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Impact of Different Household Cooking Methods on the Nutritional Composition, Total Phenolic Content and Invitro Antioxidant Activities of African nightshade (*Solanum scabrum*) and Vegetable amaranth (*Amaranthus hybridis*)

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ABSTRACT

Purpose: The objective of this study was to subject African nightshade and vegetable Amaranth to different household cooking methods (boiling, steaming, microwave and stir frying) and test them on the changes of total phenolic content (TPC), antioxidant property (ferric reducing-antioxidant power (FRAP) activity and DPPH radical scavenging activity), macronutrients and micronutrients.

Methodology: The African nightshade, (HB) and the Amaranthus leaves, (AL) used in the preparation of all the dishes were purchased from the same farmer at Nkwen in Mezam division of the North West Region of Cameroon. Standard methods were used to determine each analyte at the Laboratory of Food Science and Metabolism (LabSAM) of the University of Yaounde 1 and *Nkolbisson* Food Technology Laboratory, Yaounde, Cameroon.

Findings: The TPC of leafy vegetables ranged from 256.64 to 1184.08 mg GAE/100g, with higher levels observed in cooked forms compared to raw ones. Steaming significantly increased FRAP in both African nightshade and amaranth, followed by microwaving and boiling, with steamed samples showing the highest antioxidant activity. Cooking methods also enhanced DPPH free radical scavenging activity, with microwaved African nightshade (HBM) and steamed amaranth (ALS) exhibiting the highest activity. Nutritional analysis revealed variations in dry matter, ash, protein, crude fiber, and total sugars, with steamed vegetables (ALS, HBM, HBS) generally having higher nutrient levels. Mineral and vitamin analyses showed iron (19.08–34.87 mg/100g DW), zinc (1.06–3.92 mg/100g DW), vitamin C (93.85–231.42 mg/100g DW), and provitamin A (16.5–62.85 mg/100g DW) levels were higher in cooked vegetables compared to their raw counterparts.

Unique contribution to theory, practice and policy:

This study demonstrates that different cooking techniques impact the nutritional composition and antioxidant activities of the indigenous vegetables; African nightshade and vegetable amaranth. The findings provide valuable insights for optimizing the cooking methods of these vegetables to enhance their health benefits. Thus this study greatly contributes to providing healthy choices on the different ways in which these vegetables can be cooked.

Keywords: *Indigenous Leafy Vegetables, Cooking Methods, Total Phenolic Content, Antioxidant Activity, Nutritional Composition*

INTRODUCTION

Vegetables are important as food both from economic and nutritional viewpoints. They occupy an important place among the food crops as they provide adequate amount of vitamins, minerals and dietary fibres for humans (Bolaji *et al*., 2008; Pinki *et al*., 2016). Their nutritive significance is their richness in minerals which are very essential in the maintenance of human health. Leafy vegetables are low in calories and fat, high in protein per calories and dietary fibres. They contain water-soluble vitamins such as B and C, fat-soluble vitamins including A and D and also carbohydrates and minerals (Whitaker *et al*., 2001; and Afolabi *et al*., 2012; pinki *et al*., 2016; Ejoh *et al*.,2017, Djuikwo *et al*., 2021; Njong *et al*., 2022). Leaf concentrates made from fractioning fresh green leaves are one of the richest sources of iron. George (2003) stated that although major portion of leafy vegetables is water, they represent a variety of natural pharmacy of minerals, vitamin and phytochemicals. Phytochemicals are metabolites which includes; alkaloids, flavonoids, glycosides, gum, polysaccharides, phenols, tannins, phlobatannins, terpens and terpenoids (Okwu, 2004). Leafy green vegetables also contain a large amount of polyphenols (e.g., phenolic acids, flavonoids, and aromatic compounds), the most abundant phytochemicals in the human diet. Most of these compounds are known to act as strong antioxidants that protect human body against harmful effects of free radicals, such as heart diseases, type 2 Diabetes, tumors and aging processes (Panczenko-Kresowska., 1997, Rietjens et *al*., 2002, Wong *et al*., 2006 and Bawa., 2004; Kalmalaja *et al*., 2019). Consequently, leafy green vegetables have received substantial attention from researchers in recent years as a potential source of natural antioxidant agents.

Traditional leafy vegetables, African nightshade (*Solanum scabrum*) and vegetable amaranth (*Amaranthus hybridus*), are popularly consumed in the Sub Saharan Africa (SSA) and Cameroon in particular (Bayi *et al*., 2020; Chagomoka *et al.,* 2014). African nightshade (Ca 199mg 100 g−1, Fe 12.8mg 100 g−1) contain higher levels of Ca and Fe than raw spinach (Uusiku *et al*., 2010, Managa *et al*., 2020) while cooked African nightshade has been showed to contain crude proteins 22.8g/100g, ash content18.54g/100g, crude fibre 20.10g/100g, iron 24.75mg/100g, Zinc 7.56mg/100g, copper 26.28mg/100g (Njong *et al*., 2022; Njong *et al*., 2023). Vegetable amaranth (Fe 200.58µg/g, Zn 102.57ug/g, Ca.69g/100g, Mg 1.53g/100g, K 5.36g/100g and protein 26.78g/100g) contains higher proteins, iron, zinc and calcium than jute mallow and African eggplant (Kamga *et al*., 2013)

Consumption of vegetables may help to reduce the risks of many age-related degenerative diseases. Green leafy vegetables are sources of antioxidant components (Tang *et al*., 2004; Wong *et al*., 2006) . In addition to antioxidants, vegetables contain phenolic compounds that may, in part and provide specific protective effects against oxidative stress which can lead to coronary heart disease and cancer (Katalinic *et al*., 2006, Kaur & Kapoor, 2002) .Some authors have reported that the green leafy vegetables: African nightshade and vegetable amaranth are rich in polyphenolic

content and antioxidant activities (Kamalaja *et al*., 2019, Cheptoo *et al*., 2019; Omujal *et al*., 2012). Experimental and epidemiological evidence suggests a significant role of diet in the prevention of degenerative diseases (Harris & Ferguson, 1993). Since plant foods are often consumed in one or the other cooked forms, polyphenol and antioxidant activity intakes calculated on the basis of their content in raw foods are likely to be inaccurate (Kamalaja *et al*., 2019).

