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Full Length Research Paper

Effects of blanching time/temperature combination coupled with solar-drying on the nutritional and microbial quality of indigenous leafy vegetables in Kenya

Esther W. Njoroge[1], Joseph W. Matofari[1], Richard M.S. Mulwa[2], and Joseph O. Anyango[1*]

[1]Department of Dairy and Food Science and Technology, Egerton University, P. O Box 536-20115, Egerton, Kenya.
[2]Department of Crops, Horticulture and Soils, Egerton University, P. O Box 536-20115, Egerton, Kenya.
*Corresponding author Email: ajochieng@egerton.ac.ke

ABSTRACT

The abundance of indigenous leafy vegetables during the rainy seasons and the traditional preservation systems leads to post-harvest losses on nutrients. There is need to reduce these losses by seeking an alternative relatively cheaper, hygienic and locally adaptable preservation method. Solar drying could be a useful dehydration option. No sufficient data is available on a suitable combination of solar drying and blanching protocol for preservation of ILVs in Kenya. This study investigated the effects of controlled blanching time/temperature combination coupled with solar-drying on the nutritional and microbial load of three ILVs in finding a suitable preservation technique. The ILVs commonly consumed in Kenya, spiderplant *(Cleome gynandra)*, slenderleaf *(Crotalaria ochroleuca)* and cowpeas (*Vigna unguiculata*) were used. Two blanching conditions (80^{o}C/10 min and at 90^{o}C/5 minutes) were tested. Blanching at 100^{o}C for 30 min, followed by open sun-drying was used as control, while conventional oven drying of the ILVs was used as standard for comparison. Greatest nutrient loss was observed for ILVs that were blanched at 100^{o}C for 30 min, then sun-dried. Most nutrients were retained at 80^{o}C/10 min compared to those retained at 90^{o}C/5 min. Microbial load (5.3-5.6 cfu/g) was significantly lower for solar dried ILVs ($p<0.05$) blanched at 90^{o}C/5 min. This indicates that blanching at 80^{o}C/10 min followed by solar drying is a potential option to be used as a local preservation technique for ILVs in Kenya.

Key words: Indigenous leafy vegetables (ILVs), blanching, solar-drying, open sun-drying, dehydration.

LIST OF ABBREVIATIONS AND ACRONYMS

AOAC	Association of Official Analytical Chemists
Conc.	Concentration
DWB	Dry weight basis
Fe	Iron
H	Hours
HCl	Hydrochloric acid
H_2SO_4	Sulphuric acid
ILVs	Indigenous leafy vegetables
Kg	Kilogram
KOH	Potassium hydroxide
Mg	Magnesium
Min	Minutes
RDA	Recommended daily allowances
SAS	Statistical analysis for scientist
SD	Standard deviation
Spp.	Species
µg/g	Microgram per gram
µg	Micrograms
µmol/g	Micro molar per gram
WHO	World Health Organization
%	Percent
^{o}C	Degree Celsius

INTRODUCTION

Vegetables are rich sources of vital ingredients in healthy and balanced human diets (Osuagwe, 2008). They are important low cost foods containing low levels of fat and high levels of vitamins, minerals, fibre and protein (Bolaji et al., 2008). These nutrients are usually in short supply in daily diets (Mosha and Gaga, 1995). The indigenous leafy vegetables (ILVs) have long been part of traditional diets in communities worldwide and are important sources of vitamins, minerals, fiber, proteins and other phytochemicals with health-promoting effects (Kimura and Rodriguez-Amaya, 2003). This renders the ILVs potential candidates useful in contributing to food security and improved health.

ILVs consumption is still low partly because they are abundant mostly during the rainy seasons but scarce in dry seasons as farmers do not have proper strategies of processing the excess produce (Government of Kenya, 2003). The high moisture content of ILVs renders them perishable while their seasonal availability limits their utilization all year round. Hence, there is a need to preserve these nutrients through application of proper processing techniques for safe storage with efficient nutrient retention.

Traditional treatment of the ILVs involves boiling them in water for about 30 min then sun-drying in open air. The traditional treatment has a lot of challenges, both in terms of hygiene and lack of temperature control. This leads to heavy losses of nutritive value and microbial spoilage. Blanching pre-treatment together with hot-air oven drying methods is the commonly used standard for preserving ILVs (Shitandi et al., 2010). Blanching inactivates the endogenous enzymes contained in the vegetables, reduces microbial load, softens and shrinks product for ease of packaging. Various recommendations on the blanching medium, whether water or steam, the length of the blanching period and temperatures to be used during blanching have been presented (Sheetal et al., 2008).

