5g sample and the uniform mixture generated by shaking on an orbital shaker. The mixture was placed in a water bath at 30 ºC for 1hr. After which 40 mL 3% sulphuric acid was added and mixed

thoroughly. The resultant mixture was placed in an autoclave set at 121 ºC for 1 hour after which it was taken out and cooled in ice water bath. The mixture was then centrifuged in a 50 ml falcon tube and incubate the residue at 105 ºC for 8 hr to determine the acid insoluble lignin. The filtrate was used to determine acid soluble lignin at 280 nM as Klason lignin method by diluting the filtrate with 1ml 3% sulpuric acid. The amount of lignin was presented as the sum percentage of the acid insoluble lignin and acid soluble lignin in the vegetable sample analyzed [16].

2. Determination of anthocyanin content in selected vegetable samples

Anthocyanin content were determined following the modified method given by [17]. 1 g of the vegetable sample were homogenized with 3 ml of extraction mixture (methanol: water: HCl, 79:20:1). Homogenized material was centrifuged for 20 minutes at 13,000 rpm at 4 ºC and supernatant collected for the analysis of anthocyanin content. The absorbance of the supernatant was taken at 530 and 657 nM.

3. Determination of total phenolic content in selected vegetable samples

300 µl of the supernatant were pipetted into a clean test tube, 1ml of methanol was added and incubated in the dark at room temperature for 5 min. 3.16 ml distilled water and 200 µl Folin-Ciocalteu reagent were added. Then, after 8 min incubation at room temperature, 600 µl sodium carbonate solution (10%) was also added and the test tube covered with aluminum foil and incubated in a hot water bath at 40 °C for 30 min. A blank was prepared using the same procedure but replacing the plant extract with an equal volume of methanol. The absorbance of the sample was determined using a UV visible spectrophotometer at 765 nm. The standard curve of gallic acid was obtained. Total phenolic content was expressed as µg of gallic acid equivalents (GAE) per ml. The absorbance was obtained at 765 nm.

4. Determination of total flavonoids content in selected vegetable samples

The method is based on the formation of the flavonoids - aluminium complex which whose absorptivity was measured at 510 nM. 100 µl of each sample extract (10 mg/ml) was mixed with 100 µl of 20% aluminum trichloride in respective solvent and a drop of acetic acid, and then diluted with corresponding extraction solvent to 5 ml. The absorption at 510 nm were read after 40 min using UV-Vis spectrophotometer (Jenway 6305). Blank sample was prepared from 100 ml of sample extracts and a drop of acetic acid, and then diluted to 5ml with corresponding extraction solvent. The absorption of standard quercetin solution (0.5 mg/ml) in corresponding extraction solvent were measured under the same conditions. All determinations were carried out in triplicates accordingly [18].

5. Determination of alkaloids content in selected vegetable samples

5 ml of the vegetable extract from three different extraction solvents of two independent experiments were dissolved into 3 ml of sodium phosphate buffer (pH = 4.5) and transferred into a separating funnel. The resulting solution was mixed with 3 ml of bromocresol green prepared by heating 69.8 mg bromocresol green with 3 ml of 2N NaOH and 5 ml distilled water until completely dissolved and the solution diluted to 1000 ml with distilled water. The experiment was left to stand for 30 min. Then 5 ml of chloroform were added and vortexed for 2 minutes and left to settle for 10 min. The lower layer in the funnel was then be separated off form the upper organic layer with the dissolved alkaloids. The extraction was continued for 3 more times and the extracts mixed in a volumetric flask. 80% ethanol was used as blank and the extracts analyzed by using a UV–Vis spectrophotometer at a wavelength of 470 nm. Catechine was used as the standard [19].