Traditionally, these vegetables are consumed in cooked form. Various cooking methods, such as boiling and steaming, are adopted to improve their palatability and sensory. Cooking methods have a significant influence on the bioavailability of food nutrients. According to Miglio *et al*.(2008), cooking induces significant changes in the chemical composition, concentration and bioavailability of nutrients and bioactive compounds in vegetables. The proportion at which nutrients in vegetables are retained after cooking relative to the amount of nutrient present in the raw vegetables before processing is referred to as nutrient retention. The retention of nutrients after processing is important to ensure the consumption of foods with high nutrient density for proper human growth, development and warding off sicknesses (Ukom et al., 2023; Sharif et al., 2017). This is important to the indigenous people's nutrition whose major source of micronutrients to enhance their physiological health depends on these vegetables as food. Therefore it was considered pertinent to study the effect of household cooking methods (boiling, steaming, microwave and stir frying), on the nutritional composition, natural antioxidant activity and phenolic content of commonly consumed African nightshade and vegetable amaranth against their raw forms.

MATERIALS AND METHODS

Materials

The African nightshade, also called garden huckleberry (HB) and the Amaranthus leaves (AL) used in the preparation of all the dishes were purchased from the same farmer at Nkwen in Mezam division of the North West Region Cameroon. The tomatoes, onions and vegetable oil (*mayor*) were purchased from Nkwen market in Mezam Division. The purchased vegetables were de-stalked and the leaves washed with running clean water to remove dirt. Exactly 150g of the sliced vegetable samples were then cooked by microwave, steaming boiling and later stir fried while the raw vegetables 150g each were stored in a freezer for biochemical analysis.

Methods of cooking vegetables

Boiling

African nightshade or garden huckleberry vegetable (HB) and amaranthus leaves (AL), (150g) were boiled in 1L of water at 98◦C in a covered stainless steel pot on a moderate flame for 10min, mimicking the traditional method of cooking and then drained.

Steaming

Garden huckleberry vegetable (HB) and Amaranthus leaves (AL), (150g) were steamed in 0.5L of boiling water in a stainless steel steamer pot (98◦C) for 10 min. The vegetables were strained

Microwave Cooking

Garden huckleberry vegetable (HB) and Amaranthus leaves (AL), (150g) were placed in a glass dish in a microwave oven (Defy) (household) working at 2,450 MHz−900W for 10min and afterwards, the vegetables were drained.

Stir Frying

10ml of vegetable oil was placed onto a preheated pan, and 2.5g chopped tomatoes and 1.5g chopped onions were stir fried for 5min after which the cooked vegetables (by boiling, steaming and microwave) was each placed in the pan and stir fried for 5min. The oil temperature was ranging from 125 to 140◦C.The samples were cooled rapidly on ice-cold water after each of the above-mentioned household cooking method to stop further post-cooking biochemical changes.

Preparation of Samples for Laboratory Analysis

All the six vegetable dishes cooked above were weighed and 200g each was oven dried at 50°C for 48hours together with the raw samples after which they were weighed again. The dried samples were then ground using an electric blender and sieved to obtain different powdered samples which were labelled **HBB, HBS, HBM, ALB, ALS, ALM** (African nightshade boiled, steamed, microwaved and Amaranth vegetable boiled, steamed, microwaved respectively) all of which were then stir fried and **HB** and **AL** which were the raw or uncooked African nightshade and amaranth leaf respectively**.** All biochemical analyses were performed at the Laboratory of Food Science and Metabolism (LabSAM) of the University of Yaounde 1 and Nkolbisson Food Technology laboratory, Yaounde, Cameroon

Determination of Moisture and Dry Matter Content

Moisture content was determined following the method described by (A.O.A.C., 1990). Five grams of powder sample was weighed (M1) using a precision balance of model « OHAUS » (sensibility 1/1000). It was then allowed for drying in an oven of model « Memmert » at a temperature of 105°C for 24 hours. The samples were weighted every 2 hours until a constant mass was obtained. At each exit from the oven, the samples were placed in a desiccator for cooling and to prevent the reabsorption of humidity from the air before weighing. After drying, the total dry residue or dry matter (DM) was weight (M3) and the dry matter and water expressed as a percentage of fresh matter were calculated

Determination of total ash content

The ash content was determined by simple incineration using the protocol described by A.O.A.C. (1980). A porcelain capsule was placed in a furnace at 550°C for about 3 hours to destroy all traces of organic matter. When it was removed from the oven, it was cooled in a dessicator for 1 hour and weighed (M1). Then 0.5 g of the powdered sample (M0) was introduced in the capsule and the combination was weighed (M2) and then introduced in a furnace and incinerated at 550°C for 48 hours. After incineration, the capsule was removed from the furnace with the use of rincers then cooled in a dessicator and weighed (M3). The ash content was expressed in g/100g of dry matter:

Determination of total proteins contents

Total proteins were obtained by determining the total Nitrogen content and multiplying this total nitrogen by the coefficient, 6.25. This total nitrogen content was determined by digestion followed by nitrogen determination by the method described by Devani *et al*., (1989).This is a spectrophotometric method for the determination of nitrogen using Kjeldahl digest (AOAC, 1980).

Determination of crude fibres

Crude fibres were determined by the method described by (A.O.A.C, 1990). A mass of approximately 0.3 g of powder sample (M1) was introduced in a 200 mL beaker and 100mL of sulphuric acid 0.26 N was added. The beaker was then placed on a heater at 100°C for 30 minutes, and then its content was filtered with the help of filter papers and rinsed 3 times with distilled water. After reintroducing the residue in the same beaker, 100 mL of NaOH 0.23 N was added and the combination was set to heat for 30 minutes, and its content filtered with the help of filter, washed 3 times with distilled water and 2 times with acetone. The beaker's content was then dried in a shattered porcelain glass at 105°C for 8 hours, later dried in a dessicator and weighed (M2). The filter paper was then placed in an oven at 550°C for 3 hours then cooled in a dessicator and weighed (M3). 3 trials were done for each sample.

