

Full Length Research Paper

Effect of processing methods on the chemical composition and microbiological quality of vegetable drink extract of african bush mango (*Irvingia gabonensis*)

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The effect of processing methods on the chemical composition, proximate, mineral, vitamin and microbiological quality of vegetable drink extract of *Irvingia gabonensis* was studied. The processing methods included drying (shade and solar drying), blanching (at 0, 2, 4 and 6 min) as well as blanching and drying of the leaves. Aqueous extracts were obtained from the leaves and the analysis carried out using standard methods. The result showed that whereas some parameters analyzed varied with processing, others remained unaffected. The moisture, protein and fat content did not vary significantly ($p < 0.05$) with treatments while shade drying increased ash content significantly. Shade drying also increased the phytochemicals from 17.50 to 72.50% for total phenol; 4.53 to 6.72% for flavonoids and 2.98 to 3.86% for alkaloid. It also reduced steroids and saponin significantly ($p < 0.05$). Phytate content was non-significantly ($p < 0.05$) reduced by shade and solar drying whereas the other processing methods increased it to the range of 5.38 to 14.33 mg/100 g. Six minutes blanching reduced oxalate from 8.15 to 7.25 mg/100 g and tannin content from 0.023 to 0.019 mg/100 g. Cyanide content of 0.03 mg/100 g was increased by all the processing methods though minimally by blanching and solar drying. Carotenoid content of 164.56 IU was reduced significantly ($p < 0.05$) to the ranges of 92.83 to 151.90 IU for blanched and 16.88 to 59.07 IU for dried vegetable drink extracts. Vitamin A content of 987.34 IU was significantly ($p > 0.05$) reduced by all the processing methods to the range of 101.27 to 632.91 IU. Vitamin C, on the other hand, was increased significantly ($p < 0.05$) by all the drying methods. The rest of the vitamins and also minerals were inconsistent with the processing methods. Total plate count was negligible in blanched drink extracts while shade drying gave the highest count (1.30×10^3 cfu/g). Total coliforms were reduced in all the drinks from the processed leaves. The mould count in the blanched drink extract remained relatively low, but increased mould counts occurred in drink extract from shade dried leaves.

Key words: Blanching, *Irvingia gabonensis* leaf, shade drying, solar drying, vegetable drink extract.

INTRODUCTION

The key fruits and vegetables in human nutrition both in the developed and developing countries of the world are

the yellow corn, spinach, green leafy vegetables, fruits, tomato, watermelon, pink-fleshed guava, red-fleshed

papaya, red pepper, mango, orange, carrot, melon, yellow and orange-fleshed sweet potato, nuts, tea, wine, flaxseed, sesame seed, grapes, peanuts, cereals and pulses. Evidences of the benefits to human-health associated with their consumption have caused an increase in the demand for fresh-like fruits and vegetables (Oms-Oliu et al., 2012). Hence, the need for the identification and exploitation of other novel plants to fulfill the growing need of plant-based chemicals. The emphasis therefore shifted to the underutilized plant foods which as a result of lack of attention from research and development has meant that their potential value to human well-being and income is underexploited (IPGRI, 2002). While such crops continue to be maintained by sociocultural preferences and the ways they are used, they remain inadequately documented and neglected by formal research and conservation (IPGRI, 2002). *Irvingia gabonensis* (Family: Irvingiaceae) commonly known as the African bush mango, Dika nut, bush mango or wild mango, and *Manguier sauvage* in French is one of such crops, with the leaves only known to be used as food for livestock by farmers (Ayuk et al., 1999).

African bush mango (*I. gabonensis*) belongs to the Irvingiaceae plant family (Lamorde et al., 2010). It is a wild forest tree 15 to 40 m with a bole slightly buttressed, possessing dark green foliage and yellow flowers (Kueté et al., 2007). The ripe fruit is green while the edible mesocarp is soft, juicy, and bright orange. The fruits are sometimes referred to as 'Mangoes' (hence the synonym of African Bush Mango) although they are unrelated, since the true Mango fruits are borne from the plant *Mangifera indica* of the plant family Anacardiaceae (Bally, 2006). The pulp of this fruit is eaten fresh and can also be used for the preparation of juice, jelly and jam as well for a good quality wine (Akubor, 1996). The mango-like fruits of bush mango are especially valued for their dietary-fiber, fat- and protein-rich seeds (Jianghao and Pei, 2012). The bark of the *I. gabonensis* tree (rather than the seeds, which are commonly used as fibrous supplements) appears to be traditionally used by the Mende tribe of Africa for pain relief (Okolo et al., 1995). Studies have shown that the seeds of *I. gabonensis* could be effectively used as an ingredient in health and functional food to ameliorate certain disease states such as diabetes (Dzeufiet, 2009). And the leaves of plants have been shown to be richer in chemical composition than the fruit pulps and seeds (Nwofia et al., 2012). Bush mango leaf/root extracts have documentary inhibitory activity against several bacteria and fungi. Aqueous leaf extracts significantly protected mice against diarrhoea induced experimentally by castor oil in terms of severity and onset and the population of animals with diarrhoea (Abdulrahman et al., 2004). As reported by Kueté et al.

(2007), the aqueous maceration of the leaves is used as anti-poison. And when taken in combination with palm oil, the leaves are also used to stop hemorrhages for pregnant women in Cameroon. Thus the focus of this work was to determine the effect of processing methods on the chemical, nutrient, vitamin, mineral content and microbiological quality of vegetable drink extract of African bush mango.

Research on the effect of processing methods on the chemical composition and microbiological quality of the vegetable drink extract of *I. gabonensis* would add to the existing knowledge of the processing methods to adopt to meet specific and desired needs. Also, the knowledge of the microbiological quality would guide in the selection of process controls to apply to vegetable drink extracts prior to consumption.

The general objective of this research was to produce and evaluate the effect of processing methods on the chemical composition and microbiological quality of vegetable drink extract from leaves of African bush mango (*I. gabonensis*).

MATERIALS AND METHODS

Fresh leaves of *Irvingia gabonensis* were plucked from a single plant in a farm in Alor-Uno community in Nsukka. The plant leaves were authenticated by a botanist of the Herbarium section in the Department of Plant Science and Biotechnology, University of Nigeria, Nsukka, Enugu State. All the reagents/chemicals used for analysis were of analytical grade.

Sample preparation and extraction of vegetable drink from the leaves of *I. gabonensis*

The freshly plucked leaves were divided into five groups of 100 g each for the various processing methods. The samples were processed, and the vegetable drink extracted as outlined in the flow diagram (Figure 1). The groups were processed follows:

Group A (Vegetable drink extract from fresh leaves as control designated as sample 4): One hundred grams of the fresh leaves were wet milled with 200 ml of clean drinking water using a household blender (Kenwood model, China) and thereafter filtered using a filter cloth. A transparent plastic container was used to store the drink extract in the refrigerator at the temperature of 4°C for further analysis.

Group B (Vegetable drink extract from shade dried leaves designated as sample 5): One hundred grams of the freshly plucked leaves were air dried at room temperature of an average of 28°C for 7 days (shade drying) followed by milling using a hammer mill. The obtained powder used for extraction of drink was packaged in air-tight plastic container to avoid rehydration and stored in a cool, dry and clean area away from direct light. The extract was obtained by reconstituting leaf powder (100 g) with 200 ml of clean drinking water and filtered using a filter cloth.