6. Determination of total tannins content in selected vegetables

Follins Dennis spectrophotometric method of [20] was used to determine total tannins content in the vegetable samples by pipetting 2 ml of the extract into a 50 ml volumetric flask. Similarly, 5 ml of the standard tannic acid solution and 5 ml of distilled water were measured into separate flasks to serve as standard and blank, respectively. They were further be diluted with 35 ml distilled water separately and 1ml of follins-Dennis reagent was added to each of the flasks, followed by 2.5mls of saturated sodium carbonate solution (Na_2CO_3). The contents of each flask were made up to 50 ml (with distilled water) and incubated for 90 min at room temperature. The absorbance of the developed colour was measured at 620 nm wavelength spectrophotometrically. Readings were taken with the reagent blank at zero. The tannin content was calculated as shown below:

$$\% \text{ Tannin} = 100 \times Au \times C \times Vf \times D / (W \times As \times 1000 \times Va)$$

where W = Weight of sample analyzed, Au = Absorbance of the test sample, As = Absorbance of the standard solution in mg/ml, C = Concentration of standard solution in mg/ml, Vf = Total volume of extract, Va = Volume of extract analyzed, D = Dilution factor where applicable.

7. Antioxidant Reducing Power Assay

Antioxidant capacity as per reducing power assay was measured briefly by weighed 0.1 g of vegetable sample and homogenized in 2 ml of 80% methanol followed by 2.5 ml sodium phosphate buffer (0.2 M, pH 6.6) and 2.5 ml potassium ferricyanide (1% w/v in distilled water) and mixed well. The mixture was incubated in a water bath for 20 min at 50 °C. Then, 2.5 ml trichloroacetic acid (10% w/v in distilled water) were added, and the mixture centrifuged at 650 rpm for 10 min. The supernatant (5 ml) were taken into a test tube and 5 ml distilled water and 1 ml ferric chloride (0.1% w/v in distilled water) solution were added and mixed well. Absorbance was measured at 700 nm. Blank for each solvent was run using the same procedure but replacing the plant extract with an equal volume of solvent.

E. Comparison of Different Solvent Extraction Efficiency of Nutri-Pharmaceutical Compounds form Vegetable Samples

Non-polar and polar extraction solvents was used in the extraction of phytochemical substances in vegetable samples from different treatments basically solar direct solar drying, indirect solar drying, and oven drying and fresh sample. A

comparative study was performed to investigate the efficiency of solvents on the extraction yield and the content of phenolics, flavonoids, alkaloids and tannins. The vegetable extract was prepared according to protocol of [21] with modifications. The fresh vegetable sample (1g) was homogenized with the selected extraction solvents in a cold ceramic mortar using a pastel and 1g of vegetable flour will follow the same treatment. The homogenized sample was put into a 50 ml falcon tube and selected solvents added to the 20 ml graduation mark. Distilled water (H_2O), methanol (80%), ethanol (80%), and diethyl ether (80%), extraction solvents was used at a sample: solvent ratio of 1: 20 (w/v), put on the orbital sharker for efficient extraction for 1 hour and then centrifuged at 6000 rpm at $^{+}4$ ^{o}C for 15 minutes to obtain a clear pigmented supernatant. All experiments were technically carried out in triplicate.

F. Statistical Data Analysis

The raw data collected for each of the treatments used on the vegetable sample were analyzed using one-way Analysis of Variance (ANOVA) to find out whether there was any statistically significant variation within and among treatments at the means (p =0.05). All data generated was analyzed using R version 3.5.2 (2018-12-20) to determine the extent of variation in vegetable's nutrition composition, nutri-pharmaceutical concentrations and solvent extraction efficiency treated with different drying techniques and fresh treatment. Relationships among nutrition composition and nutri-pharmaceutical concentrations from different vegetable sample treatments were analyzed using Pearson correlation and significance of the correlation was determined at 5%.

III. Results and Discussion

A. Results

According to the quantification and determination methods used to obtain data on phytochemicals and nutrients retention following drying as the method of preserving vegetables. Proximate analyses were carried out on dried samples to establish the retained nutrient content. For the control experiment, fresh vegetables were analyzed for the same parameters.