Determination of Total Sugars

Total sugars was estimated by spectrophotometry using methods described by Fischer and Stein (1961) at a wavelength of 540nm

An amount of 2.5 mL of 1.5N sulphuric acid was introduced into a test tube. A weighed amount of 0.1 g of sample each was introduced into the test tube containing the sulphuric acid. The different mixtures were then put into a water bath with boiling water for 45mins. They were then cooled at room temperature. Into each test tube 5mL of 70% ethanol, 0.5 mL of ZnSO4 and 0.5mL of potassium ferrocyanide were added. The mixture was then filtered through a filter paper into a 25mL volumetric flask and the filtrate level was completed to 25mL with distilled water.

A solution of 50 mL of dinitosalicyclate (DNS) was prepared by dissolving 50µmol DNS reagent and adjusted to the 50 mL mark with distilled water. A standard glucose solution was also prepared by weighing 20mg of glucose and dissolving in distilled water. The solution was then poured into

a 25 mL standard flask and the volume adjusted to the mark with distilled water. Test tubes were labeled from 0 – 5 in duplicates where in DNS, glucose and distilled water were added in different volumes and these were used to produce a standard calibration curve.500 µL of the filtered samples was transferred into dry test tubes in triplicates, 125µL of DNS and 2mL of distilled water were added and boiled for 5mins and absorbance was taken at 15 seconds and 30 seconds interval at 540nm.

Determination of vitamin C contents

Vitamin C contents were determined using the titrimetric method proposed by (Idah *et al*., 2010). About 0.5 g of the sample was introduced into a beaker containing 10 ml of acetic acid 90 %, then mixed and filtered. The filtrate obtained was placed into a 50 ml volumetric flask and completed to 20 ml with acetic acid 90%. From the filtrate, 1ml was removed and 9ml of acetic acid was added to dilute before being titrated with a solution of DCPIP until a colour change was observed from blue to pale pink. Vitamin C contents was then calculated with the following equation

$$\textbf{Vit. C (mg)} = \textbf{T} - \textbf{B1} / \textbf{St} - \textbf{B1}$$

With Vit. C (mg/ 100ml) = Vitamin C content, T= Volume of extract, B1=Volume of blank, St= Volume of the standard, DCPIP used to titrate

Determination of total Carotenoids

The carotenoids were extracted using a hexane-acetone: 30/70 (v/v) and the absorbance read using a spectrophotometer between 430 and 450 nm. (Rodriguez-Amaya and Kimura, 2004).). One gram of the sample was measured using an electronic balance and introduced into separate conical flasks. To each conical flask, 20ml of hexane-acetone: 30/70 (v/v) was added. The mixture was heated at reflux for hour and filtered. The filtrate was transferred into a 25mL volumetric flask and made up to the mark using hexane. The solution was diluted 10 times using hexane and the optical density read at wavelength between 430 and 450nm to determine the maximal absorbance.

Expression of results

The concentration (mg/L) of carotenoid is given by the relation: C = (DO x f)/(196xm) with DO : optical density obtained for a maximal absorption; f : dilution factor and m : mass of sample. The quantity of carotenoids in the diluted solution for the spectrophotometric reading is with QC= CV. For 100g dry matter, QC' = (QC*100*100)/(100-TE).

Determination of Mineral Contents

The determination of the mineral content of the raw and cooked vegetable samples were following the method described by Benton and Vernon (1990). Into 2 tubes of 25 mL numbered 1 to 3 were introduced: 0.5 mL of aqua regia solution and 19.5 mL of strontium chloride solution and then homogenized. From these tubes were taken and introduced into other tubes respectively 0.25; 0.50

and 0.75mL of solutions. Into these same tubes, same quantities of the stock solution were later added and the mixtures were vigorously homogenized.

For the dosage of Fe and Zn, 0.5 mL of the supernatant were diluted in 19.5 mL strontium chloride solution. For each assay series, 2 tubes were prepared using the same procedure as before with the difference that the supernatant was replaced by deionized water. Samples and blanks were later passed through an Atomic Absorption Spectrophotometer. The absorbances were read at 384.2 nm and 248.3 nm respectively for zinc and Iron. The calibration curve for each standard enabled the determination of the concentration (mg/100g DM) of each mineral.

Determination of Phenolic compounds and Antioxidant capacities of the Raw and Cooked Vegetables

Determination of Phenolic Compounds

It was performed following the method described by Vinson *et al.*, (1998). To 100µL of each extract, 2000 µL of distilled water, 200 µL of Folin-Ciocalteu reagent 2 N were added. After agitation and incubation for 5 minutes, 1000 µL of sodium carbonate solution 10 % were added and stirred. The mixture was incubated at room temperature in the dark for 15mins, diluted to 1/10th and vortexed to obtain a homogenous mixture. The absorbance was read at 700 nm against the blank tube containing extracting solvent instead of extract. The phenolic compound content of each sample was determined using the calibration curve with gallic acid used as standard.

Expression of results:

The experiments were done in triplicate and phenolic compound contents were calculated by using a calibration curve (OD= f (Cp)) using the following linear regression line equation: $Y= aX + b$

Where (Y) represents optical densities (OD) of the solutions;

(X) Represents the ponderal concentrations (Cp) in phenolic compounds;

(a) is the slope of the curve;

(b) is the intercept of the Y-axis

Phenolic compound contents were expressed in mg EGA/g of the extract

Determination of 2.2-diphenyl-1-picrylhydrazyl radical (DPPH)

The evolution of the antioxidant activity for the extracts was performed according to the protocol described by Lopes-Lutz *et al.*, (2008). Into test tubes were introduced extract concentrations of 50µL. 3 mL of DPPH methanolic solution 0.004% (w/v) was added. After agitation, the tubes was kept in the dark at room temperature for 30 minutes and the absorbance was read at 517 nm. DPPH in the absence of samples was used as negative control and hydroethanolic solvents (30/70) as the blank. Gallic acid was the standard used for this investigation to compare antiradical efficiency.

Expression of results:

The results were expressed as percentage inhibition of free radicals using the following formula: The inhibitory concentration 50 (IC50) is the antioxidant concentration capable of trapping 50% of free radicals. It is obtained from the curve representing the percentage trapped as a function of the extract concentration using a non-linear regression.