Water blanching temperatures at 70-100^{o}C for 1-5 min for leafy vegetables is recommended but it has a short holding time and this may stimulate enzyme actions instead of denaturing them. Blanching for a longer time cooks the vegetables destroying the vitamins, minerals, flavour and colour (Flatman, 1995). Additionally, Pradeep and Susanta (2001) reported that the above stated blanching time/temperature combinations cause loss of nutrients especially, through leaching of minerals and loss of water-soluble vitamins. Although blanching is a prerequisite for preserving leafy vegetables, information on specific temperature and length of holding time is not available for ILVs preservation. Hot air oven-drying has not been widely adopted in Kenya probably because it requires electric power to run therefore it is relatively expensive. Hence there is need for a cheaper alternative dehydration technique for the ILVs. In this regard, solar-drying could be a suitable option. This study was done to determine which blanching time/temperatures regime in combination with solar-drying would achieve a good retention of nutritive value and safe microbial load on ILVs in Kenya.

MATERIALS AND METHODS

Study site

Certified seeds of three commonly consumed ILVs, spiderplant *(Cleome gynandra)*, slenderleaf *(Crotalaria ochroleuca)* and cowpeas (*Vigna unguiculata*), were purchased from Kenya Seeds Company, Kitale, Kenya. The ILVs were grown at the horticulture teaching and research station at Egerton University, Njoro, between the months of October 2014 and November 2014. The station lies between longitudes 35^{o} 28' and 35^{o} 36' east and latitudes 0^{o}1' and 1^{o}10' south, receives erratic rainfall with an average of 600-900 mm annually and the daily temperatures range from 22-28°C while the soil is loamy and free draining (Jaetzold et al*.,* 2007).

Study design and data collection

Completely randomized design (CRD) in a factorial arrangement was used in the study. The main factors were the three blanching temperatures (80^{o}C/10 min, 90^{o}C/ 5 min and 100^{o}C/30 min) and the three drying methods (solar-drying, hot air-oven drying and open sun-drying). The samples were analyzed for, moisture content, crude protein, crude fiber, vitamins (vitamin C and β-carotene), minerals (iron and calcium), total viable counts, coliform counts, yeast and moulds counts. The effects of the blanching regime and drying methods on the nutritional quality and microbial safety parameters were determined.

ILVs sample collection

The ILVs were harvested 40 days after planting. Tender leafy shoots were picked for spiderplant and slenderleaf (Figure 1 and 2), while trifoliate leaves were harvested for cowpea (Figure 3). A cool box was used to carry the ILVs to the laboratory. Both raw and processed ILVs were analyzed for total viable counts, coliform counts, moisture content, crude protein, crude fiber, vitamins (vitamin C and β-carotene), minerals (iron and calcium).

Sample preparation

The tender shoots were sorted, washed, shredded and weighed into equal amounts. They were prepared for blanching at specified time/temperature combination and

Figure 1. Spiderplant, 5 weeks from planting at the horticulture teaching and research station, Egerton University, Njoro

Figure 2. Slenderleaf, 5 weeks from planting at the horticulture teaching and research station, Egerton University, Njoro

drying methods to determine the effects of the treatments on nutritional quality and microbial load.

Blanching of ILVs

Tender shoots of ILVs (2.5 kg) were blanched at 80^{o}C/10 min and at 90^{o}C/ 5 min. Another batch was blanched at 100^{o}C/30 min (in boiling water) to serve as control. This was performed by bringing a large pan half-full of water to 80^{o}C, 90^{o}C and 100^{o}C respectively. Then the shredded vegetables were put into a wire basket and gently lowered into the blanching water. At the end of blanching period, the baskets with vegetables were removed from the boiling water and plunged into cold water at room temperature to stop the blanching process. The blanched

Figure 3. Cowpeas, 5 weeks from planting at the horticulture teaching and research station, Egerton University, Njoro

Figure 4. ILVs placed in a solar-drier positioned in a level platform

leaves were put in wooden boxes to drain off the water and then held at room temperature for 5 min to cool. The 80°C/10 min and 90°C/5 min blanched vegetables were then divided into two equal portions for solar-drying and for hot-air oven-drying.

Drying of ILVs

The blanched vegetables (1.25 kg) were spread on trays and placed in a hot-air oven (Electrolux E130GF35JS Struers, Stockholm, Sweden) set at 65°C. They were