TABLE 1: Showing Average Concentration for Total Carotene Content Obtained in the Fresh and Dried Samples (mol^{-1} cm^{-1})

Sample name	Drying Methods			
	F	A	B	C
Carrot	0.511±0.01	0.761±0.005	0.540±0.03	0.806±0.01
Cabbage white	0.409±0.03	1.249±0.05	0.412±0.02	0.532±0.05
Cabbage purple	0.384±0.01	0.770±0.03	0.407±0.03	0.515±0.004
Doodo	0.258±0.004	0.672±0.05	0.352±0.02	0.546 ±0.01
Buga 1	0.341±0.05	1.533±0.05	0.801±0.05	0.622±0.003
Buga 2	0.317± 0.01	1.917 ±0.04	0.965±0.001	0.708±0.00
Narocasi 1	0.757±0.005	0.687±0.02	0.5854±0.003	0.948±0.01
Ugic18224	0.648±0.01	0.934±0.005	0.581±0.04	0.963±0.005

The values are expressed as mean ± SD. F= Fresh sample, A= Oven drying, B = Direct sun drying, C= Indirect sun (solar) drying.

TABLE 2: Showing Total Proteins Obtained in Both Fresh and Dried Samples (mol^{-1} cm^{-1})

Sample name	F	A	B	C
Carrot	0.054±0.001	0.076±0.002	0.056±0.001	0.07±0.002
Cabbage w f	0.080±0.001	0.076±0.002	0.061±0.04	0.065±0.002
Cabbage r	0.063±0.002	0.459±0.003	0.671±0.01	0.410±0.003
Doodo	0.235±0.001	0.070±0.001	0.085±0.001	0.085±0.004
Buga 1	0.071±0.002	0.137±0.002	0.125±0.001	0.09±0.002
Buga 2	0.057±0.002	0.222±0.001	0.113±0.002	0.142±0.001
Narocasi 1	0.061±0.001	0.073±0.001	0.203±0.002	0.056±0.002
Ugic18224	0.064±0.001	0.071±0.001	0.086± 0.002	0.059±0.002

The values are expressed as mean ± SD.

TABLE 3: Concentration of Total Carbohydrates in the Selected Vegetables (mol^{-1} cm^{-1})

Sample name	F	A	B	C
Carrot	0.572 ±0.002	1.882 ±0.01	1.643 ±0.01	1.977 ±0.002
Cabbage white	0.378 ±0.004	1.461 ±0.003	1.304 ±0.003	1.593 ±0.001
Cabbage purple	0.430 ±0.001	1.549 ±0.002	1.408 ±0	1.807 ±0.002
Doodo	0.161 ±0.001	0.314 ±0.001	0.279 ±0.02	0.324 ±0.001
Buga 1	0.102 ±0	0.192 ±0.002	0.238 ±0	0.864 ±0.003
Buga 2	0.044 ±0	0.206 ±0.001	0.222 ±0.002	0.215 ±0.002
Narocas 1	0.368 ±0.001	0.789 ±0.003	0.829 ±0.004	0.607 ±0.002
Ugic18224	0.385 ±0.002	0.685 ±0.001	0.696 ±0.004	0.614 ±0.002

The values are expressed as mean ± SD.

TABLE 4: Showing Total Reducing Sugars in Both Fresh and Dried Vegetable Samples (mol^{-1} cm^{-1})

Sample name	F	A	B	C
Carrot	0.556 ±0.002	0.180 ±0.005	0.228 ±0.002	0.938 ±0.01
Cabbage white	0.275 ±0.02	0.136 ±0.003	0.065 ±0.005	0.472 ±0.003
Cabbage purple	0.441 ±0.004	1.115 ±0.01	0.392 ±0.003	1.734 ±0.01
Doodo	0.562 ±0.008	1.952 ±0.05	0.373 ±0.001	1.841 ±0.03
Buga 1	1.176 ±0.002	1.567 ±0.03	1.419 ±0.01	1.862 ±0.01
Buga 2	1.066 ±0.002	1.419 ±0.004	1.549 ±0.002	1.981 ±0.001
Narocas 1	0.446 ±0.003	0.624 ±0.005	0.905 ±0.004	1.405 ±0.006
Ugic18224	0.727 ±0.005	0.569 ±0.002	0.458 ±0.005	0.710 ±0.005

The values are expressed as mean ± SD.

TABLE 5: SHOWING VITAMIN C CONTENT IN THE SELECTED PRESERVED AND FRESH VEGETABLES (mol^{-1} cm^{-1}).