Determination of Ferric Reducing Antioxidant Power Assay (FRAP)

This was done following the method described by Benzie and Strain (1996). To 0.1 mL of extract, 3 mL of freshly prepared FRAP reagent was added. After 5 minutes of incubation, the absorbance of the reactant medium was read at 593 nm against a blank.

Expression of Results

Ferrous ions contents were determined from the calibration curve using the regression equation of this plot. The reducing power was expressed in mg of Fe (II)/100g

Data Analyses

Chemical analyses of the samples were carried out in triplicate. Data on the nutritional composition and antioxidant properties of the vegetable dishes were evaluated using a one-way analysis of variance using the statistical package SPSS 20.0. Differences between samples were determined according to the Fischer test and considered to be significant when $P < 0.05$

RESULTS AND DISCUSSIONS

Nutritional Composition of the Vegetable Dishes

Table 1 : Proximate composition of vegetable Dishes

Samples	Dry matter (%)	Moisture content (%)	Proteins (%)	Total sugars(%)
HBB	96.68±2.73^{c}	3.33±0.07^{a}	13.68±0.83^{b}	9.36±0.91^{a}
HBM	95.55±1.11^{b}	4.46±0.2^{c}	29.91±1.02^{f}	15.19±1.7^{d}
HBS	96.27± 1.71^{bc}	3.73± 0.17^{ab}	16.64± 0.41^{c}	17.78± 1.6^{e}
HB	91.76 ±2.11^{a}	8.24±0.9^{d}	12.46±0.63^{b}	10.34±1.38^{ab}
ALB	96.68 ±2.69^{c}	4.21±0.43^{c}	13.46±0.63^{b}	14.34±1.38^{d}
ALM	96.67± 1.97^{c}	3.31±0.26^{a}	18.47± 0.42^{d}	10.97± 0.89^{ab}
ALS	96.32±1.57^{c}	3.04±0.29^{a}	20.34± 0.28^{e}	12.93± 1.61^{c}
AL	90.45 ±1.88^{a}	9.55±0.7^{e}	10.46±0.63^{a}	9.34±1.38^{a}

Values are expressed as mean ± standard deviation (n=3). Values marked with different letters in each column are significantly different (p<0.05).HBB=Huckleberry boiled, HBM=huckleberry microwaved, HBS= huckleberry steamed HB=raw huckleberry, control, ALB= Amaranthus leaf boiled, ALM=Amaranthus leaf microwaved, ALS= Amaranthus leaf steamed, AL=raw Amaranthus leaf, control

Dry matter content of the vegetable dishes

The table 1 presents the proximate composition of different cooked vegetables samples, based on moisture content, dry matter, proteins, and total sugars. The dry matter contents of the vegetable dishes ranged from 90.45g/100g to 96.68g/100g (table 1).There were no significant differences ($p>0.05$) in the dry matter contents of ALB, ALM, ALS and HBB; HB and AL, respectively while the rest of the dishes (HBM and HBS) were significantly different.The nutrients in foods reside in the dry matter portion, which is the material remaining after removal of water (Kibiwot, 2011). The high dry matter in the vegetable dishes reflects the low moisture content of the dishes which render them less perishable. The dry matter values (90.45g/100g to 96.68g/100g) obtained for the the 6 vegetable dishes in this study are not similar with values (87.2g/100g) obtained by Kibiwot, (2011) but are similar to values (90.130g 100g to 95.626g/100g) obtained by Njong *et al*.,(2022).

Crude Protein Content of the vegetable Dishes

The crude protein contents of the dishes ranged from 10.46g/100g (AL) to 29.91g/100g (HBM). There were no significant differences ($p>0.05$) in crude protein contents of dishes HB, HBB and ALB while the rest of the dishes were significantly different (table 4.1). The protein values obtained in this study are twice more than values obtained by Djuikwo *et al*., (2021) ; Ponka *et al*., (2005). Given these high values, the population is encouraged to consumes these dishes as food sources of protein, as they will meet the RDA for protein.

Total Sugar Content of the vegetable dishes

The total sugar contents of the dishes ranged from 9.34g/100gDW (AL) to 17.78g/100gDW (HBS). There were no significant differences ($p>0.05$) in total sugar contents of dishes AL and HBB ; HB and ALM ; HBM and ALB respectively while the rest of the dishes were significantly different (table 1).The values of total sugar obtained in this study are twice more that those found by Njong *et al.*, 2022, Djuikwo *et al*., 2021. HBS dish which is huckleberry leaves steamed and stir fried recorded the highest total sugar content (17.78g/100gDW). The RDA values of carbohydrates for children, adults, pregnant and lactating mothers are 130g, 130g, 175g and 210g, respectively (Sareen *et al*., 2009). Most leafy vegetable are generally not good sources of carbohydrate even though carbohydrate are pivotal nutrients required for adequate diet (Emebu and Anyika, 2011), The 6 vegetable dishes studied here are moderate sources of carbohydrates as most other leafy vegetables.

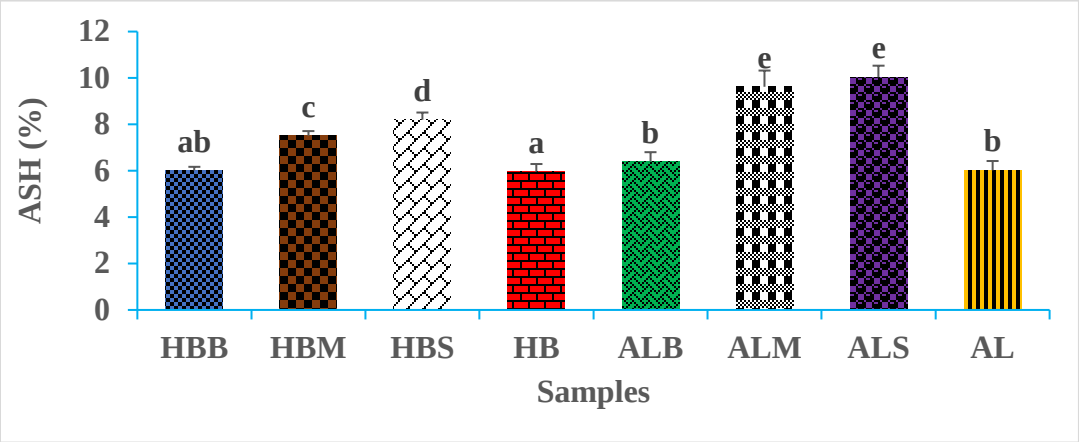


Fig 1 Total ash composition of the vegetable dishes

Values are expressed as mean ± standard deviation (n=3). Values marked with different letters are significantly different (p<0.05).HBB=Huckleberry boiled, HBM=huckleberry microwaved, HBS= huckleberry steamed HB=raw huckleberry, control, ALB= Amaranthus leaf boiled, ALM=Amaranthus leaf microwaved, ALS= Amaranthus leaf steamed, AL=raw Amaranthus leaf, control