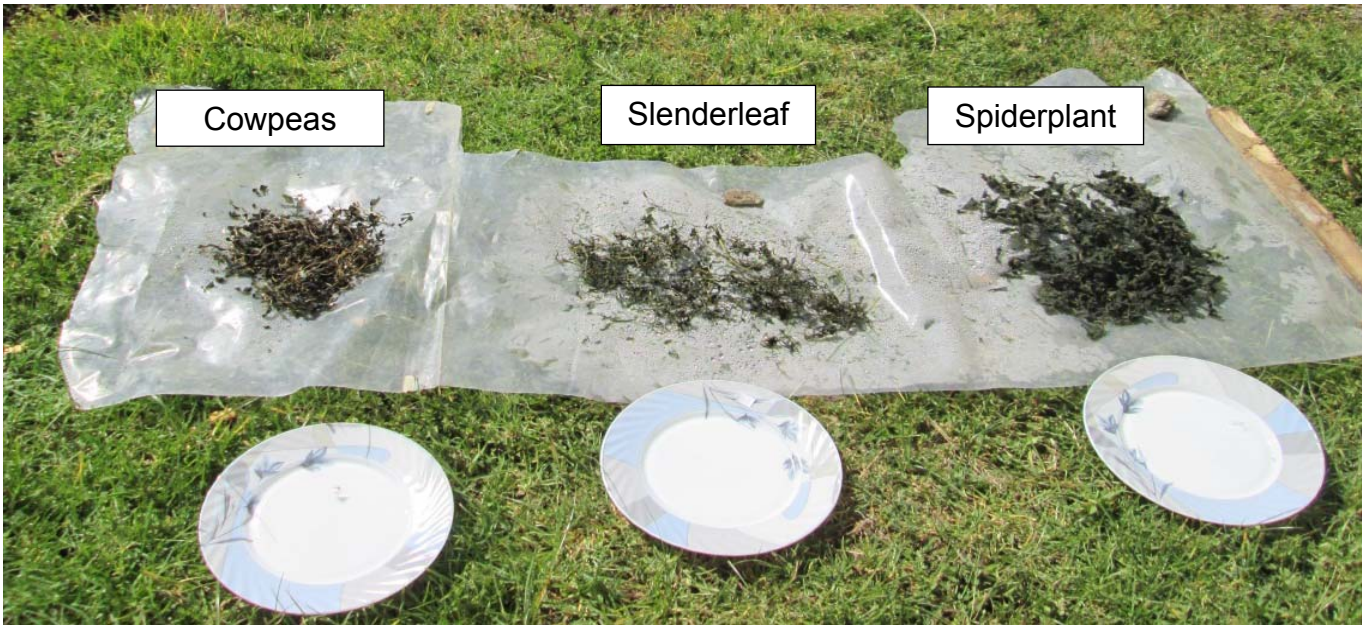

Figure 5. Open sun-drying of ILVs

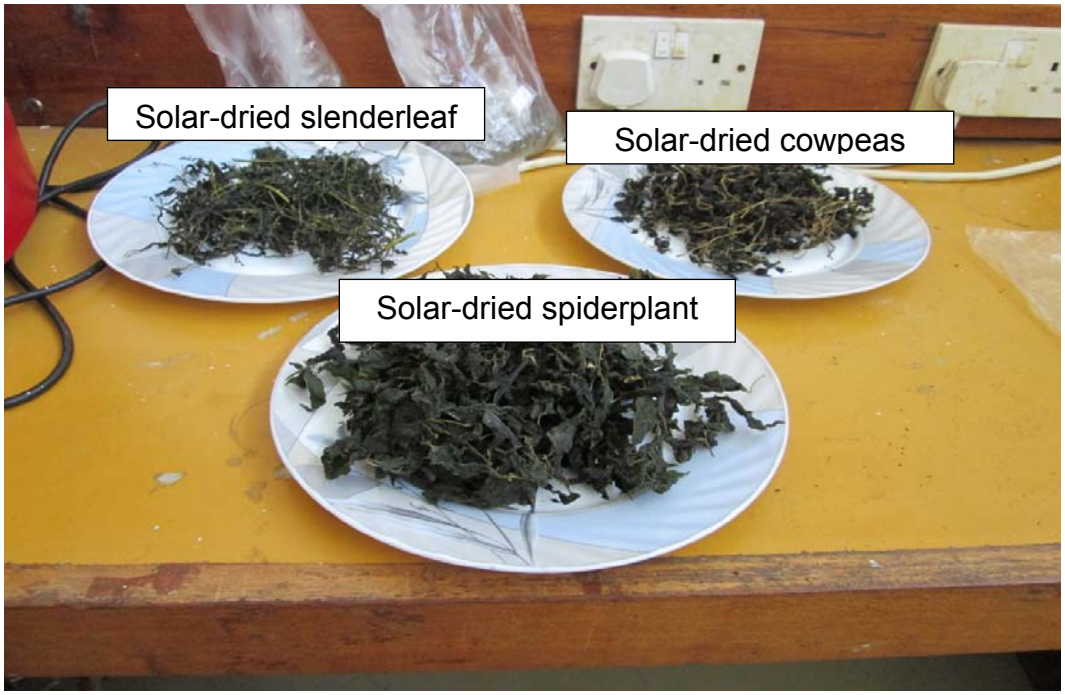

Figure 6. ILVs gridding into fine powder and packaging in zip-lock packaging bags

dried to constant weight which took approximately 7h with the temperature being maintained throughout. The other 1.25 kg was placed in a fabricated solar dryer designed by the Department of Agricultural Engineering, Egerton University, Njoro, Kenya (Figure 4). The solar dryer dries approximately 8 kg vegetables in 2 sunny days to 13% moisture content. The solar drier was positioned in a level platform unobscured by trees and buildings so that it was fully exposed to the sun throughout the day. It was sunny and the vegetables

dried for two full days at 60°C in the dryer. Moisture loss was monitored by regular weighing of the samples until a constant weight was achieved. Those blanched at 100°C/30 min were open sun-dried (control) (Figure 5). They were dried in the sun to constant weight, (approximately three days of drying). The blanched-dried vegetables were later ground using a mortar and pestle into fine powder then packaged in zip-lock packaging bags (Figure 6), labeled and stored to await chemical and microbial analyses.