Sample name	F	A	B	C
Carrot	0.512 ± 0.003	0.762 ± 0.02	1.540± 0.02	0.406±0.006
Cabbage white	0.409 ±0.005	1.249 ± 0.01	0.412± 0.002	0.532 ± 0.01
Cabbage purple	0.384± 0.003	0.371± 0.01	0.407± 0.02	0.515± 0.004
Doodo	0.258± 0.03	0.372± 0.008	0.352± 0.007	0.346± 0.005
Buga 1	0.141±0.001	0.534±0.003	0.801±0.006	1.621±0.002
Buga 2	0.317±0.001	0.917±0.005	0.965±0.013	0.508±0.002
Narocasi 1	0.757± 0.01	0.687±0.004	1.854±0.004	0.648±0.008
Ugic18224	0.648± 0.008	0.634±0.006	0.981±0.001	0.363±0.008

The values are expressed as mean ± SD.

TABLE 6: SHOWING SOLUBLE AND INSOLUBLE LIGNIN CONCENTRATION IN SELECTED VEGETABLES.

Sample name	Solubility	F	A	B	C
Carrot	Soluble	24.85	41.99	48.68	54.44
	Insoluble	6.4	50	27	38.2
Cabbage white	Soluble	53.32	56.88	50.32	48.99
	Insoluble	3.8	19.6	20.6	18.4
Cabbage purple	Soluble	55.33	59.99	53.90	57.16
	Insoluble	2.2	15.4	12.4	13.6
Doodo	Soluble	22.56	27.43	33.59	43.72
	Insoluble	4.8	26.2	21.6	26.6
Buga 1	Soluble	23.08	68.28	24.90	24.76
	Insoluble	5	10.2	12.4	48.9
Buga 2	Solube	61.42	52.78	64.20	76.49
	Insoluble	12.8	9	4.4	6.4
Narocas 1	Soluble	54.21	62.26	53.27	53.46
	Insoluble	6.4	19.4	26.6	11.6
Ugic18224	Soluble	26.66	31.74	24.11	23.17
	Insoluble	8.8	3	23	31.2

These values were expressed in percentages.

TABLE 7: SHOWING TOTAL ANTHOCYANIN CONCENTRATION IN PRESERVED AND FRESH SELECTED VEGETABLES

Wavelength	530 nm				657 nm			
Sample name	F	A	B	C	F	A	B	C
Carrot	0.051± 0.002	0.249± 0.003	0.127± 0.001	0.223± 0.002	0.039± 0.002	0.086± 0.0004	0.054± 0.002	0.153± 0.005
Cabbage white	0.034± 0.003	0.152± 0.01	0.228± 0.004	0.186± 0.0005	0.035± 0.004	0.049± 0.002	0.124± 0.0002	0.101± 0.005
Cabbage purple	0.855± 0.02	1.377±0.0002	1.183± 0.01	0.968± 0.003	0.416± 0.003	0.049± 0.001	0.019± 0.001	0.030± 0.001
Doodo	0.193± 0.0005	0.554± 0.02	0.245± W0.003	0.280± 0.002	1.416± 0.03	0.259± 0.001	0.235± 0.01	0.501± 0.005
Buga 1	0.375± 0.01	1.175± 0.03	0.450± 0.01	0.303± 0.002	0.08± 0.002	0.353± 0.001	0.294± 0.0005	0.501± 0.0002
Buga 2	0.349± 0.03	1.284± 0.001	0.48± 0.0004	0.568± 0.03	0.08± 0.005	0.353± 0.004	0.294± 0.001	0.510± 0.01
Narocasi 1	1.177± 0.001	0.755± 0.02	1.34± 0.005	1.291± 0.0002	0.645± 0.01	0.625± 0.002	0.612± 0.005	1.244± 0.02
Ugic18224	0.809± 0.01	1.169± 0.01	0.937± 0.004	0.644± 0.003	0.637± 0.003	1.246± 0.01	0.708± 0.01	1.066± 0.001

The values are expressed as mean ± SD.