Group C (vegetable drink extract from solar dried leaves designated

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Figure 1. Flow diagram for the preparation of vegetable drink extract from from raw (control treatment), raw/dried, blanched (2, 4 and 6 min), blanched/shade-dried (2, 4 and 6 min), leaves of *Irvingia gabonensis*.

as sample 6): One hundred grams of the freshly plucked leaves were solar dried at 35°C for 18 h followed by milling using a hammer mill. The resulting powder for vegetable drink extract formation was packaged in air-tight plastic container to avoid rehydration and stored in a cool, dry and clean area away from direct light. The extract was obtained by reconstituting leaf powder (100 g) with 200 ml of clean drinking water and filtered using a filter cloth.

Group D (Vegetable drink extract from blanched leaves designated as sample 1 to 3): Four portions of leaves weighing 100 g each were separately sliced and steam blanched at 100°C (boiling water) for 0 (same as control), 2, 4 and 6 min (designated as samples 3, 2 and 1) respectively. Blanching for varying times helped to determine the blanching time that ensured maximum nutrient retention. The blanched leaves were wet milled with 200 ml of water and thereafter filtered using a filter cloth. Transparent plastic containers were used to store the drink extracts in the

refrigerator at the temperature of 4°C for further analysis.

Group E (vegetable drink extract from blanched and shade dried leaves designated as samples 7 to 9): four portions of leaves weighing 100 g each were separately sliced and steam blanched at 100°C (boiling water) for 2, 4 and 6 min (designated as samples 9, 8 and 7) respectively (while the unblanched sample served as the control). The blanched leaves were shade dried followed by milling using a hammer mill. The obtained powders used for vegetable drink extract formation were packaged in air-tight plastic containers to avoid rehydration and stored in a cool, dry and clean area away from direct light. The extract was obtained by reconstituting powder (100 g) with 200 ml of clean drinking water and filtered using a filter cloth.

Analysis of the vegetable drink extract

The analyses were carried out using appropriate analytical methods.

Proximate analysis

Moisture, protein, crude fat, ash and carbohydrate contents were determined according to the standard methods of AOAC (2010).

Quantitative evaluation of phytochemicals

Determination of total phenol content

The total phenol content of the vegetable drink extract was determined by the spectrophotometric method (Obadori and Ochuko, 2001). Two grammes of the test sample was weighed into a flask and defatted with petroleum ether. The residue was allowed to stand for five minutes to air dry and thereafter boiled with 50 ml of diethyl ether for 15 min to extract the phenol. Five milliliter of the aliquots of the boiled sample was transferred into test tube and 2 ml of NH₄OH solution and 5 ml of amyl alcohol were added and allowed to stand for 30 min for colour development. The blank and the standard were prepared. The total phenol was calculated using the formula:

$$\text{Phenol (mg/100 g)} = \frac{\text{Absorbance of sample} \times \text{Concentration of standard}}{\text{Absorbance of standard}} \times \frac{100}{1}$$

Determination of flavonoid

The flavonoid was determined using the method of Harborne (1973). Ten grammes of the sample was weighed and extracted repeatedly with 100 ml of 80% aqueous methanol at room temperature. The solution was filtered using Whatman No. 42 (125 mm) filter paper and the filtrate transferred into a weighed crucible. The filtrate was evaporated into dryness and the crucible reweighed to a constant weight. The percentage flavonoid was calculated using the formula:

$$\text{Flavonoid (\%)} = \frac{\text{Weight of flavonoid}}{\text{Total weight used}} \times \frac{100}{1}$$

Determination of alkaloid content

The gravimetric method of Harbone (1973) was used. Five grammes of the sample was weighed out and dispersed into 50 ml of 10% acetic acid solution in ethanol. The mixture was shaken very well and then allowed to stand for 4 h before filtering. The solution was concentrated and the alkaloids precipitated with concentrated NH₄OH by adding it drop wise. This was allowed to cool and the precipitate filtered with a weighed filter paper. The precipitate in filter paper was dried in the oven at 60°C and reweighed to obtain the weight of the filter paper and the alkaloid.

The percentage alkaloid was calculated using the formula:

$$\text{(Alkaloid (\%))} = \frac{(\text{weight of filter paper} + \text{alkaloid}) - (\text{weight of filter paper})}{\text{weight of sample}} \times \frac{100}{1}$$

Determination of tannins

The Folin-Dennis colorimetric method as described by AOAC (2010) was used to determine tannin content. One gram of the test sample was weighed out and 10.0 ml distilled water added. This was shaken at 5 min intervals for 30 min and then centrifuged to get the extract. Two and a half milliliter of the supernatant was transferred into a test-tube. Also, 2.5 ml of standard tannic acid

solution was added into a 50 ml flask and 1.0 ml Folin-Denis reagent added into the flask, followed by 2.5 ml of saturated Na₂CO₃ solution. The solution was made up to the mark and the absorbance read after 90 min incubation at room temperature. Percentage tannin was calculated as shown:

$$\text{Tannin (\%)} = \frac{A_n}{A_s} \times C \times \frac{100}{W} \times \frac{V_f}{V_a}$$

Where, A_n = absorbance of test sample; A_s = absorbance of standard solution; C = concentration of standard solution; W = weight of sample used; V_f = total volume of extract; V_a = volume of extract analyzed.

Determination of saponin content

The method of Obadori and Ochuko (2001) was used to determine the saponin content of the sample. Twenty grammes of the sample was weighed into a conical flask and 100 ml of 20% aqueous ethanol added. The sample was heated over hot water bath for 4 h with continuous stirring at about 55°C. This was filtered and the residue re-extracted with another 200 ml of 20% ethanol. The extract was concentrated to 40 ml in the water bath at 90°C and 20 ml of diethyl ether added and shaken vigorously to separate. The aqueous layer was recovered and 60 ml of n-butanol added and then washed twice with 10 ml 5% aqueous sodium chloride. The extract was evaporated in the oven and the weight of saponin quantified in percentage using the formula:

$$\text{Saponin (\%)} = \frac{\text{weight of dry extract}}{\text{weight of sample}} \times \frac{100}{1}$$

Determination of steroid content

This was carried out as described by Subhadhirasakul and Pechpongs (2005). Two grammes of the sample was weighed out and 20 ml of chloroform added. This was allowed to stay for 2 h and filtered. The chloroform layer was the steroid and it was dried in the oven and the percentage steroid was calculated using the formula:

$$\text{Steroids (\%)} = \frac{\text{final weight} - \text{initial weight}}{\text{weight of sample used}} \times \frac{100}{1}$$

Determination of phytate content

The method of Oberleas (1973) was used to determine the phytate content. The solutions used were: Solution 2: A 0.2 g ammonium iron III sulphate in 100 ml 2 N HCl made up to 1000 ml with distilled water; Solution 3: A 10 g bipyridine and a 10 ml thioglycolic acid in distilled water made up to 1000 ml. One milliliter of the extract was pipetted into a test tube and 2 ml of solution (2) added. The test tube was covered and heated in a boiling water for 30 min and cooled to room temperature. Four milliliter of solution (3) was added and mixed well. The absorbance was measured at 519 nm and the phytate content calculated using the formula:

$$\text{Phytate (mg/100 g)} = \frac{\text{absorbance of sample}}{\text{absorbance of standard}} \times \frac{\text{concentration of standard}}{1}$$