The ash contents of the dishes ranged from 5.96g/100g (HB) to 10.03g/100g (ALS). There were no significant differences ($p>0.05$) in the ash contents of dishes ALM and ALS ; ALB and AL respectively while the rest of the dishes were significantly different (fig.1).The lowest ash content (5.96g/100g) was recorded by HB, the raw huckleberry which is the control and the highest ash content (10.03g/100g) was recorded by dish ALS. Ash content is an index of minerals in food materials (Ngobidi *et al*., 2016). Generally all 6 dishes under study had a high ash content when compared to the ash content for vegetables and vegetable products (FAO, 1968). These values were also found to be lower than values obtained for raw African nightshade (Ngobidi *et al*., 2016 and Kibiwot, 2011) ; cooked African nightshade (Kibiwot, 2011 ; Ponka *et al*., 2005 Njong *et al*., 2023) ; *Amaranthus* species (Singhal and Kulkarni 1987)

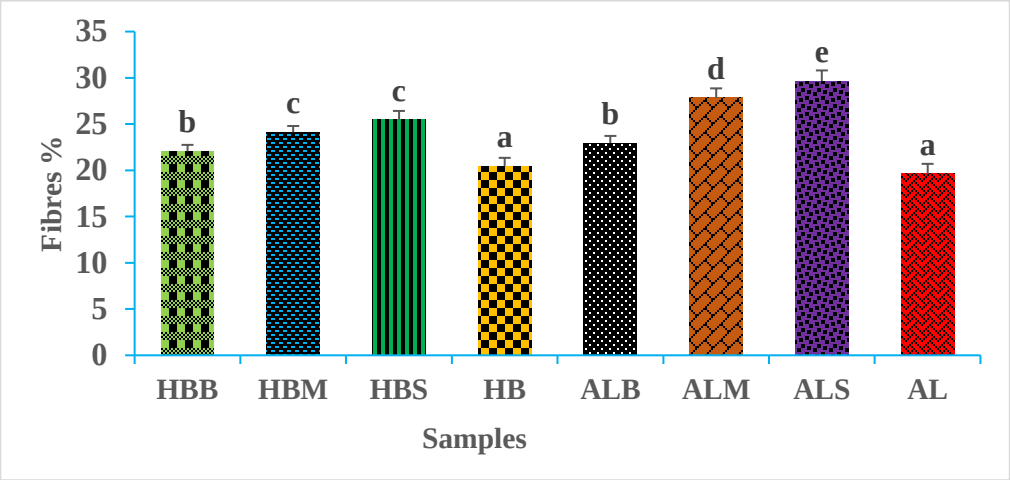


Fig 2: Crude Fibre content of the vegetable dishes

Values are expressed as mean ± standard deviation (n=3). Values marked with different letters are significantly different (p<0.05).HBB=Huckleberry boiled, HBM=huckleberry microwaved, HBS= huckleberry steamed HB=raw huckleberry, control, ALB= Amaranthus leaf boiled, ALM=Amaranthus leaf microwaved, ALS= Amaranthus leaf steamed, AL=raw Amaranthus leaf, control

The crude fibre contents of the dishes ranged from 18.60g/100g (AL) to 29.64g/100g ALS). There were no significant differences (p>0.05) in the crude fibre contents of dishes ALand HB ; ALB and HBB ; HBM and HBS respectively while the rest of the dishes were significantly different (fig 2). The raw vegetables (HB and AL) recorded crude fibre values much lower than their cooked counterparts. Thus from this study it shows that cooking significantly increased dietary fibre content as values obtained for the 6 dishes were all above the range in the raw vegetable. The crude fibre contents of all the dishes under study were hihger than those obtained by Ponka *et al*.,(2005) for *zom non sale* (13.89g/100g). The recommended dietary allowance (RDA) values of dietary fibre for children, adults, pregnant and lactating mothers are 19-25, 21-38, 28 and 29g, respectively (Akubugwo *et al.*, 2007) therefore most of the vegetable dishes can significantly contribute to the the RDA for dietary fibres.

Table 2 : Iron and Zinc content of the vegetable Dishes

Samples	Zn (mg/100gMS)	Iron(mg/100gMS)
HBB	1.41±0.08^{b}	26.53±0.81^{d}
HBM	1.90±0.04^{c}	21.27±1.22^{b}
HBS	1.22±0.04^{a}	32.32±1.77^{e}
HB	1.06±0.07^{a}	19.08±1.11^{a}
ALB	3.46±0.08^{f}	26.08±1.11^{d}
ALM	3.23±0.03^{e}	24.08±1.25^{c}
ALS	3.92±0.1^{g}	34.87±1.28^{f}
AL	2.87±0.1^{d}	22.75±1.02^{b}

MS = dry matter ; Values are expressed as mean ± standard deviation (n=3). Values marked with different letters in the same column are significantly different (p<0.05). HBB=Huckleberry boiled, HBM=huckleberry microwaved, HBS= huckleberry steamed HB=raw huckleberry, control, ALB= Amaranthus leaf boiled, ALM=Amaranthus leaf microwaved, ALS= Amaranthus leaf steamed, AL=raw Amaranthus leaf, control

Levels of Iron in the vegetable dishes

The Iron levels of the dishes ranged from 19.08mg/100g DW to 34.87mg/100g DW (table 2).There were no significant differences (p>0.05) in the iron contents of of dishes HBB and ALB (table 2) while the rest were significantly different. The raw vegtables had lower iron contents when compared to their cooked counterparts. Thus cooking significantly improves the iron content of the vegetables. The recommended daily intake (RDI) for iron content is between10 to 8 mg (NIN, 1992; Abukutsa-Onyango, 2003); thus the vegetables dishes under study could significantly contribute to the recommended daily intake of iron.The mean levels of iron in the 6 vegetable dishes in this study slightly differ to the levels found in a study by Njong *et al*., (2022) ; Djuikwo *et al*., (2021) ; Habwe *et al,* (2009) ;Abukutsa-Onyango (2010) and Wakhanu (2014).