TABLE 8: SHOWING TOTAL PHENOLICS CONTENT IN FRESH AND DRIED SELECTED VEGETABLE SAMPLES (mol^{-1} cm^{-1}) USING TWO SOLVENTS

n-hexane	Drying Methods			
Sample name	F	A	B	C
Carrot	0.059± 0.002	0.068± 0.001	0.065± 0.001	0.120 ±0.001
Cabbage white	0.143±0.002	0.102±0.005	0.081±0.0002	0.030±0.001
Cabbage purple	0.042±0.001	0.155±0.006	0.108±0.004	0.101±0.01
Doodo	0.123± 0.01	0.138± 0.004	0.048± 0.002	0.112± 0.003
Buga 1	0.114± 0.01	0.146± 0.005	0.071± 0.004	0.147± 0.005
Buga 2	0.016± 0.003	0.146± 0.002	0.139± 0.002	0.112± 0.002
Narocas 1	0.086± 0.003	0.118± 0.01	0.228± 0.002	0.068± 0.003
Ugic18224	0.091± 0.004	0.098± 0.003	0.131± 0.002	0.107± 0.005
Ethyl ether: Ethanol				
Carrot	0.015± 0.001	0.061± 0.003	0.056± 0.002	0.061±0.0004
Cabbage white	0.012± 0.001	0.065± 0.002	0.118± 0.003	0.052± 0.001
Cabbage purple	0.077± 0.001	0.067± 0.002	0.058± 0.002	0.022± 0.001
Doodo	0.131± 0.002	0.199± 0.002	0.127± 0.001	0.103± 0.001
Buga 1	0.104± 0.001	0.146± 0.002	0.152± 0.001	0.155± 0.005
Buga 2	0.155± 0.003	0.413± 0.001	0.222± 0.004	0.126± 0.002
Narocas 1	0.264± 0.002	0.312± 0.004	0.453± 0.003	0.604± 0.002
Ugic18224	0.242± 0.002	0.282± 0.01	0.353± 0.002	0.405± 0.004

The values are expressed as mean ± SD.

TABLE 9: SHOWING FLAVONOIDS CONTENT IN THE SELECTED FRESH AND DRIED VEGETABLES (mol^{-1} cm^{-1}) USING TWO SOLVENTS

n-hexane	Drying Methods			
Sample name	F	A	B	C
Carrot	0.146 ± 0.01	0.644 ±0.01	0.129 ± 0.01	0.345 ± 0.02
Cabbage white	0.026± 0.002	0.151 ± 0.01	0.021± 0.005	0.113 ± 0.01
Cabbage purple	0.243 ± 0.01	0.093± 0.002	0.024± 0.001	0.055± 0.001
Doodo	0.008 ±0.002	0.015± 0.003	0.425 ± 0.01	0.015± 0.001
Buga 1	0.329 ± 0.01	0.039± 0.002	0.028± 0.001	0.021± 0.001
Buga 2	0.08 ± 0.002	0.312 ± 0.01	0.021± 0.001	0.039± 0.001
Narocas 1	0.163 ± 0.01	0.193 ± 0.01	0.188 ± 0.01	0.258 ± 0.03
Ugic18224	0.033 ± 0.04	0.445 ± 0.02	0.049± 0.003	0.140 ± 0.01
Ethyl ether: Ethanol				
Carrot	0.606 ± 0.01	0.919 ± 0.01	0.617± 0.002	0.992 ±0.01
Cabbage white	0.477 ±0.01	0.641 ±0.005	0.671 ±0.003	0.475 ±0.04
Cabbage purple	0.752 ±0.01	0.905 ±0.002	1.022 ±0.01	0.939 ±0.001
Doodo	0.937 ± 0.01	0.788± 0.002	0.895 ± 0.01	0.803± 0.004
Buga 1	0.650± 0.004	1.249 ± 0.02	1.151 ± 0.1	1.183 ± 0.04
Buga 2	1.108± 0.004	1.510 ± 0.01	1.598± 0.014	0.774 ± 0.01
Narocas 1	1.319± 0.002	1.871 ± 0.02	1.859 ± 0.01	1.839 ± 0.01
Ugic18224	1.362± 0.004	1.465 ± 0.01	1.420 ± 0.01	1.947 ± 0.04

The values are expressed as mean ± SD.