Determination of oxalate content

Oxalate content was determined by the method of Kirk and Sawyer

(1998). A 2.0 g of the sample was weighed into 300 ml flask and 20 ml of 30% HCl added and allowed to stand for 20 min. A 4.0 g of ammonium sulphate was added and allowed to stand for 30 min. The solution was filtered and the filtrate made up to 50 ml with 30% HCl. A 10 ml of the filtrate was transferred into a 100 ml flask and 30 ml diethyl ether added. The pH was adjusted to 7.0 with NH_4OH and the solution titrated with 0.1 M KMnO_4 . Oxalate content was calculated from the formula:

$$\text{Oxalate (\%)} = \frac{\text{Titre} \times \text{mol KMnO}_4 \times \text{dilution factor} \times 100}{\text{Weight of sample used}}$$

Determination of cyanide content

The method of Wangaffin as described in Harborne (1973) was used for cyanide determination.

Cyanide extraction

Cyanide extraction was done by weighing 5 g of the sample into a clean 250 ml flask and adding 50 ml of deionized water. This was allowed to stay overnight, filtered and the filtrate used for the cyanide determination.

Preparation of alkaline picurate solution

Alkaline picurate solution was prepared by dissolving 1 g of picrate and 5 g of sodium carbonate in warm water and the volume made up to 200 ml with deionized water.

Procedure for cyanide determination

A 4 ml alkaline picrate was added to 1 ml of the sample filtrate in a test tube and allowed to stand for 5 min. The absorbance was read at 490 nm after colour development (redish brown colour). The absorbance of the blank and the standard was also read and the cyanide content of the test sample extrapolated from cyanide standard.

Estimation of mineral elements

The sodium and potassium contents were determined by Flame photometry (Jenway Ltd Dunmow, Essex, UK). Estimation of iron, zinc, magnesium, and calcium contents were by atomic absorption spectrophotometry as described in Buck scientific operations manual (model 220DGB).

Estimation of sodium contents

A 2.0 g of sample was ashed in a furnace at the temperature of 450°C for 3 h. The ashed sample was dissolved with 5 ml of 30% HCl before the solution was made up to 50 ml with deionized water in a volumetric flask. This was filtered and aspirated into the enablizer of the flame photometer and the electron emission reading taken at 539 nm wavelength. The standard was prepared using sodium salt, and the concentration of the test sample extrapolated from the standard reading (7 = 10 ppm).

Estimation of potassium contents

A 2.0 g of sample was ashed in a furnace at the temperature of

450°C for 3 h. The ashed sample was dissolved with 5 ml of 30% HCl before the solution was made up to 50 ml with deionized water in a volumetric flask. This was filtered and aspirated into the enablizer of the flame photometer and the electron emission reading taken at 767 nm wavelength. The standard was prepared using potassium salt, and the concentration of the test sample extrapolated from the standard reading (16 = 20 ppm).

Estimation of iron contents

Iron content was determined by Buck Scientific atomic absorption spectrophotometry (Model 210 VGP). The first step in the procedure was digestion of sample. It involved mixing 0.2 g of sample with 15 ml of aquaregia (30% HCl and 10% HNO_3) inside a Teflon crucible and heating in the oven at 130°C for 2 h. This was allowed to cool and then filtered using Whatman No. 42 filter paper and the filtrate made up to 250 ml in a 250 ml volumetric flask. This was transferred to a clean container that was used for the analysis. Prior to the analysis, the equipment was calibrated using three different working standards of iron which were prepared from the stock standard (a concentrated solution of iron prepared in the laboratory with an assayed reference compound). The working standards for iron used were:

5 ppm (5 ml of stock + 100 ml distilled water);
3 ppm (3 ml of stock + 100 ml distilled water);
1 ppm (1 ml of stock + 100 ml distilled water).

The above working standards were used to plot a graph of absorbance against concentration to obtain a straight line graph (calibration curve).

Absorbance, $A \propto$ Concentration

$$A = \log_{10} \frac{I_0}{I_t}$$

Where: A = absorbance; I_0 = incident light; I_t = transmitted light

The digested sample was aspirated into the equipment and the various concentrations (in parts per million, ppm) were displayed according to Pearson (1976).

Estimation of zinc contents

Zinc content was determined by Buck Scientific atomic absorption spectrophotometry (Model 210 VGP). The digestion of sample was as described above. Also prior to the analysis, the equipment was calibrated using three different working standards of zinc prepared from the chloride of the salt (ZnCl_2). The working standards for zinc used were:

2 ppm (2 ml of stock + 100 ml distilled water);
1 ppm (1 ml of stock + 100 ml distilled water);
0.2 ppm (0.2 ml of stock + 100 ml distilled water).

The above working standards were used to plot a graph of absorbance against concentration to obtain a straight line graph (calibration curve).

Absorbance, $A \propto$ Concentration

$$A = \log_{10} \frac{I_0}{I_t}$$

Where: A = absorbance; I_0 = incident light; and I_t = transmitted light. The digested sample was aspirated into the equipment and the various concentrations (in parts per million, ppm) were displayed.

Estimation of magnesium contents

Magnesium content was determined by Buck Scientific atomic absorption spectrophotometry (Model 210 VGP). The digestion of sample was as described previously. Also prior to the analysis, the equipment was calibrated using three different working standards of magnesium prepared from the chloride of the salt ($MgCl_2$). The working standards for magnesium used were:

1.5 ppm (1.5 ml of stock + 100 ml distilled water);
1 ppm (1 ml of stock + 100 ml distilled water);
0.5 ppm (0.5 ml of stock + 100 ml distilled water).

The above working standards were used to plot a graph of absorbance against concentration to obtain a straight line graph (calibration curve).

Absorbance, $A \propto$ Concentration

$$A = \log_{10} \frac{I_0}{I_t}$$

Where: A = absorbance; I_0 = incident light; I_t = transmitted light
The digested sample was aspirated into the equipment and the various concentrations (in parts per million, ppm) were displayed.

Estimation of calcium contents

Calcium content was determined by Buck Scientific atomic absorption spectrophotometry (Model 210 VGP). The digestion of sample was as described previously. Prior to the analysis, the equipment was also calibrated using three different working standards of calcium prepared from the chloride of the salt ($CaCl_2$). The working standards for calcium used were:

6 ppm (6 ml of stock + 100 ml distilled water);
3 ppm (3 ml of stock + 100 ml distilled water);
1 ppm (1 ml of stock + 100 ml distilled water).

The above working standards were used to plot a graph of absorbance against concentration to obtain a straight line graph (calibration curve).

Absorbance, $A \propto$ Concentration

$$A = \log_{10} \frac{I_0}{I_t}$$

Where: A = absorbance; I_0 = incident light; I_t = transmitted light
The digested sample was aspirated into the equipment and the various concentrations (in parts per million, ppm) were displayed.