Levels of Zinc in the vegetable dishes

The zinc content of the dishes ranged from 1.06mg/100g DW to 3.92mg/100g DW (Table 2).There were no significant differences (p>0.05) in the zinc contents of HBS and HB while the rest of the dishes were significantly different. The trend shows that there has been an increase in the Zinc contents of the dishes compared to the raw state. This is because cooking increases the

bioavaliabilty of nutrients (Djuikwo *et al*., 2015).The values of zinc in the 6 vegetable dishes in this study agree closely with the values (3.73 – 4.24mg/100g) obtained by Wakhanu, (2014) and Tumet, (2013) respectively.The RDA for zinc is 11 mg/100g (WHO, 1999) thus the consumption of these vegetable dishes can moderately contribute to the RDA for zinc.

Vitamin content of the Vegetable Dishes

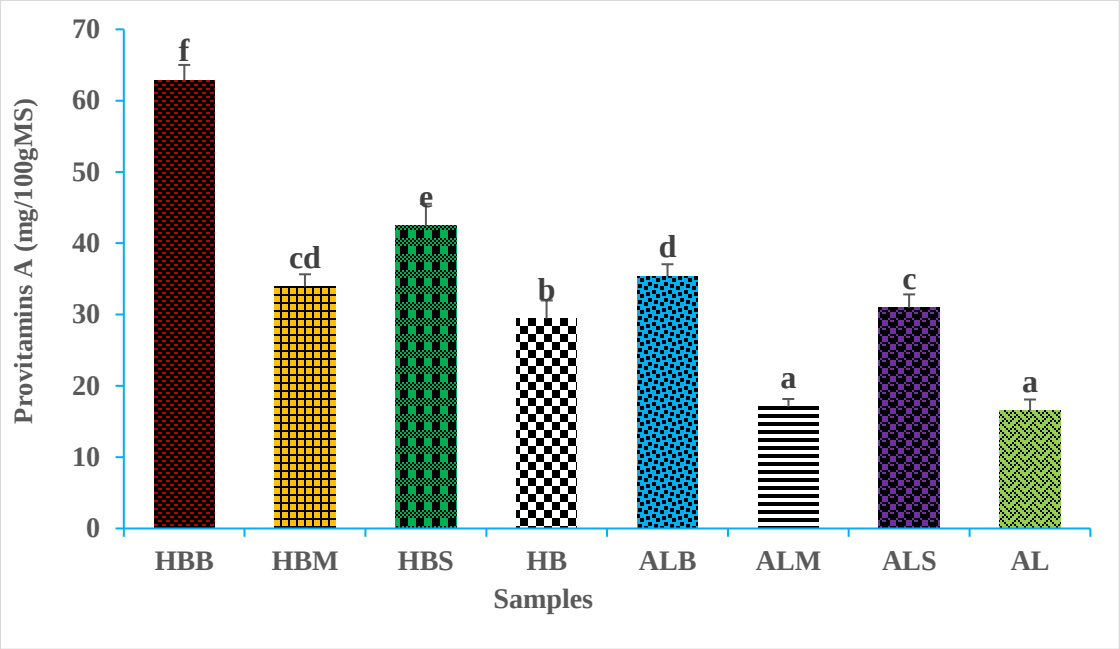
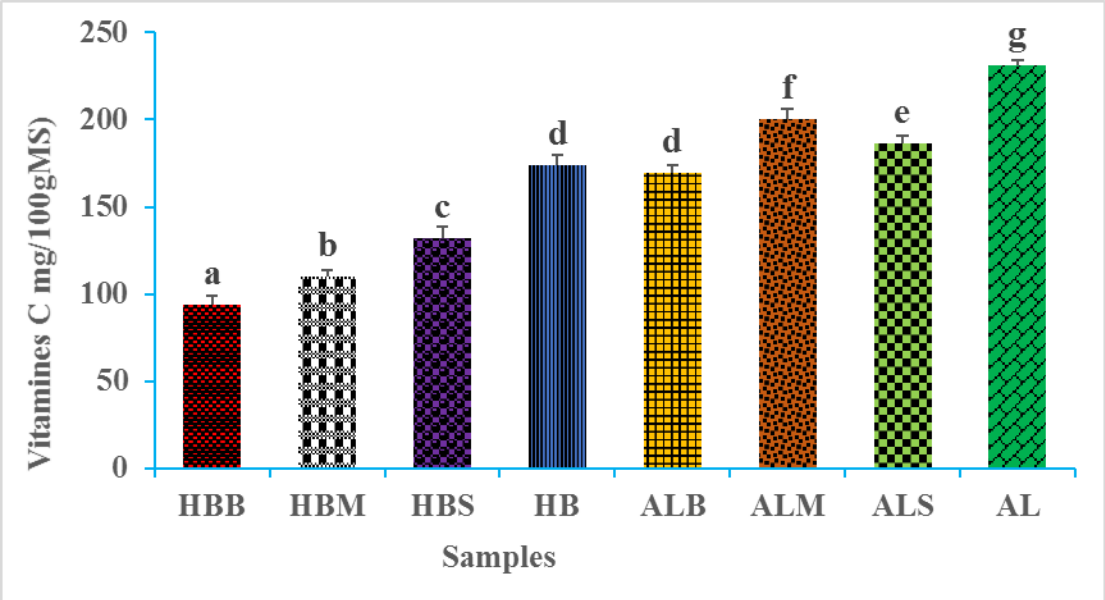