TABLE 10: TOTAL ALKALOIDS IN DRIED AND FRESH SELECTED VEGETABLES (mol^{-1} cm^{-1}) USING TWO SOLVENTS

n-hexane	Drying methods			
Sample name	F	A	B	C
Carrot	0.673± 0.003	0.582± 0.001	0.627± 0.004	0.532± 0.04
Cabbage white	0.579± 0.01	0.519± 0.01	0.485± 0.02	0.766± 0.005
Cabbage purple	0.399± 0.005	0.505± 0.002	0.524± 0.001	0.484± 0.004
Doodo	0.585± 0.002	0.398± 0.001	0.457± 0.002	0.532± 0.01
Buga 1	0.570± 0.004	0.466± 0.01	0.528± 0.003	0.567± 0.001
Buga 2	0.435± 0.01	0.423± 0.003	0.452± 0.005	0.414± 0.003
Narocas 1	0.570± 0.002	0.164± 0.005	0.436± 0.001	0.250± 0.013
Ugic18224	0.613± 0.014	0.529±0.0014	0.084± 0.002	0.169± 0.001
Ethyl ether: Ethanol				
Carrot	0.397±0.002	0.346± 0.001	0.392± 0.001	0.389± 0.001
Cabbage white	0.420± 0.001	0.341±0.0005	0.345± 0.002	0.378± 0.002
Cabbage purple	0.497±0.0005	0.417± 0.005	0.693± 0.003	0.444± 0.002
Doodo	0.393± 0.003	0.508± 0.01	0.912± 0.01	0.363± 0.01
Buga 1	0.427± 0.004	0.366± 0.04	0.468± 0.02	0.428± 0.002
Buga 2	0.266± 0.003	0.417± 0.002	0.445± 0.03	0.379± 0.01
Narocas 1	0.420± 0.01	0.576± 0.003	0.336± 0.01	0.433± 0.005
Ugic18224	0.513± 0.01	0.531± 0.01	0.310± 0.02	0.365± 0.01

The values are expressed as mean ± SD.

TABLE 11: SHOWING TOTAL TANNINS OBTAINED IN FRESH AND DRIED SAMPLES (mol^{-1} cm^{-1}) USING TWO SOLVENTS

Ethyl ether: Ethanol	Drying methods			
Sample name	F	A	B	C
Carrot	0.159 ±0.01	0.167 ±0.001	0.131 ± 0.001	0.229 ± 0.002
Cabbage white	0.044 ± 0.002	0.134 ± 0.002	0.073 ± 0.002	0.106 ± 0.002
Cabbage purple	0.104 ± 0.001	0.192 ± 0.002	0.205 ± 0.01	0.251 ± 0.004
Doodo	0.299 ± 0.005	0.339 ± 0.003	0.245 ± 0.002	0.174 ± 0.002
Buga 1	0.633 ± 0.002	0.543 ± 0.002	0.221 ± 0.003	0.516 ± 0.005
Buga 2	0.121 ± 0.004	1.679 ± 0.001	0.921 ± 0.002	0.338 ± 0.01
Narocasi 1	1.082 ± 0.001	1.136 ± 0.001	0.971 ± 0.002	0.864 ±0.003
Ugic18224	0.642 ± 0.002	0.424 ± 0.002	0.831 ± 0.002	0.747 ± 0.001
n-hexane				
Sample name	F	A	B	C
Carrot	0.032 ± 0.002	0.115 ± 0.001	0.054 ± 0.004	0.123 ± 0.002
Cabbage white	0.099 ± 0.002	0.171 ± 0.002	0.040 ± 0.002	0.070 ± 0.002
Cabbage purple	0.115 ± 0.001	0.182 ± 0.002	0.122 ± 0.001	0.509 ± 0.01
Doodo	0.136 ± 0.001	0.139 ± 0.01	0.055 ± 0.001	0.156 ± 0.002
Buga 1	0.061 ± 0.001	0.056 ± 0.003	0.073 ± 0.012	0.117 ± 0.004
Buga 2	0.121 ± 0.002	0.076 ± 0.01	0.045 ± 0.004	0.181 ± 0.004
Narocasi 1	0.139 ± 0.003	0.052 ± 0.005	0.055 ± 0.002	0.271 ± 0.004
Ugic18224	0.036 ± 0.002	0.015 ± 0.005	0.017 ± 0.002	0.067 ± 0.01

The values are expressed as mean ± SD.