Determination of vitamins

Vitamin A

The procedure of Jakutowicz et al. (1977) was used. One gram of the sample was weighed. Then the proteins were first precipitated with 3 ml of absolute ethanol before the extraction of vitamin A with 5 ml of heptane. The test tube containing this was shaken vigorously for 5 min. On standing, 3 ml from the heptane layer was taken up in a cuvette and read at 450 nm against a blank of heptane. The standard was prepared, read at 450 nm and vitamin A calculated using the formula:

$$\text{Vitamin A (IU)} = \frac{\text{Absorbance of sample} \times \text{Concentration of standard}}{\text{Absorbance of standard} \times \text{weight of sample used}}$$

Vitamin C

Vitamin C analysis was carried out by the method described by Olokodona (2005).

Reagents:

1. Freshly prepared standard Indophenol's solution: A 0.05 g of 2,6-dicrophenol-indophenol was dissolved in water, diluted to 100 ml and filtered.
2. Standard ascorbic acid solutions: A 0.05 g of pure ascorbic acid was dissolved in 60 ml of 20 % metaphosphoric acid and diluted with water to 250 ml.
3. 20% meta-phosphoric acid
4. Acetone

Standardization of indophenol's solution

A 10 ml of standard ascorbic acid solution was pipetted into a small flask and titrated with indophenol's solution until a faint pink colour persisted for 15 s. The concentration was expressed as mg ascorbic acid equivalent to 1 ml of dye solution (10 ml ascorbic acid solution = 0.002 g ascorbic acid).

Procedure for analysis

A 5 g of sample was weighed into a 100 ml volumetric flasks, and 2.5 ml of 20 % meta-phosphoric acid added as stabilizing agent and diluted to volume with distilled water. Ten millilitre of the solution was pipetted into a small flask and 2.5 ml of acetone added. The solution was titrated with the indophenol solution until a faint pink colour persisted for 15 s and the vitamin C content in the sample was calculated as mg/100 ml.

Determination of riboflavin

Riboflavin was extracted with dilute acids after removing the interfering substances by treatment with $KMnO_4$ (Jakutowicz et al., 1977). A 5 mg weight of the sample was taken, and 50 ml of 0.2 N HCl added and boiled on a water bath for an hour. This was afterwards cooled and the pH adjusted to 6.0 using NaOH. A 1 N HCl was added to lower the pH to 4.5 and then filtered in a 100 ml measuring flask and the volume made up to mark. A 10 ml of aliquot was taken from the 100 ml volume and 1 ml of acetic acid (glacial) added to each tube and mixed. Then 0.5 ml of 3% $KMnO_4$ solution was added. This was kept away for 2 min and then 0.5 ml of 3% H_2O_2 added and mixed well before taking the reading at 470 nm. Riboflavin content was calculated using the formula:

$$\text{Riboflavin (mg/100 ml)} = \frac{\text{Absorbance of sample} \times \text{Concentration of standard}}{\text{Absorbance of standard} \times \text{weight of sample used}}$$

Determination of thiamin

Thiamin complex was extracted with dilute HCL and the resultant solution treated with phosphatase enzyme to liberate free thiamin (Jakutowicz et al., 1977). A 1 g of the sample was weighed into a flask and 100 ml of 0.2 N HCl added and all heated to boil for 30 min on a water bath. This was cooled, and 5 ml of phosphatase

enzyme added and incubated at 37°C. This will be filtered and 3 g of anhydrous Na₂SO₄ added. A 5 ml of the solution was put into 5 ml stopped flask and 3 ml of 15 % NaOH added. The absorbance was taken at 435 nm wavelength and thiamin calculated using the formula:

$$\text{Thiamin} = \frac{\text{Absorbance of sample} \times \text{Concentration of standard}}{\text{Absorbance of standard} \times \text{weight of sample used}}$$

Determination of carotenoid

The method of AOAC (2010) was used for the determination of total carotenoid in the samples. Five grams (5 g) of the sample was mixed with hexane and ethanol (40:60 ml) to extract the carotenoid. The mixture was transferred into a separating funnel and swilled vigorously after adding 2% NaCl solution. It was thereafter allowed to settle and the aqueous layer ran off. The top layer which contained the carotenoid was collected. It was diluted and optical density determined in a spectrophotometer at 460 nm. The result was compared with carotenoid standard curve prepared using carotenoid stock solution of 0.8 mg/ml of hexane. The content of carotenoid in the sample was calculated using the formula:

$$\text{Mg carotenoid/100 g sample} = \frac{\text{standard curve reading} \times \text{dilution factor} \times 100}{\text{weight of sample}}$$

Determination of pH

pH determination was by the use of the pH meter (Hanna HI96107, Italy). The pH meter was standardized using buffer solutions of pH 4 and 9. The electrode was rinsed with de-ionized water and dipped into 20 ml of the sample, allowing sufficient time for stabilization before taking the reading.

Microbiological analysis of the processed vegetable drink extract

Determination of total plate count

The pour plate method as described by Harrigan and McCance (1976) was used to determine the total plate count. One milliliter of the solution (extract) was mixed with 9 ml of the diluent (Ringer's solution). The first of such dilution from the stock gives 10⁻¹ while the next of the dilution made from 10⁻¹ gives 10⁻² dilution. One milliliter solution from each of the dilutions (up to 10⁻⁶) was seeded into petri dishes (in duplicate) and 15 ml of sterile nutrient agar poured and mixed thoroughly with the inocula by gently rocking the plates. The plates were incubated at 37°C for 24 h after which the colonies formed were counted and expressed as colony forming unit per gram of sample (cfu/g) using the formula:

$$\text{cfu/g} = \frac{\text{Number of colonies} \times \text{original dilution}}{\text{Dilution factor volume of inoculum}}$$

Determination of total coliforms

Total coliform was determined as outlined by Sharma (2009). About 1 ml from each of the samples was inoculated into lactose broth and incubated at 37°C for 48 h. Serial dilutions of 10⁻¹ and 10⁻² were made from the resulting cultures and about 1 ml of solution from each of the dilutions used to inoculate eosin methylene blue (EMB) agar plates (in duplicates) using the pour plate technique. The plates were incubated at 37°C for 48 h and the characteristic

metallic green colonies counted and expressed as colony forming unit per gram of sample (cfu/g) as stated above.

Determination of mould count

The pour plate method as described by Harrigan and McCance (1976) was used to determine the mould count. A volume of 1 ml of inoculum of sample serial dilutions was deposited in the empty petri dishes and covered with 15 ml of sterile Sabouraud Dextrose Agar (SDA) and thoroughly mixed by gently rocking the plates. The inoculated plates were incubated at 25°C for three days. The observed colonies were counted using the Quebec counter and the counts obtained expressed as colony forming units per gram of sample (cfu/g) as stated above.

Data analysis/experimental design

The experiment was performed in duplicates and the results expressed as the average. One-way analysis of variance (ANOVA) in Split plot design was performed using Cropstat (version 7.2) for the determination of significant differences in the parameters for the various processing treatment groups. Significance was accepted at (p<0.05) probability (Steele and Torrie, 1980).