Determination of ILVs moisture content

Moisture content was determined by oven drying according to the Association of Official Analytical Chemists (AOAC) International (2000) Method 970.30. Samples were dried in an oven at 105°C for 3 h with cooling being done in a desiccator for 10 min. Moisture content was calculated as the loss in weight expressed as a percent of the original weight of the ILVs sample.

Determination of ILVs crude protein content

Crude protein was determined by the Kjeldahl method (AOAC International 2000) Method 991.20. The weighed sample was placed in the micro-Kjeldahl digestion tubes into which 10 ml concentrated nitrogen free sulphuric acid was added together with one selenium tablet as a catalyst per tube. The samples were digested in a DK-20S digester (Velp Scientifica, Bohemia, Italy) at 445°C for 3 h. The products of digestion were distilled using the Kjeldahl distillation unit. The distillate was collected in a 15 ml 0.1 M HCl in which a mixed indicator of methyl red and methylene blue had been added. The excess HCl was titrated against 0.1 M NaOH. The crude protein (CP) was calculated as;

Crude protein (g/100 g) = $(V_1 – V_2) \times M \times 1.4 \times 6.25 / W$,Where V_2 is volume of HCl used for test portion, V_1 is volume of HCl used for blank test M is molarity of acid, W is weight of test portion and 6.25 is the conversion factor.

Determination ILVs crude fiber content

Crude fiber content was determined by gravimetric method according to AOAC International (2000), Method 984.04. Approximately 5 g samples were added into 25 ml of 2.04 M H_2SO_4 (acid) with distilled water used to top the contents to 200 ml. The mixer was then digested in a digester (DK-20S digester, Velp Scientifica, Bohemia, Italy) at 445°C for 30 min. A glass wool rolled at the ends of the filtering stick was inserted in the suction pump to obtain the filtrate that was washed twice with hot water to make the filtrate clear. A second digestion was done using 1.78 M NaOH with similar treatment. A final washing was done in 70% ethanol and the product transferred in weighed crucibles for drying at 105°C for 3 hours in an oven. Weight of the contents was recorded after the 3 h and then ashing was done in a muffle furnace at 550°C overnight and weights recorded. Crude fiber was then calculated as the difference between sample weights from furnace and that of oven.

Fiber (g/100 g) = (Residue weight from oven – weight from ashing) / original sample weight

Determination of ILVs β-carotene content

Vitamin A content was determined as β-carotene spectrophotometrically according to AOAC International (2000), Method 2000.10, as modified by Imungi and Wabule (2001). The samples (1 g) were ground in acetone and the homogenate filtered through glass wool. The residue was ground again and rewashed several times with acetone until a colourless filtrate was observed. The volume of the combined extracts was raised to 50 ml by adding acetone. The extract (25 ml) was evaporated to dryness in an evaporator in a water bath at 65°C. Separation was then carried out in a chromatographic column packed with silica gel to 15 cm depth while the top was filled with 1cm layer of anhydrous sodium sulphate to remove any traces of water in the samples. The evaporated samples were then dissolved in 2 ml petroleum spirit, then quantitatively spotted into the column, and eluted with petroleum spirit. The first yellow eluate was collected in a 25 ml flask and made to the mark with the petroleum spirit. The concentrations of β-carotene were measured using a CE 440 UV/Vis double beam scanning spectrophotometer (V-200-RS, London, United Kingdom), at 450 nm, calibrated with standard solutions of pure β-carotene in petroleum spirit. The β-carotene contents were calculated using the formula:

C_X (mg/100 g) = [$A_X \times C_S$ (mg/ml) × total volume of extract (ml)] / [$A_S \times$ sample weight (g)], Where C_X is the concentration of β-carotene, A_X is the peak area of β-carotene, C_S is the concentration of the standard and A_S is the peak area of the standard.

Determination of ILVs ascorbic acid (vitamin C) content

Ascorbic acid was determined by titration with 2, 6-dichlorophenolindophenol dye according to AOAC International (2000), Method 990.23. The samples were homogenized in metaphoric acid solution and the extract filtered, then diluted appropriately to a concentration of 100 mg ascorbic acid/100 ml. A standard solution was prepared by dissolving 50 mg of pure ascorbic acid in 100 ml of water. Samples filtrate was titrated against the standard solution to a pink endpoint in 10 seconds. Ascorbic acid content was calculated as:

Mg ascorbic acid/100 g or ml sample = C×V× (DF/WT), where C= mg ascorbic acid/ml dye,

Table 1. Nutritional composition of fresh ILVs

ILVs	Moisture (%)	Crude protein (g/100 g)	Crude fiber (g/100 g)	Vitamin (mg/100g)	C β-carotene (mg/100g)	Iron (mg/100g)	Calcium (mg/100g)
Spiderplant	81.1^{b}±0.6	8.3^{c}± 0.1	4.2^{b}±0.2	178.0^{c}±0.2	10.3^{b}± 0.5	21.0^{b}±0.4	281^{c}±1.4
Slenderleaf	81.8^{b}±0.3	6.4^{a}±0.1	3.5^{a}±0.2	160.0^{b}±0.1	6.6^{a}±0.5	46.5^{c} ±1.1	44^{a}±1.4
Cowpeas	71.1^{a}±0.2	6.8^{b}±0.0	4.6^{c}±0.2	91.0^{a} ±1.5	6.5^{a}±0.4	10.8^{a}±0.2	174^{b} ±0.8