Fig 3: Provitamins A estimation of the vegetable dishes

Values marked with different letters are significantly different (p<0.05). HBB=Huckleberry boiled, HBM=huckleberry microwaved, HBS= huckleberry steamed HB=raw huckleberry, control, ALB= Amaranthus leaf boiled, ALM=Amaranthus leaf microwaved, ALS= Amaranthus leaf steamed, AL=raw Amaranthus leaf, control

Levels of Provitamin A of the vegetable Dishes

The provitamin A levels of the dishes ranged from 16.5mg/100g DW (AL) to 62.85mg/100g DW (HBB) (fig. 3).There were no significant differences (p>0.05) in the provitamin A contents of dishes ALM and AL. AL recorded the least provitamin A value (16.53mg/100g). While HBB recorded the highest provitamin A value (62.85mg/100g).This could be due to the cooking method boiling and the shorter cooking time 10min (Ejoh *et al.*, 2017).



Values marked with different letters are significantly different (p<0.05). *HBB=Huckleberry boiled, HBM=huckleberry microwaved, HBS= huckleberry steamed HB=raw huckleberry, control, ALB= Amaranthus leaf boiled, ALM=Amaranthus leaf microwaved, ALS= Amaranthus leaf steamed, AL=raw Amaranthus leaf, control*

Fig. 4: Vitamin C content of the vegetable dishes

Levels of Vitamin C of the vegetable dishes

The vitamin C levels of the dishes ranged from 93.85mg/100g DW to 231.42mg/100g DW (fig 4).There were no significant differences (p>0.05) in the vitamin C contents of HB and ALB. The dish HBB recorded the least vitamin C value (93.85mg/100g).This can be attributed to the cooking method boiling as vitamin C a water soluble vitamin is leached out. Generally there was a decrease in the vitamin C content of the cooked vegetables when compared to their raw counterparts. However the vitamin C contents of all the dishes were all higher compared to values obtained by Wakhanu (2014) (0.18 mg/100g to 5.37 mg/100g) and Habwe *et al*., (2010) (5.7mg/g to 6.9mg/g), Leung *et al* .,(1968) (24mg/100g) , K'Opondo *et al* .,(2005) (20mg/100g).The RDA of vitamin C is 50mg/100g (WHO, 1999). The reported mean levels in the all the 6 vegetable dishes were by far higher than the RDA Hence the consumption of these vegetable dishes can contribute significantly to the RDA of vitamin C.

Table 3 : Total phenolic content and antioxidant properties of the vegetable dishes

Samples	TPC (mgEAG/100gMS)	FRAP(gFeII/EAG)	DPPH/ IC50 µg/g
HBB	900.03±7.64^{e}	161.09±3.59^{d}	0.58±0.03^{bc}
HBM	1184.08±8.61^{g}	137.19±2.22^{a}	0.49±0.01^{a}
HBS	1075.79±5.73^{f}	188.38±3.94^{f}	0.54± 0.02^{ab}
HB	887.83±12.32^{e}	154.76±2.09^{c}	0.78±0.03^{d}
ALB	665.61±11.51^{c}	154.29±1.87^{c}	0.68±0.03^{d}
ALM	443.95±13.42^{b}	167.43±2.88^{d}	0.79± 0.07^{e}
ALS	795.54±9.43^{d}	178.90±2.57^{e}	0.61± 0.02^{cd}
AL	256.64±8.47^{a}	146.43±2.57^{b}	0.84± 0.02^{f}

IC50 µg/g of Gallic acid :(0.11±0.005^{a}) *; MS = dry matter ; Values are expressed as mean ± standard deviation (n=3). Values marked with different letters are significantly different (p<0.05).*

Total Phenolic content of the vegetable dishes

Leafy vegetables proved to be the most abundant in phenolic content amongst all vegetables. TPC of leafy vegetables ranged from 256.64 to 887.83mg GAE/100g in Control extracts (raw form) and from 443.95 to 1184.08mg GAE/100g in the cooked vegetables. The TPC of the leafy vegetables were enhanced after cooking. The TPC was increased (HBM>HBS>HBB) in the cooked garden huckleberry vegetable compared to the raw form whereas for amaranth vegetable (ALS>ALB>ALM) also increased compared to its raw form. Generally the TPC content of the vegetables were enhanced upon cooking especially by the cooking method steaming. Previous studies have found that cooking gave rise to an increase in phenolics in green beans, pepper and broccoli (Azizah *et al.*, 2009). The authors suggested that this is probably due to the increased level of free flavonols in the vegetables as affected by the heat treatment The total phenolic content of leafy vegetables were significantly different at p<0.05. Details are presented in table 3. Values of TPC obtained in this study are twice higher than those obtained by Kamalaja *et al.*, (2019) for amaranth, mint, Coriander and Gogu for open cooking and pressure cooking

Antioxidant properties of uncooked and cooked leafy vegetables

The antioxidant property (FRAP activity) of African nightshade (HB) and Amaranth leaves (AL) after different types of cooking methods is shown on table 3. All tested household cooking methods showed higher antioxidant activity than the raw vegetables. Steaming demonstrated a significant ($p< 0.05$) increase in FRAP activity, followed by microwaving and then boiling for amaranth vegetable, which could be due to polymerization of phenols during cooking increasing the antioxidant activity. Polymerization of procyanidins was reported to increase the antioxidant activity (Ferracane *et al*., 2008, managa *et al*., 2020). Similarly, steamed African nigntshade showed the highest antioxidant activity (FRAP) compared with the microwaved and boiled samples. This present pattern concurs with the findings of managa *et al.,* (2020) who demonstrated that steaming significantly increased the FRAP activity of Chinese cabbage and Nightshade vegetables

The antioxidant property (DPPH radical scavenging activity) of African nightshade (HB) and Amaranth leaves (AL) after different types of cooking methods is shown on table 2.It is the IC_{50} (half maximal inhibitory concentration) that was determined for all the vegetable samples. It is inversely proportional to the free radical in DPPH free radical scavenging method. All tested household cooking methods showed higher antioxidant activity (DPPH activity IC_{50}) than the raw vegetables. The highest DPPH free radical scavenging activity was shown by HBM which was African night shade microwaved and then stir fried. This was followed by the steaming and boiling methods. While for Amaranth leaves ALS (amaranth leaves steamed) showed the highest DPPH free radical scavenging activity