RESULTS AND DISCUSSION

Effect of treatment methods on the proximate composition of vegetable drink extract from *Irvingia gabonensis* (African bush mango) leaves

The effect of treatment methods on the proximate composition of vegetable drink extract from *Irvingia gabonensis* is presented in Table 1. The moisture contents are, however, higher in vegetable drink from steam blanched leaves which could be due to the absorption of moisture by the leaves during the blanching process. According to Yousif et al. (1999), during the long hours of drying, heat was conducted from the surface to the interior of the leaves and the rate of evaporation of water on the surface of the leaves was faster than the rate of diffusion to the surface. The protein content is low in all the vegetable drinks, ranging from 0.02 to 0.06%. Similar observation was made by Dauthy (1995), that most fresh vegetables and fruits are high in water content, low in protein, and low in fat. The seeming increase in protein content with the various drying treatment methods may be due to the concentration of nutrients by loss of water (Finglas and Faulks, 1985). The highest value (0.06 %) was obtained in the vegetable drink from leaves dried after 6 min of blanching. The fat content of the vegetable drink from the unprocessed leaf was 2.02%. Leafy vegetables are known to be poor sources of lipids, thus the low fat content. However, the values compares with that of Baobab (1.68%) (Ihekoronye and Ngoddy, 1985). The six minutes leaf blanching resulted in a significant (p<0.05) increase in fat value while the rest of the processing methods led to a significant (p<0.05) reduction in fat content.

Although many studies have shown fat to increase with

Table 1. Effect of different treatment methods on the proximate composition of *I. gabonensis* vegetable drink extract.

Treatments	Moisture (%)	Protein (%)	Fat (%)	Fibre	Ash (%)	Carbohydrate (%)
1	96.61	0.03*	2.88	Trace	0.48	0.52
2	96.71	0.03*	1.25	Trace	0.46	2.02
3	96.80	0.03*	0.61	Trace	0.44	2.88
4	96.10*	0.02*	2.02	Trace	0.49*	2.94*
5	94.33	0.04*	0.78	Trace	1.33*	3.63*
6	95.31	0.03*	1.00	Trace	0.46	4.07*
7	95.06	0.06*	1.38	Trace	0.93*	2.72
8	94.11*	0.04*	0.60	Trace	0.44	4.97*
9	95.10	0.02	1.00	Trace	0.46	2.97
Mean	95.57	0.033	1.28	-	0.61	2.96
LSD	1.85	0.67-05	0.19	-	0.17	0.12
CV (%)	0.80	0.00	6.50	-	12.20	1.70

Any two means having difference greater than LSD (%) is significantly different at 5% level of probability. *Significant difference between processing method and control. 1 = 6 min blanched/raw; 2 = 4 min blanched/raw; 3 = 2 min blanched/raw; 4 = Control; 5 = shade dried/raw; 6 = solar dried/raw; 7= 6 min blanched/dried; 8 = 4 min blanched/dried; 9 = 2 min blanched/dried

Table 2. Effect of different treatment methods on the phytochemical composition of *I. gabonensis* vegetable drink extract.

Treatments	Total phenol (%)	Flavonoids (%)	Alkaloids (%)	Carotenoids (IU)	Saponins (%)	Steroids (%)
1	15.00	4.73	1.90	105.49*	9.36	0.86*
2	22.50*	3.54	3.24	92.83*	5.09*	0.46*
3	25.00*	4.44	2.68	151.90*	4.34*	0.94*
4	17.50*	4.53*	2.98	164.56*	9.71*	1.51*
5	72.50*	6.72*	3.86	37.97*	2.82*	0.94*
6	32.50*	5.87	2.99	59.07*	5.31*	0.48*
7	30.00*	7.00*	3.61	16.88*	7.80*	0.46*
8	47.50*	6.71*	3.40	25.32*	4.83*	0.48*
9	37.50*	6.44*	2.69	29.54*	4.57*	0.47*
Mean	33.33	5.55	3.04	75.95	5.98	0.73
LSD	4.43	1.55	1.63	2.73	1.20	0.12
CV (%)	5.8	12.1	23.2	1.6	8.7	7.0

Any two means having difference greater than LSD (%) is significantly different at 5% level of probability. *Significant difference between processing method and control. 1 = 6 min blanched/raw; 2 = 4 min blanched/raw; 3 = 2 min blanched/raw; 4 = Control; 5 = shade dried/raw; 6 = solar dried/raw; 7= 6 min blanched/dried; 8 = 4 min blanched/dried; 9 = 2 min blanched/dried.

different processing methods, the finding from this work agrees with that of Tsado et al. (2015) who in their work reported that all the methods they used in processing *Vernonia amygdalina* caused reduction in lipid. The ash content of vegetable drink from fresh leaf was low (0.49), an indication of a low mineral content. However, this was significantly ($p < 0.05$) increased in the drink from shade dried (treatment 5) and 6 min blanched and dried leaves (treatment 7). The trace amount of crude fiber detected in the vegetable drink could be as a result of dilution effect and filtration process that removed most of the fiber (Kennedy, 1993). The variation in the carbohydrate content did not follow a particular trend. However, the highest increase was obtained from vegetable drink from

dried leaves, attributable to the effect of drying which removed volatile moisture thereby concentrating the nutrient. Thus, the optimal blanching condition was 6 min blanched and fresh leaf extracts.

Effect of treatment methods on the phytochemical composition of vegetable drink extract from *I. gabonensis* (African bush mango) leaves

Table 2 shows the effect of treatment methods on the phytochemical composition of vegetable drink from the leaves of *I. gabonensis*. The total phenols in the vegetable drinks produced from the unprocessed leaf

Table 3. Effect of different treatment methods on the antinutrients in *I. gabonensis* vegetable drink extract.

Treatments	Tannin (mg/100 g)	Phytate (mg/100 g)	Oxalate (mg/100 g)	Cyanide (mg/100 g)
1	0.037*	9.52*	7.25*	0.04
2	0.008*	5.38	9.55*	0.04
3	0.040*	14.33*	8.25	0.04
4	0.023*	5.00*	8.15	0.03*
5	0.031	4.71	10.85*	0.08*
6	0.025	4.52	13.55*	0.05
7	0.019	11.25*	13.90*	0.10*
8	0.010*	10.33*	10.50*	0.09*
9	0.030	9.04*	10.05*	0.07*
Mean	0.02	8.68	10.21	0.06
LSD (%)	0.01	1.02	0.12	0.03
CV (%)	17.2	5.1	0.5	20.8

Any two means having difference greater than LSD (%) is significantly different at 5% level of probability. *Significant difference between processing method and control. 1 = 6 min blanched/raw; 2 = 4 min blanched/raw; 3 = 2 min blanched/raw; 4 = Control; 5 = shade dried/raw; 6 = solar dried/raw; 7 = 6 min blanched/dried; 8 = 4 min blanched/dried; 9 = 2 min blanched/dried

(control).was 17.5%, which is much higher than what has been reported for some commonly consumed green leafy vegetables in Nigeria (Oboh et al., 2005). The total phenols in the drinks from processed leaves, however, varied significantly ($p < 0.05$) from that of the fresh leaves, with the highest increase of 72.5% occurring in vegetable drink from the shade dried leaves. Similarly, Nayak et al. (2015) in their review, reported that processing and storage can promote or enhance the stability and quantity of phenolic antioxidants in the processed foods. In most of the cases, processing diminishes the natural antioxidants, while forming new compounds with potential antioxidative properties. These newly formed antioxidative compounds compensate the total antioxidant capacity of processed foods.