Values are means ± standard deviations, n=2.Values in a column followed by different letter notations are significantly different p≤0.05

Table 2: Effects of blanching time-temperature combinations and drying methods on nutritional composition of ILVs

ILVs	Treatment	Moisture (%)	Protein (g/ 100 g)	Crude fiber (g/100 g)	Vitamin C (mg/100 g)	(- carotene (mg/100 g)	Iron (mg/100 g)	Calcium (mg/100g)
Spiderplant	H810	11.8^{a}±0.0	5.5^{g}±0.6	3.4^{a}±0.0	82.9^{k}±1.9	3.7^{d}±0.0	1.2^{c}±0.0	7.6^{g}±0.0
	H905	12.2^{b}±0.7	4.9^{e}±0.6	3.9^{c}±0.2	79.0^{j}±0.2	3.3^{b}±0.1	0.9^{b}±0.0	7.2^{f}±0.2
	S810	13.3^{d}±1.6	5.5^{g}±0.5	4.1^{c}±0.2	103.7^{n}±0.0	3.5^{c}±0.0	1.4^{c}±0.7	7.1^{f}±0.2
	S905	12.5^{c}±0.3	4.7^{d}±1.1	4.3^{d}±0.0	84^{l}±0.3	3.7^{d}±0.0	0.9^{b}±0.0	6.7^{e}±0.1
	03B	16.7^{g}±0.0	1.3^{a}±0.3	3.6^{b}±0.2	79.1^{j}±0.6	3.1^{b}±0.1	1.1^{b}±0.0	7.0^{f}±0.1
Slenderleaf	H810	12.5^{c}±0.0	5.0^{e}±0.7	4.0^{c}±0.2	53.6^{e}±0.9	3.2^{b}±0.0	2.2^{e}±0.1	1.6^{b}±0.0
	H905	11.9^{a}±0.0	5.4^{f}±0.7	4.3^{d}±1.2	51.8^{d}±0.8	3.3^{b}±0.0	1.8^{d}±0.7	1.4^{b}±0.1
	S810	12.5^{c}±1.4	4.5^{d}±1.1	3.4^{a}±0.7	26.8^{a}±1.9	3.1^{b}±0.0	1.7^{d}±0.2	1.1^{a}±0.0
	S905	12.3^{b}±0.3	4.6^{d}±0.7	3.9^{c}±0.7	61.9^{g}±1.6	2.7^{a}±0.2	1.3^{c}±0.0	1.1^{a}±0.0
	03B	16.0^{f}±0.8	2.3^{b}±1.1	3.2^{a}±0.0	69.8^{i}± 1.2	3.6^{c}±0.0	1.8^{d}±0.0	0.9^{a}±0.0
Cowpeas	H810	12.0^{a}±0.7	5.2^{f}±0.3	4.2^{d}±0.4	48.9^{c}±0.8	3.4^{c}±0.0	0.6^{a}±0.0	6.7^{e}±0.2
	H905	12.0^{a}±0.0	4.7^{d}±1.0	4.7^{e}±0.1	45.1^{b}±0.5	3.4^{c}±0.0	0.6^{a}±0.0	6.5^{e}±0.0
	S810	12.1^{b}±0.0	3.9^{c}±0.7	4.9^{e}±0.4	91.6^{m}±1.0	3.2^{b}±0.0	0.4^{a}±0.0	6.2^{d}±0.0
	S905	12.3^{b}±0.3	4.7^{d}±0.3	4.3^{d}±0.2	64.8^{h}±0.7	3.1^{b}±0.2	0.6^{a}±0.0	5.8^{c}±0.1
	03B	14.8^{e}±0.3	4.1^{c}±0.7	3.2^{a}±0.0	57.9^{f}±0.7	3.1^{b}±0.2	0.5^{a}±0.0	6.2^{d}±0.0
RDA*	-	-	0.8**	38**	60***	5.8***	20***	1000***

Values are means ± standard deviations, n =2. Values in a column followed by different letter notations are significantly different p≤0.05. * =WHO/FAO RDA (average adult) (2008). ** = RDA g/day, ***=RDA mg/day. H810- Blanched at 80°C /10 min hot air-dried, H905-Blanched at 90°C /5 min hot air dried, S810- Blanched at 80°C /10 min solar-dried, S905-Blanched at 90°C/5min solar-dried, O3B-Blanched at 100°C/30 min Open sun-dried.

V= volume of dye used in titrating sample, DF= dilution factor and WT= sample weight (g).

