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Determination of Chemical Compositions and Effects of Selected Drying Methods on Tropical Plant Leaves and Edible Green Vegetable

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Abstract: This present study determines the chemical compositions and effects of selected drying methods on *Carica papaya, Manihot esculenta Crantz* leaves and edible green vegetable ("tete") *Amaranthus hybridus*. Vegetables play a crucial role in human nutrition. They contribute vital components such as vitamins, minerals, antioxidants and bioactive compounds regulating biological processes in the body, especially when fresh. However, their short shelf lives can be a major problem in terms of nutrient and phytochemical activeness/retention when they are to be preserved, especially during the out-of-season. Drying is an ancient physical procedure for conservation of food materials including vegetables. Quest into phytochemical content of pawpaw and cassava leaves, which are only used for medicinal purposes and thrashed afterwards, justifies researching into their edibility and storage-ability for a long shelf life, using sun and oven drying at 40 °C and 60 °C. Results from this study revealed that *C. papaya*, *M. esculenta* and *A. hybridus* all contain appreciable nutrients (%): Moisture (6.30 – 82.15), protein (9.99 – 36.93), crude fibre (2.91 – 20.61), fat (0.15 – 5.57), ash (1.34 – 31.00) and carbohydrate (2.06 – 34.08); antinutrients (mg/g): phytate (7.39 – 83.78), oxalate (0.23 – 7.58), saponins (7.64 – 31.45) and tannins (4.55 – 13.41); antioxidants: FRAP (6.53 – 42.12 %), total phenols (TPC 1.79 – 13.65 mg/g) and total flavonoids (TFC 0.83 – 10.19 mg/g); and vitamins (mg/g): Vitamin C (4.62 – 93.62), vitamin B_1 (1.63 – 9.99), vitamin B_2 (1.77 – 9.48) and vitamin B_3 (1.66 – 8.64) irrespective of leaves and treatment methods. The drying methods showed favourable results for the chemical constituents of the leaf samples. All drying methods favourably reduced anti-nutrients appreciably (0.23 mg/g oven dried at 60 °C to 61.80 mg/g raw) irrespective of leaf samples but unfavourably also reduced vitamin contents (1.63 mg/g, oven dried at 60 °C to 116.19 mg/g, raw) and antioxidants (1.17 mg/g Oven dried at 60 °C to 13.65 mg/g Raw) irrespective of the leaf samples. Drying the leaves examined in this research for preservation/storage is commendable, and using sun drying and oven drying methods at temperatures not higher than 40 °C are recommendable for nutrients retention.

Keywords: *Chemical Compositions; Drying Methods; Effect; Tropical Plant Leaves; Edible Green Vegetable.*

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I. INTRODUCTION

Plants and their parts- leaves, roots, shoots, flowers, seeds and fruits are usually referred to as vegetables and eaten with starchy foods after cooking as a condiment [1–2]. Vegetables play an extremely crucial role in human nutrition. They contribute to the maintenance of good human health status by providing components regulating biological processes in the body [3]. Fresh vegetables in human diet supply taste, texture, essential amino acids, phytochemicals, vitamins, minerals, medicinal and therapeutic solutions that enhance human growth and development [1,2,4].

Vegetables offer efficient and cheapest source of nutritional benefits. Their consumption as food could be beneficial to nutritionally marginalised communities and impoverished developing countries with harsh climatic conditions and poor health insurance [5]. African vegetables are recommendable dietary supplements for fight against malnutrition and oxidative stress-related diseases such as

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inflammation, cardiovascular diseases, cancer and aging-related disorders. These own to their high levels of essential assimilable minerals and low anti-nutritional components [1,6].

The short shelf lives of leaves and vegetables can be a major problem in terms of nutrient and phytochemical retention when they are to be preserved, especially at the out-of-season [7,8]. Thorough understanding of factors that influence the quality of vegetables is required for the production of effective and consistent herbal products for medicine [9]. According to [3], the quality and storage potential of fresh vegetables are unstable. So, extension of their stability and nutrient retention is possible through preservation/conservation.

Drying is an ancient physical procedure for conservation of food materials including vegetables. It involves removal of (i) bound moisture retained in the microstructural matrix and (ii) excess unbounded moisture from solid and liquid products using heat [10–11]. Drying is considered an important post-harvest preservation process since it reduces plants' microbial growth and enzymatic degradation. Depending on the method applied, drying facilitates the preservation of taste, aroma, and high contents of bioactive compounds [3,5,9,11]. Dried vegetables are convenient to store and transport for distribution across the globe, where they may be used for several semi-products which can later be processed into finished products such as medicines, foods and herbs for human consumption [3].