Antioxidant activity is correlated with the occurrence of phytochemicals including phenolics, flavonoids, and anthocyanins in foods (Sun et al., 2002). Phenols have antioxidant capacities that are much stronger than those of vitamins C and E (Oloyede et al., 2014). The flavonoids in the vegetable drink from fresh leaf was 4.53% and this increased significantly ($p < 0.05$) with the drying methods except solar drying which gave a non-significant ($p < 0.05$) increase. Similar results were reported by Mudau and Ngezimana (2014) in bush tea, who concluded that shade and freeze drying methods were shown to be more useful for retention of phytochemicals. The alkaloid content of vegetable drink from the variously treated leaves varied non-significantly ($p < 0.05$) from that obtained from the fresh leaf. This result is almost in consonance with the report of Ebuehi et al. (2005) that alkaloids are relatively stable when food is subjected to heat treatment. Odufuwa et al. (2013), however, reported that the effect of processing on alkaloids content in plants and its product is controversial

and inconclusive. The level of carotenoid in the vegetable drink from the fresh leaf of *Irvingia gabonensis* was found to be 164.56 IU. A significant ($p < 0.05$) reduction occurred in all the processed groups. However, there is much greater retention of carotenoid in the blanched fresh leaves than in the dried leaves; also among the dried groups, the solar dried had the highest retention of carotenoid. The saponins content in the vegetable drink from fresh leaf is 9.71%. The closest value of 9.36% was obtained with 6 min blanching while the rest of the treatment methods gave a significant ($p < 0.05$) reduction in the saponin content. The percentage steroids in the vegetable drink from the fresh of *I. gabonensis* is 1.51% and this was reduced significantly ($p < 0.05$) for all the vegetable drinks from the treatment groups.

Effect of treatment methods on anti-nutrients in vegetable drink extract from (African bush mango) *I. gabonensis* leaves

The data for the effect of treatment methods on the anti-nutrients in the vegetable drink extract of *I. gabonensis* is presented in Table 3.

The tannin content is quite low in the drink from fresh leaf (0.023 mg/100 g) and variations from the treatment groups were inconsistent. Foods rich in tannins are considered to be of low nutritional value because they precipitate proteins, inhibiting digestive enzymes and iron absorption and affect the utilization of vitamins and minerals from meals (Tinko and Uyano, 2001). The tannin contents of the vegetable drink extracts in the present study were found however to be too low to pose any danger to the users. The phytate content was slightly reduced in the vegetable drink extracts from the shade

Table 4. Effect of different treatment methods on the vitamin content of *I. gabonensis* vegetable drink extract.

Treatments	Vitamin A (IU)	Vitamin C (mg/100 g)	Vitamin E (mg/100 g)	Vitamin B ₁ (mg/100g)	Vitamin B ₂ (mg/100 g)
1	632.91*	0.32	6.00	7.80	3.45
2	556.96*	0.40	6.00	7.80	1.91
3	911.39*	0.37	6.25	11.00*	1.00
4	987.34*	0.35*	8.50*	8.00*	2.64*
5	227.85*	0.88*	2.75*	15.80*	6.64*
6	354.43*	0.90*	13.75*	9.00	4.73*
7	101.27*	0.83*	11.45	10.70*	9.00*
8	151.90*	0.86*	10.25	5.80	3.55
9	177.22*	0.78*	11.25	10.80*	8.36*
Mean	455.70	0.63	9.58	9.63	4.59
LSD	16.38	0.11	3.46	2.18	2.06
CV (%)	1.60	7.50	15.60	9.80	19.50

Any two means having difference greater than LSD (%) is significantly different at 5% level of probability. *Significant difference between processing method and control. 1 = 6 min blanched/raw; 2 = 4 min blanched/raw; 3 = 2 min blanched/raw; 4 = Control; 5 = shade dried/raw; 6 = solar dried/raw; 7 = 6 min blanched/dried; 8 = 4 min blanched/dried; 9 = 2 min blanched/dried

dried and solar dried leaves. Significant ($p < 0.05$) increases occurred in vegetable drink extracts from the 2 and 6 min blanched and from the 2, 4 and 6 min blanched and dried leaves. With the drying methods without blanching pretreatment (shade and solar drying), there was however, non-significant ($p < 0.05$) decrease in phytate contents. The above trends are consistent with the results of other research findings. In a study on the effect of thermal processing on antinutrients in common edible green leafy vegetables (Udousoro et al., 2013), heating caused the phytate levels to decrease in all the samples analyzed. Yet in some other studies, phytate levels remain unchanged or increased after heat treatments (Yagoub and Abdalla, 2007; Martin-Cabrejas et al., 2009; Embaby, 2011). Likewise for the oxalates, there were significant increases ($p < 0.05$) in the vegetable drink extracts from all the dried leaves as well as from the 4 min blanched leaf. Only the vegetable drink extract from the six 6 min blanched leaves gave a significant ($p < 0.05$) reduction in the oxalate content. The cyanide in the vegetable drink extracts from fresh leaf was also low (0.03 mg/100 g). However, it is not clear why there was increased level of cyanide in all the processed groups. Significant increase ($p < 0.05$) was obtained with shade drying.

Effect of treatment methods on vitamins content of vegetable drink extract from *I. gabonensis* (African bush mango) leaves

Table 4 shows the effect of treatment methods on the vitamins content of the vegetable drink extracts from *I. gabonensis* leaf. The drink extract from fresh leaf had an appreciable level of vitamin A (987.34 IU). Vitamin A belongs to the classes of vitamins known to be soluble in

fat and fat solvents. They are not easily lost by ordinary cooking as is the case with the result obtained in this study with steam blanching. However, pronounced losses were observed with the drying methods. The losses were more pronounced in the drink extract from dried leaves, 227.85 and 101.27 IU for shade dried and 6 min blanched and dried respectively. Vitamin C had slight variations with blanching. However, there were significant increases in vitamin C content with drying, the highest (0.90%) occurring in vegetable drink extract from solar dried leaves followed by that from shade dried leaves (0.88%). This result does not fully agree with the findings of Babalola et al. (2010) on the effect of processing on the vitamin C content of seven Nigerian leafy vegetables. Their result showed that the vitamin C values were generally high for all the raw vegetables when compared with their processed counterparts. However, their observation that sun drying had the least effect on vitamin C content when compared with other processing methods compares with the findings in this work except that theirs did not involve shade drying. In another work that involved shade drying, Onoja (2014) in her result showed that the dried leaf curd and the sun-dried sample had similar ascorbate (0.16 and 0.18 mg/100 g) while the shade dried and fresh leaves had similar ($p > 0.05$) levels (0.28 mg/100 g respectively).