TABLE 12: SHOWING ANTIOXIDANT ACTIVITY RESULTS OBTAINED IN FRESH AND DRIED SAMPLES (mol^{-1} cm^{-1})

Sample name	Drying methods			
	F	A	B	C
Carrot	0.389± 0.004	0.322 ± 0.002	0.257± 0.002	0.325± 0.01
Cabbage white	0.385± 0.003	0.388± 0.01	0.204± 0.002	0.204± 0.03
Cabbage purple	0.333± 0.003	0.321± 0.001	0.375± 0.03	0.243± 0.003
Doodo	0.318± 0.004	0.450± 0.003	0.267± 0.002	0.420± 0.001
Buga1	0.335± 0.01	0.287± 0.002	0.277± 0.003	0.312± 0.001
Buga 2	0.322± 0.001	0.25± 0.002	1.186± 0.003	0.244± 0.005
Narocas 1	0.395±0.003	0.444± 0.003	0.305± 0.01	0.332± 0.002
Ugic18224	0.410± 0.003	0.427± 0.003	0.312± 0.002	0.291± 0.002

The values are expressed as mean ± SD.

B. Discussion

The results of this study indicate that the leafy vegetables are high in bioactive compounds as exhibited by high total Alkaloids content in particular. The difference in losses caused by the different drying processes could be attributed to the length of exposure to light, oxygen, heat and other accelerating factors. Since open sun drying vegetables took more time in light than indirect solar dried ones, it could explain why more total carotene loss took place in open sun-dried vegetables than indirect solar dried ones. The mechanism of degradation for vitamin C is influenced by temperature, salt and sugar concentrations, pH, enzymes, metal catalysts and the presence of oxygen [22], [23]. All the drying methods used in the study lost vitamin C and this could be attributed to the fact that vitamin C is highly prone to oxidative destruction in the presence of heat, light, oxygen, enzymes and moisture [23]. Comparison of the nutrients of fresh vegetables with the vegetables dried by the different methods shows that, of the three drying technologies (sun drying, solar drying and oven drying), oven drying generally seemed better, especially with regard to total carotene retention followed by solar drying. Drying time varied depending on the moisture content, equipment used for drying, humidity in the air. Indirect solar drying took the longest time to dry the sample until constant weights were obtained because during cold conditions, vegetable samples would absorb moisture content from the environment.

1. Nutrient composition for fresh vegetables

All the nutrient composition, nutrient retention and nutri-pharmaceutical compounds retention drying methods had no statistically significant different mean ($P > 0.05$). Indirect solar drying presented the highest average mean in carbohydrates. Cassava fresh leaves showed highest total carotene content and vitamin C. Open-air sun drying method resulted in the greatest losses of total carotene and vitamin C contents according to concentrations differences obtained. The results for nutrient composition show the variation with drying methods for the selected vegetables. The results showed that all the nutrients experienced losses but the losses varied from one nutrient to another depending on the treatment employed. Beta-carotene was found to be very susceptible to sun drying. During food processing, some key nutrients are often lost [24].

2. Effect of drying methods on nutrient retention

All the results show that temperature conditions in oven drying, open sun drying and indirect sun drying had no significant effect on retention of the nutrients and bioactive compounds in the selected vegetables. Anthocyanins, water-soluble antioxidant pigments which are responsible for most of the bright colors of vegetables [25], were high in oven drying. Pearson correlation as shown revealed no significant correlation for phytochemicals and nutrient retention in vegetables preserved using different drying methods. Very high correlation for Nutrients retention in the order; total carbohydrate ($r = +0.944546$), > vitamin C ($r = +0.87862$), > total reducing sugars ($r = +0.873193$) > total protein ($r=+0.821468$). This revealed the retention of nutrients on proper drying effectively. Phytochemicals in foods are influenced by food processing such as fermentation, drying, etc. [26], [27].

3. Phytochemicals in fresh vegetables

All the targeted phytochemicals (flavonoids, total phenolics, total tannins and alkaloids) were detected in the selected vegetable in significant amounts; and can help the body to reduce on the risks of getting affected by chronic diseases [25], [28], [29]. In fresh vegetables, appreciable amounts of phytochemicals were extracted using 80% ethanol: ethyl ether solvent than n- hexane.