Determination of ILVs iron and calcium content

absorption spectrophotometer (AAS) according to AOAC International (1995), Method 970.30. The spectrophotometer (2380, Perkin Elmer, Osaka, Japan) was equipped with an air acetylene flame, hollow cathode lamp and recorder. Iron readings were taken at 234 nm while for calcium were done at 248 nm. Approximately 0.5 g dried and ground samples were digested in a digester (DK-20S digester, Velp Scientifica, Bohemia, Italy) using 10 ml of concentrated.

The two minerals were determined using atomic

HCl and 20 ml of concentrated HNO3. The samples were cautiously heated at 250oC until vigorous reaction subsided. Heating continued to 450oC for 45 minutes. Filtering the distillate using Wattman filter paper No. 4 (22 µm pore size) was done in 60 ml sampling bottles.

The filtrate was filled to the mark with distilled water.

The amount of each element was calculated against the standards.

Determination of total viable counts on the ILVs

The total viable counts were determined by following AOAC International (2010), Method 986.33 for microbiological testing of dried fruits and vegetables. Homogenized ground sample (10 g) was added to 90 ml peptone solution as diluent. A tenfold serial dilution was prepared and 1 ml of each sample was transferred to a Petri-dish that had been appropriately labeled with marker. From the appropriated 10-fold dilutions, total bacteria were enumerated by use of standard plate count agar (Hi media laboratories) incubated at 37°C for 48 h. Coliform bacteria were enumerated on violet red bile agar (VRBA) incubated at 37°C for 24 h, and confirmed in brilliant green bile lactose broth incubated at 37°C for 24 h. Potato dextrose agar was used for moulds and yeast and incubated at 25°C for 2 days. All the Petri-dishes were incubated upside down, and after the stated incubation period, the microbial count was carried out. Colonies appeared as clusters and each plate was counted and the averages computed for each sample. The isolates were sub-cultured to obtain pure cultures. The plates were incubated at 30°C for 24 h and 72 h for bacteria and fungi respectively. The bacterial isolate was identified using morphological and biochemical characteristics. Moulds were identified using microscopy and cultural characteristics.

Isolation and identification of microorganisms in ILVs

This was performed according to Bridson (2006). Five isolates were taken from the highest dilution plates and continually streaked on agar to obtain pure colonies. Isolates of coliforms, yeast and molds were initially examined by Gram stain, catalase and oxidase tests.

Identification of moulds and yeast

Moulds and yeast isolates were identified in potato dextrose agar (Hi media laboratories) incubated at 25°C for 2 days by colony and cell morphology (Himelbloom and Crapo, 1998).

Confirmation of coliforms

Coliforms were confirmed in brilliant green bile lactose broth incubated at 37°C for 24 h (Bridson, 2006).

Statistical analysis

The data were analyzed by one way analysis of variance (ANOVA) as outlined by (Gacula *et al*., 1984) using sample as the independent variable and the measured parameters as the dependent variables. Fisher's least significant difference (LSD) test was used to identify significant differences among treatment means ($p \leq 0.05$).

RESULTS AND DISCUSSION

Effects of blanching time-temperature regimes and drying methods on nutritional composition of ILVs

The nutrient composition of the fresh three species is given in Table 1. Fresh slenderleaf had the highest moisture content (81.8%) followed by spiderplant leaves (81.1%) and cowpeas (71.1%). The moisture content and nutritional composition of the three species was significantly different ($p<0.05$) for each species. Heat treatment and drying methods significantly affected the nutritional composition of the leaves (Table 2). The three drying methods resulted in different amount of moisture content among the three species. Open sun-drying was the least effective method while oven drying (standard method) was the most efficient in dehydrating the ILVs. The mean moisture content for the solar dried ILVs was 13.3% which was almost similar to the oven-dried ILVs (12.4%). The two drying methods were significantly different ($p<0.05$) from the open sun-dried ILVs whose mean moisture content was 16.2%. The differences in the amount of moisture between the solar-dried and open sun-dried ILVs may be attributed to the ability of the solar-drier to generate heat through solar radiations that were absorbed by the ILVs, thus, the rate of moisture removal was fast unlike in the open-sun dried ILVs. Additionally, the removal of moisture from the ILVs in the solar drier may have been contributed by the transparent polythene paper that probably created a greenhouse effect in the drier thereby enhancing air exchanges and ensuring a balanced air regulation in the drier. The agronomic reasons such as difference in maturity stage and harvesting time may also have contributed to a difference in moisture content of the dried ILVs as suggested by Uusiku et al. (2010).