Vitamin E content of vegetable drink extract from fresh leaf (control) was 8.50 mg/100 g. This was non-significantly reduced in vegetable drink extract from blanched leaf but increased with all the drying methods. Significance ($p < 0.05$) was however only observed in vegetable drink extract from solar dried leaves (13.75 mg/100 g) and shade dried leaves (12.75 mg/100 g). Thiamin (vitamin B₁) and riboflavin (vitamin B₂) contents of the vegetable drink extract from fresh leaf were 8.0 mg/100 g and 2.64 mg/100 g, respectively. These values

Table 5. Effect of different treatment methods on the mineral composition of *I. gabonensis* vegetable drink extract.

Treatments	Sodium (ppm)	Potassium (ppm)	Calcium (mg/100 g)	Magnesium (mg/100 g)	Zinc (mg/100 g)	Iron (mg/100 g)
1	2.57*	6.25*	17.30*	246.00	0.00*	0.00*
2	2.57*	6.25*	22.70*	186.00	0.01	0.04
3	1.43	6.25*	19.65	218.00	0.01	0.08
4	1.43*	2.5*	19.45*	201.00	0.01*	0.08*
5	1.43	11.25*	25.80*	139.00	0.00*	0.17*
6	0.71*	10.00*	31.75*	126.00	0.02*	0.52*
7	0.71*	11.25*	33.15*	170.00	0.00*	0.58*
8	1.43	12.25*	25.05*	150.00	0.02*	0.59*
9	0.71*	13.75*	23.85*	199.00	0.01	0.41*
Mean	1.44	8.86	24.30	168.22	0.01	0.27
LSD	0.17	0.45	0.35	127.50	0.00	0.06
CV (%)	5.00	2.20	0.60	32.90	0.01	8.7

Any two means having difference greater than LSD (%) is significantly different at 5% level of probability. *Significant difference between processing method and control. 1 = 6 min blanched/raw; 2 = 4 min blanched/raw; 3 = 2 min blanched/raw; 4 = Control; 5 = shade dried/raw; 6 = solar dried/raw; 7= 6 min blanched/dried; 8 = 4 min blanched/dried; 9 = 2 min blanched/dried

are much higher than were obtained in selected Tanzanian vegetables (0.62 - 1.71 and 0.09 - 0.30 mg/100g for ascorbic and thiamine respectively) according to Mosha et al. (1995). Also, result from the present study shows that drying led to further increase (significant at $p < 0.05$) in thiamin and riboflavin in the vegetable drink from the leaves of *Irvingia gabonensis* contrary to their report on the decrease in the vitamins resulting from sun/shade drying for all vegetables they examined (Mosha et al., 1995). The only exception is with drying preceding 4 min blanching.

Effect of treatment methods on the mineral content of vegetable drink extract from *I. gabonensis* (African bush mango) leaves

The effects of processing treatments on mineral contents of vegetable drink extracts are given in Table 5. The vegetable drink from fresh leaf contains a high level of magnesium (201 mg/100 g). Thus the drink is a good source of magnesium as the majority of good magnesium sources contain only about 10 % or less of recommended daily amounts (200 - 350 mg/day) (DRI, 1997). In line with report from earlier researches, there was reduction of magnesium with processing although this was non-significant ($p < 0.05$). Calcium level of the vegetable drink is also appreciable and in line with other studies (Joshi and Mehta, 2010), increased significantly ($p < 0.05$) with drying but variably with blanching. A comparison of the levels of potassium and iron in the vegetable drink extract from the dried leaves with that present in fresh leaves also showed significant increases ($p < 0.05$). For iron, a

non-significantly reduction ($p < 0.05$) was observed in the drink from steam blanched leaves.

This result, however, does not agree with the report of Yan et al. (2002) that iron bioavailability increases when certain vegetables are cooked. Blanching equally caused significant ($p < 0.05$) increase in potassium content but the increase was more with drying processes. The zinc content of the vegetable drink extract was quite low. But that notwithstanding, solar drying and 4 min blanching prior to drying increased zinc content significantly ($p < 0.05$). The variation of sodium with processing appeared inconsistent.

Effect of treatment methods on the microbiological quality of vegetable drink extract from *I. gabonensis* (African bush mango) leaves

The effect of treatment methods on the microbiological status of vegetable drink extract from the leaves of *I. gabonensis* is presented in Figures 2 to 4. In the figures, the vegetable drink extract from fresh leaves had a total viable, coliform and mould counts of 13×10^2 , 4.2×10^2 and 5.1×10^2 cfu/ml, respectively. The main microbial contamination of plant materials, in general, are attributed to total aerobic mesophilic, enterobacterial, yeast and mould (Kneifel et al., 2002). These derive from contamination from air, soil, water, insects, animals, workers, and harvesting and transportation equipment (ICMSF, 1998). The figures obtained in this study however, falls below WHO specification for plant material for use as teas and infusions, not more than 10^7 cfu/g for total aerobic microorganisms and 10^5 cfu/g for the yeasts and moulds

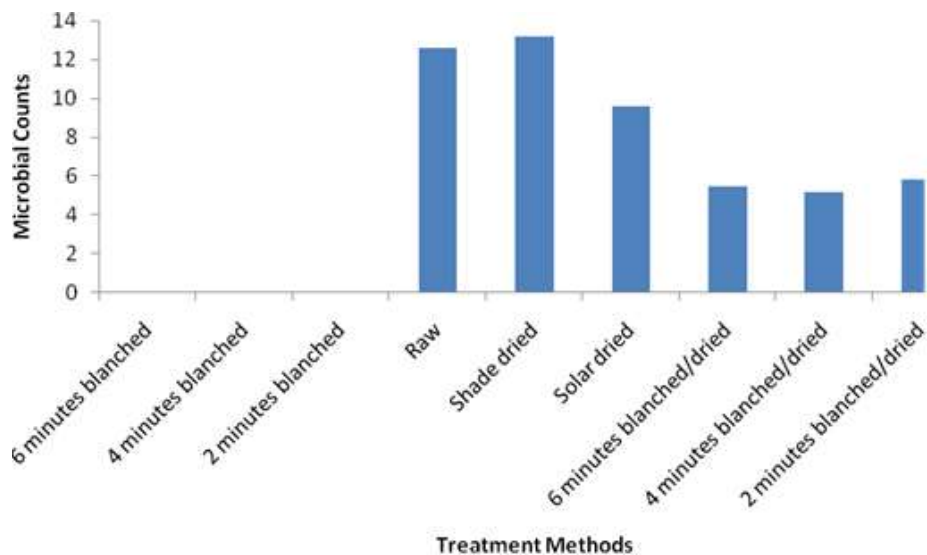


Figure 2. Effect of treatment methods on the total plate count (cfu × 10²) of *I. gabonensis* vegetable drink extract.