4. Total Phenolic and Flavonoid, alkaloids antioxidant Contents in Relation to Solvents and Drying Methods

The flavonoid was best extracted in the 80% (V/V) ethanol: ethyl ether solvent than in n- hexane. Generally, the open sun, indirect sun, and oven dried samples had the best extraction with ethanol ethyl ether. The fresh, open sun, and indirect sundried leaves of the 80% ethanol: ethyl ether solvent extract had substantially higher amount of all the phytochemicals. Thus, the 80% ethanol: ethyl ether solvent extract had the overall significantly high phytochemical content. The highest flavonoid retention was observed in cassava leaves and there was no significant difference between the effects of drying methods. The results obtained showed that all the targeted compounds, namely tannins, phenolics (major phytochemicals), flavonoids and alkaloids were detected in all extracts but with different amounts because they have high polarity and solubility in ethanol: Ethyl ether than n-Hexane. Hence Ethanol: Ethyl ether solvent was more effective in extraction of phytochemicals. The choice of selection was based on their polarity. Solvent polarity, solvent-to-solid ratio, and contact time significantly affected the solvent extraction of tannins. Extract yield of tannins was the lowest with n hexane because Snyder's solvent polarity index (n-hexane = 0.1) almost causes low yield extract of tannins ($p<0.05$). Solvent extraction is one of the effective ways of extracting phytochemicals [25], [29].

IV. Conclusion and Recommendation

A. Conclusion

The results obtained indicated that drying processing methods maintained the stability of valuable nutrient so any method can be used to preserve vegetables to bridge the gap between the times of plenty and scarcity with oven drying as the best. Although the statistical analysis of the results shows no significant losses in minerals as a result of drying, the amount of nutrients retained could be valuable especially in communities that have limited alternative sources of these micronutrients. Drying of vegetables should be encouraged as a way of ensuring all year- round supply of nutri-pharmaceutical compounds and nutrients to at-risk communities and groups in the region. Vegetables could be preserved when they are in season and fed to children and elderly who are singled out as being at high risk when they are out of season. The use of solar dryers should be encouraged in drying of vegetables. Since they can be locally constructed, local farmers for example can be mobilized to form associations and through those small groupings they can contribute and construct their own solar dryer structures or

soft loans can be advanced by micro finance institutions to purchase solar driers. Solar drying of vegetables is also recommended by FAO/ILSI as an appropriate low-level technology for preserving foods. These drying methods remain the only affordable approaches of mitigating malnutrition in the developing countries, like Uganda where the majority of the people cannot afford marketed nutrient supplements and fortified foods.

B. Recommendations

Based on the findings of this study, the following recommendations are made for policy actions to reduce the healthy associated problems thereby encouraging the use of drying methods to preserve their vegetables in times plenty to be fed on during scarcity seasons.

1) Provision of good drying facilities to preserve the produce that are harvested during their plenty season. This will help to reduce the bio unavailability of nutrients.

2) Training initiatives on drying methods of perishable products such as vegetables should be encouraged and follow ups, feedback and adoption measurement should be conducted periodically for sustainability.

With the use of drying methods for preservation, vegetable availability would be increased significantly throughout the year. This is absolutely essential to ‘‘end hunger, achieve food security and improved nutrition and promote sustainable agriculture, by 2030, and end all forms of malnutrition by 2025.

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CONFLICT OF INTEREST

The authors declare no conflict of interest whatsoever.

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ABBREVIATIONS

BSA	Bouvine Serum Albumen
DPPH	2, 2-diphenyl-1-1-picrylhydrazyl
FAO	Food Agricultural Organisation
ILSI	International Life Science Institute
NaCRRI	National Crops Resources Research Institute-Namulonge
GAE	Gallic Acid Equivalent
HCN	Hydrogen Cyanide.
HCl	HydroChloric Acid (hydrogen chloride)
RPM	Rotations Per Minute
RSA	Radical scavenging activity
SDGs	Sustainable Development Goals
$KMnO_4$	Potassium permanganate
NaOH	Sodium hydroxide
NH_4OH	Ammonium hydroxide
$AlCl_3$	Aluminium (iii) Chloride
Na_3CO	Sodium Carbonate
TCC	Total Carotenoid Content
ml	Millilitre