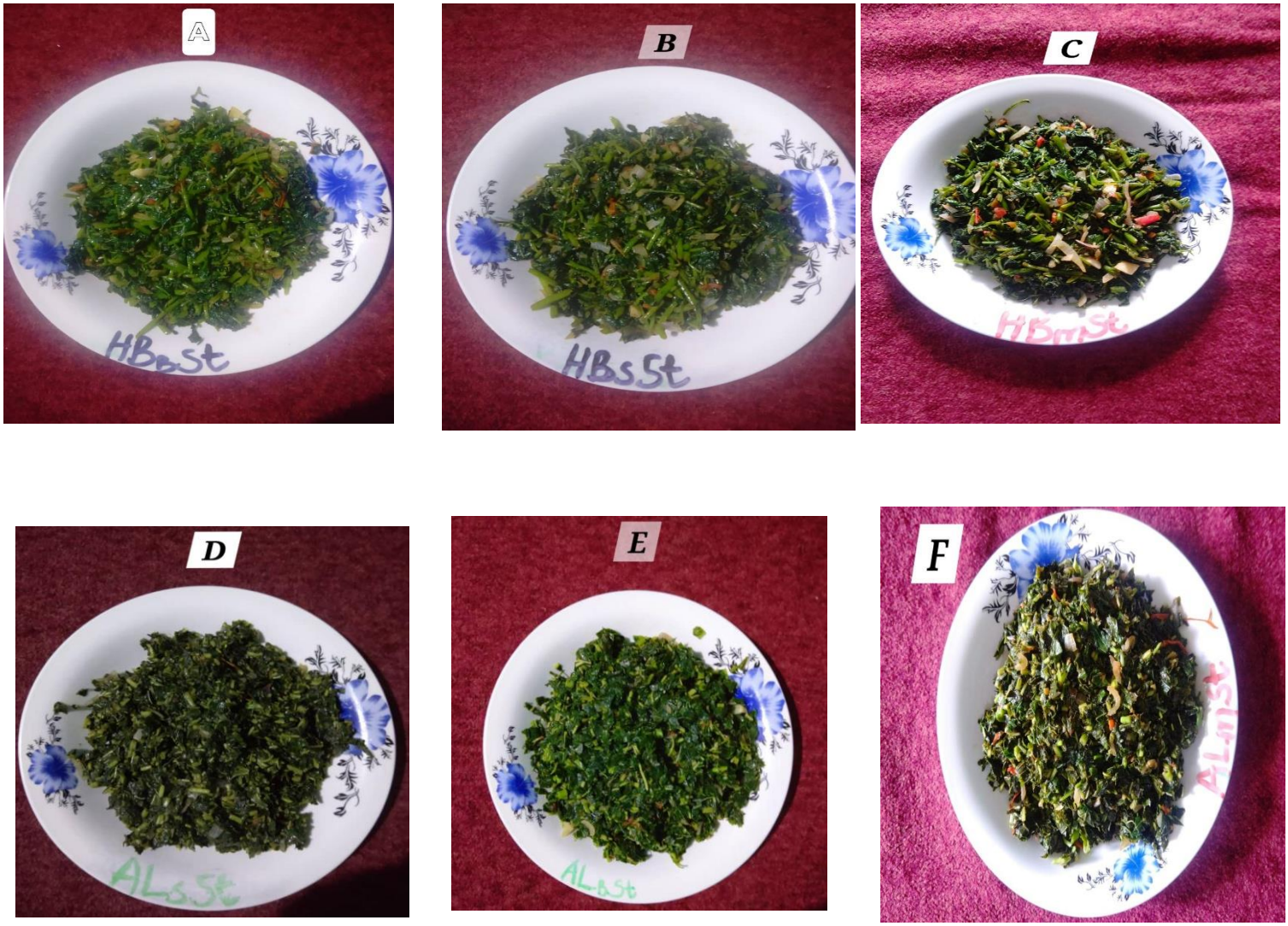


Fig.5: vegetable dishes: A;African nightshade boiled then stir fried;B;African nightshade steamed then stir fried; C;African nightshade microwaved then stir fried; D;Amaranthus steamed then stir fried; E;Amaranthus boiled then stir fried; F;Amaranthus microwaved then stir fried

CONCLUSION

This study was carried out to evaluate the effectiveness of different cooking methods (boiling, steaming and Microwaving methods) and their effects on total phenolic content, antioxidant activities and nutrient retention in leafy vegetables amaranth and African nightshade. The micronutrient profile established for the six vegetable dishes shows that they are rich sources of these micronutrients especially Provitamin A, Iron, vitamin C and moderate sources of zinc. Apparently amaranthus leafy vegetables cooked by boiling, steam and microwaving (ALB, ALM, and ALS) are superior sources of vitamin C. Most of vegetable dishes were extremely rich in Iron especially amaranths and garden huckleberry cooked by steaming (ALS and HBS) respectively.

The macronutrient profile established for the six vegetable dishes shows that they are rich sources of dietary fibres especially amaranthus leaf vegetable steamed (ALS), amaranths leaf vegetable microwaved (ALM) and garden huckleberry vegetable steamed(HBS), moderate sources of proteins and carbohydrates. Thus starchy staples like cassava, plantains, cocoyam and corn could be used as accompaniment for these vegetable dishes to improve energy intake. Interestingly, all cooking methods exhibited significantly higher antioxidant capacity when compared to uncooked as well as the total phenolic contents.

RECOMMENDATIONS

1) Steam cooking retained more nutrients and had stronger antioxidant activity than microwaving and boiling, thus the most recommended method of cooking African nightshade and amaranth vegetable is by steaming.
2) Overall, these vegetables possess high concentrations of functional constituents that can make them be used to boost human nutrition and benefit the health of consumers.
3) These vegetable dishes could serve as potential sources of antioxidants for people with non-communicable diseases like Diabetes type 2 and cardiovascular diseases

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CONFLICT OF INTEREST

The authors have no competing interest with regards to the study

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