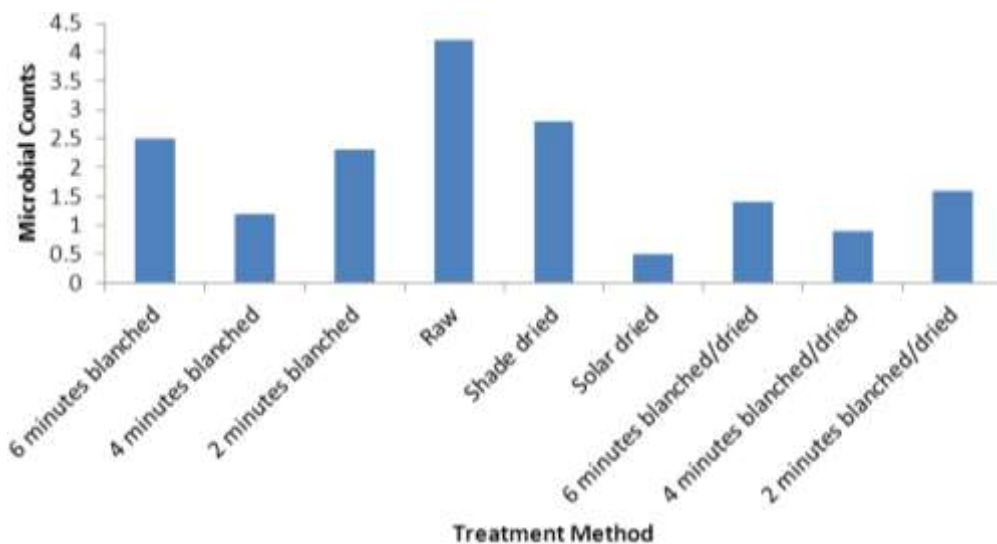


Figure 3. Effect of treatment methods on the total coliforms (cfu × 10²) of *Irvingia gabonensis* vegetable drink extract.

(WHO, 1998). For the total plate count, negligible growth was observed in the vegetable drink extract from the steam blanched leaves. This could be as a result of the heat treatment as the reduction of plant enzyme activity and inactivation of microorganisms achieved by heating (Kneifel et al., 2002). The highest count occurred in vegetable drink extract from shade dried leaf which can be explained by the fact that the drying period would have exposed them to more contaminations, unlike the solar drying method which is faster and also provides isolated atmosphere that minimizes the contamination of

the plant material (Kassem et al., 2006).

The total coliform count, as shown Figure 3, was highest in the vegetable drink from the raw unprocessed leaf (control). This finding agrees with the findings of Saranraj et al. (2012) that among the groups of bacteria commonly found on plant vegetation are mainly coliforms or precisely faecal coliforms, such as *Klebsiella* and *Enterobacter* (Saranraj et al., 2012). This count was however reduced by all the processing methods, with the lowest count (cfu/ml) of 0.5 × 10² occurring with solar drying. In Figure 4, the effect of processing methods on

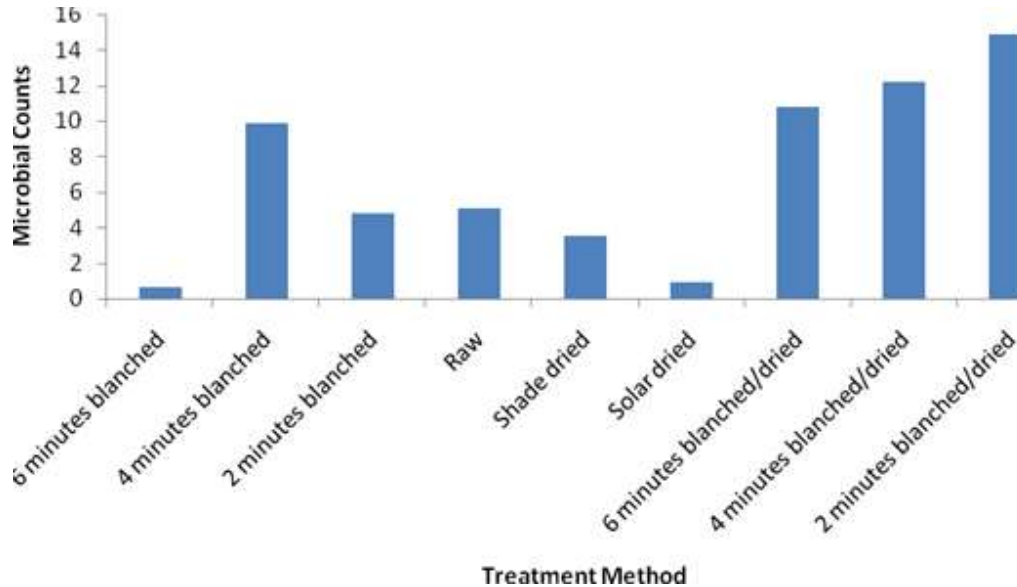


Figure 4. Effect of treatment methods on the mould counts (cfu × 10²) of *Irvingia gabonensis* vegetable drink extract.

mould counts is shown. The highest counts occurred in vegetable drink extract from shade dried leaves while the least occurred in drink extract from solar dried leaves.

Conclusion

The present study found that moisture was the major component of the vegetable drink extract of the leaves of *I. gabonensis* and that this was fairly stable in all the aqueous products. The drink extract was also seen to have an appreciable level of phytonutrients which is an important nutritional indicator of the usefulness of this plant leaves in producing vegetable drink extract. Amongst these, total phenol, flavonoids and alkaloids were most enhanced by shade drying, while carotenoids, saponins and steroids were decreased by same. The concentrations of anti-nutrients in the vegetable drink extracts were low to significantly interfere with nutrients utilization and the effect of the different processing methods on their concentrations appeared inconsistent. For instance, the oxalates were stable with blanching but increased with drying; cyanides increased in all the processed groups while the variations of the concentrations of tannins and phytates with processing lacked a trend. The vegetable drink also had appreciable levels of vitamins A, E and B₁. Vitamin A is necessary for a broad range of bodily function, including production of vision pigments, resistance to infectious agents and maintenance of health in many epithelial cells. Vitamin E is essential for absorption of iron, slowing of the ageing process, and fertility. It is a powerful antioxidant which helps protect cells from damage by free radicals. Vitamin

B complexes are necessary for converting blood sugar to energy, keeping the nervous system healthy; B₁ promotes growth. Steam blanching had a high retention of vitamin A while solar drying gave the highest increase of vitamin E. Shade drying gave the highest increase of vitamin B₁ but the least retention of vitamin E. The vegetable drink extract was also seen to be rich in calcium and magnesium which are in the group of the essential minerals that cannot be synthesised by the body and must, therefore, be ingested as part of the diet. The microbial contaminants detected in the fresh vegetable drink extract, which included the aerobic mesophiles, the moulds and the coliforms were all reduced by all the processing methods. The leaves of *I. gabonensis* has been shown to contain important bioactive substances (phenols, alkaloids and carotenoids), minerals (K, Ca and Mg), vitamins (A, E, B₁, B₂); low in anti-nutrients (tannins and cyanide). It is therefore recommended for use in production of vegetable drink extract. Following the results that processing was not detrimental to the nutritional value of the vegetable drink extract from the leaves of *I. gabonensis*, it is being recommended that the leaves be processed so as to enhance their availability out of season. However, the selection of a processing method for use should be guided by the compounds of interest to the food processor. It is also recommended that shade drying be carried out in a clean environment, if possible in an enclosure since it has been observed from the result of this study that there could be possible exposure of the sample materials to greater chances of contamination than when the solar drier was used. Further research is recommended to ascertain the effect of these treatments on the toxicological properties of the vegetable

drink extract.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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