The protein content in the fresh ILVs was found to be highest in spiderplant (8.3 g/100g) and lowest in slenderleaf (6.4 g/100 g) (Table 1). After blanching and drying the ILVs, there was a slight loss in protein amounts in all processed ILVs (Table 2) which was not expected. However, the solar-dried spiderplant leaves blanched at 80^{o}C/10 min had the highest amount (5.5 g/ 100 g) of crude protein while the cowpea leaves blanched at 100^{o}C/30 min had the lowest crude protein amounts (2.3 g/ 100 g). This slight loss in crude protein was probably due to loss of water soluble nitrogen-containing compounds in the ILVs such as free amino acids, nucleic acids, nucleotides and certain water soluble vitamins during blanching. Less loss in crude protein was observed for solar and oven dried ILVs, while greatest loss was recorded for open sun-dried ILVs. This was

Table 3: Microbial population expressed in log_{10} cfu/ g of freshly harvested ILVs

ILVs	Total viable counts (log_{10} cfu/g)	Yeasts and molds counts (log_{10} cfu/g)	Coliform counts (log_{10} cfu/g)
Spiderplant	8.4^{a} ± 0.8	3.7^{b}± 1.4	1.5^{a} ± 1.2
Slenderleaf	8.3^{a} ± 0.9	2.4^{a} ± 0.6	1.4^{a} ±0.4
Cowpeas	8.0^{a} ±0.9	2.8^{a}± 1.0	1.9^{a} ±1.7

Values are means (log_{10} cfu/g) ± standard deviation of ILVs. Cfu/ g = colony forming unity per gram. Values in a column followed by different letter notations are significantly different (p≤0.05)

Table 4. The microbial quality in log_{10} cfu/ g of processed ILVs

ILVs	Treatment	Total viable counts (log_{10} cfu/g)	Yeasts and molds counts (log_{10} cfu/g)	Coliform counts (log_{10} cfu/g)
Spiderplant	H810	6.1^{a}± 1.1	2.2^{a}±1.2	0.9^{a}±0.7
	H905	5.8^{a}± 0.9	2.0^{a}±1.7	0.8^{a}±0.6
	S810	6.3^{b}± 0.5	2.1^{a}±1.3	1.3^{a}±0.3
	S905	5.4^{a}± 0.8	1.8^{a}±0.9	1.1^{a}±0.9
	03B	6.7^{b}± 0.4	2.6^{b}±1.2	1.4^{a}±0.2
Slenderleaf	H810	6.0^{a}± 0.9	2.1^{a}±1.1	0.7^{a}±1.1
	H905	5.2^{a}±0.7	2.0^{a}±0.3	0.7^{a}±0.8
	S810	6.2^{a}±1.2	2.3^{a}±0.4	1.6^{b}±1.1
	S905	5.3^{a}±0.5	$2.^{a}$1±1.1	1.5^{a}±0.8
	03B	6.4^{b}±0.7	2.6^{b}±0.7	1.8^{b}±0.7
Cowpeas	H810	6.2^{a}±0.3	2.4^{a}±0.9	1.0^{a}±0.2
	H905	5.8^{a}±0.8	2.0^{a}±0.5	0.8^{a}±0.2
	S810	6.0^{a}±1.2	2.2^{a}±1.2	1.6^{b}±1.1
	S905	5.6^{a}±0.6	1.9^{a}±0.8	0.9^{a}±0.2
	03B	6.3^{b}±1.1	2.8^{b}±0.4	1.9^{b}±0.3
Recommended criteria	-	$≤10^{5}$	$≤10^{3}$	$≤10^{3}$

Values are means (log_{10} cfu/g) ± standard deviation of blanched-dried ILVs. Cfu/ g =colony forming unity per gram. Values in a column followed by different letter notations are significantly different (p≤0.05).

probably because of relatively mild blanching conditions used for solar and oven-dried ILVs. The FAO/WHO RDA for protein is 0.8 g/kg/day. An average adult weighing 64 kg requires 51.2 g/kg/day which may not be obtained from ILVs under study. Relatively, more benefit could be achieved by practicing solar-drying in order to have better protein retention, unlike open sun-drying of boiled ILVs. Additionally, the amounts obtained after the preservation can play a significant role in providing cheap and affordable protein for rural communities.

The lowest fibre content (3.5 g/100 g) was recorded for slenderleaf (Table 1). After processing, slenderleaf blanched at 90^{o}C/5 min with solar-drying had the highest amount of crude fiber (7.3 g/100 g). ILVs boiled at 100^{o}C/30 min with open sun-dried recorded lower amounts (3.3 g/100 g) of crude fiber than solar-dried samples (4.5 g/100 g). The difference in crude fiber contents may be due to soil fertility and age of leaves at harvesting as noted by Bruinenberg et al. (2001). Crude fiber content for both fresh and processed ILVs was lower than the FAO/WHO RDA for an average adult (38 g/day). Combining the three species could supply the body with the FAO/WHO RDA/day.

Fiber adds bulk to the food and prevents the intake of excess starchy foods and may thus guard against metabolic conditions such as diabetes mellitus (Mensah et al., 2008).

The three species in their fresh form meets the RDA for vitamin C (75 mg/day) for an average adult (Table 1). A loss in ascorbic acid (44.4%, 39.2% and 32.3%) for spiderplant, slenderleaf and cowpeas respectively, blanched at 100°C/30 min with open sun-drying, was observed. The above losses were higher when compared to solar-dried spiderplant and cowpeas (37% and 41%) blanched at both 80°C/10 min and 90°C/5min.The difference in loss of ascorbic acid in the ILVs treated under similar conditions could be attributed to difference in ILVs internal tissues structures (size and shape), mechanical damage, fresh ILVs ascorbic acid content and enzymatic activities. It can be observed that spiderplant and cowpeas blanched at both 80°C/10 min and 90°C/5min with solar-drying meets the RDA (75 mg/day) for ascorbic acid.

Amount of β-carotene for the leaves blanched at 80°C/10 min and 90°C/5 min blanched/solar-dried samples was found to be higher than the control and this might be due to the effect of direct sun radiations on the vitamin. The total β-carotene significantly decreased ($p<0.05$) which correlates with a study done by Gayathri et al. (2004), who found that boiling resulted in the greatest loss of β-carotene in *Amaranthus* species. The vitamin is not a heat-sensitive nutrient, although heat facilitates the breakdown of cell walls to release β-carotene making it more readily available for absorption into the bloodstream. Intake of the three species in combination could meet the β-carotene RDA/day. Alternatively, since the solar-dried leaves attains almost similar β-carotene as the standard hot air-oven drying, it could be advantageous to solar-dry the leaves so as to obtain higher amounts of β-carotene. β-carotene is determined as a precursor of vitamin A where, 6–12 µg of β-carotene is equivalent to 1 µg of vitamin A. Nutritionally, the total amount of vitamin A n foods is expressed as µg retinol activity equivalents (RAE), calculated from the sum of µg of preformed vitamin A +1/12 × µg β-carotene (Gibney et al., 2009). It is recommended that an average person consume 700 µg/ 100 g/ day amounts of vitamin A.

Comparing the iron content among the three blanching time/temperature combinations, slenderleaf blanched at 80°C/10 min had the highest iron content (2.2 mg/100g) while cowpeas blanched at 90°C/5 min had the lowest iron content (0.4 mg/100g). As expected, blanching of the leaves decreased the content of iron. This may be because more iron could have leached out in the blanching water during the heat treatment (Vorster et al., 2002).

Blanching and drying caused significant ($p<0.05$) reductions in calcium content of the three species. This suggests consumption of large quantities of calcium to meet the RDA for calcium. For instance, adult minimum calcium requirement for health set by the FAO/WHO RDA is 1000 mg daily. Thus, meeting the RDA amount of calcium from blanched spiderplant; 376.2 mg/100g would be required from leaves blanched at 80°C/10 min. Generally, solar dried ILVs had higher mineral content than the open sun-dried vegetables for all the minerals. This may be because solar dried foods are dried at high air, temperature and low humidity. This hastens the drying rate and helps to retain more minerals as well as enable the products to be stored longer. This is further corroborated by reports of Fuller (1991) and Ruel (2001), that solar drying helped retain more minerals in fruits and vegetables.

Effects of blanching time-temperature regimes and drying methods on microbial quality of ILVs

Spiderplant had both the highest total viable bacterial counts (8.4 cfu/g) and yeast and moulds (3.7 cfu/g) counts which may be connected to the high moisture contents and a rich chemical composition of the ILVs since microorganisms utilize the nutrients to multiply in number (Table 3).

However, despite the low moisture content of the blanched-dried vegetables, microbial counts were recorded in all the three samples. The results showed that microbial load in solar dried vegetable samples were significantly lower ($p<0.05$) than that of sun dried samples at the end of the drying period (Table 4). Mean concentrations (10^1-10^3 cfu/g) for the total bacteria in all the samples was done with the solar-dried samples blanched at 90°C/5 min recording slightly lower populations. This could be attributed to the higher blanching temperatures and enclosure of the samples in a solar-drier. Counts for moulds, yeast and coliforms were done at concentration10^1 to10^4 cfu/g.

The yeasts and moulds results (Table 4) shows relatively low viable counts for blanching done at 90°C/5 min with solar-drying compared to those blanched at 100°C with open sun-dried samples. This could be due to the effect of heating since most of them are heat sensitive. The occurrence of coliforms in high numbers in most of the dried vegetables is an indication of poor handling of the vegetables during processing (Ezeronye and Ubalua, 2005).

Factors which could be responsible for the counts may include drying vegetables on exposed surfaces and packing them in containers not adequately cleaned (Kudjawu, et al. 2011). The results further showed that microbial load was not high (10^3-$10^{5)}$ to harm the body and that the vegetables could be preserved over a considerable period of time. FAO (2004) reports showed that solar dryers are free from microbial contamination and are better preservers and give good quality products than sun dried products.

CONCLUSION AND RECOMMENDATIONS

Solar-drying especially after blanching at 80°C/10 min, is an effective dehydration method for ILVs, which retains a good proportion of vitamins (61%) and minerals (73%). Additionally, the microbial load is significantly lower (4.2-5.1 cfu/g) for solar dried ILVs that is almost similar to the standard hot air-drying. This research has shown that blanching at 80°C/10 min followed by solar drying is a potential option that can be used as a local preservation technique for ILVs in Kenya. This technology being relatively cheap compared to oven-drying and effective should be adopted by the local communities and women groups for preservation of all ILVs. Additionally, there should be promotion program to increase acceptability and consumption of solar-dried ILVs among the rural communities.

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