Despite the reports that green vegetables, cassava and pawpaw leaves are valuable supplementary sources of proteins, vitamins and bioactive compounds suitable for human nutritional benefits [12–13], they are still being treated as useless and abandoned in the field in Nigeria. These plants' leaves are not considered consumable and dish-able as edible vegetable foods that can be eaten like the *Amaranthus hybridus*, popularly called "tete", "aleifo" and "inise" in Yoruba, Hausa and Ibo, Nigerian main languages respectively. In addition, information about the reports of pawpaw and cassava leaves being used as vegetable soup in Nigeria is scanty. This research therefore tries to examine sun and oven drying preservation effects on the chemical composition/nutritional values of the leaves in the face of dry seasons, with the view to offer valuable insights into the choice of acceptability/consumption of the leaves by the society, to encourage domesticated cultivation of the plants and discourage indiscriminate disposal of the plants leaves. This will enhance income generation and environment free of littered leaves.

II. METHODS

Green vegetable, *Amaranthus hybridus* was collected (purchased) from New Market, Kontagora, while cassava and pawpaw leaves were obtained from Faculty of Agriculture, Federal University of Education, Kontagora, Niger State. Each of the leaf samples was destalked and divided into four (4) parts. First, second, third and fourth portions of each sample was raw, sun dried to constant weight, oven dried at 40 °C and at 60 °C to a constant weight respectively. The samples were then separately grinded, stored in airtight polythene bags and stored in the refrigerator at controlled temperature of 4 °C prior to analysis of chemical parameters.

➢ *Proximate Analysis*

Proximate analysis was carried out using the recommended methods of the Association of Official Analytical Chemist [14] for:

- *Moisture content*

Flat bottomed evaporating dishes were cleaned, thermostatically dried in oven at 105 °C and cooled in desiccators before weighing (W_1). 3.0 g of the dry powdered samples were put into the dishes (W_2), weighed and distributed evenly over the bottom of the dishes. The dishes plus the samples were placed in the oven at 105 °C for about 3 hrs. The samples were then removed from the oven and placed in a desiccator to cool and weighed. The processes of heating, cooling and weighing were continued at interval of 30 minutes until a constant weight (W_3) was obtained. The percentage moisture content was determined using equation (1).

$$\%\ moisture\ content = \frac{W_2 - W_3}{W_2 - W_1} \times \frac{100}{1} \quad (1)$$

Where W_1 = mass of empty dish, W_2 = mass of dish + wet sample, W_3 = mass of dish + dried sample.

- *Ash content*

A crucible was heated for 5 minutes, cooled and weighed (W_1). A mass of 1.5 g of each sample was weighed into the crucible. The crucible plus the samples was then placed in the muffle furnace at 550 °C to ash the samples until all the carbon was burnt off. The crucible plus ash was cooled in desiccator and weighed (W_2). The percent ash content was calculated using equation 2.

$$\%\ \text{Ash} = \frac{W_1 - W_2}{W_t\ \text{of sample}} \times \frac{100}{1} \quad (2)$$

Where W_1 = mass of empty crucible, W_2 = mass of crucible + ash, W_t = weight of sample

➢ *Crude Fibre*

A mass of 2.0 g of dried powdered samples was defatted and placed in a 250 ml conical flask. 200 ml of 0.125 M H_2SO_4 was added and heated to boiling for 30 minutes while rotating the flask to mix the content and remove particles from its sides. The acid mixture was allowed to cool for one minute and filtered through Muslin cloth, stretched over 9 cm Buchner funnel. They were rinsed with distilled water until acid free and then washed back into the original flask using wash bottle containing 0.125 M sodium hydroxide solution. The mixture was boiled for 30 minutes and then allowed to stand for 1 minute before filtering with hot distilled water, rinsed once with 0.1 M HCl and finally with boiling water until it was free of acid. It was then washed twice with alcohol and thrice with petroleum ether. The residue was dried, scrapped into a crucible, dried in the oven at 100 °C, cooled in a desiccator and weighed (W_2) and then transferred into a muffle furnace at 450 °C for 90 minutes to ash. The ash was cooled in a desiccator and

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weighed (W_3). The percentage crude fibre was determined using equation 3.

$$\% \text{ Crude Fibre} = \frac{W_2 - W_3}{W_t \text{ of sample } (W_1)} \times \frac{100}{1} \quad (3)$$

Where W_2 = mass of dried residue, W_3 = mass of cooled ash, W_t = weight of sample

➢ *Crude Fat*

Crude fat was determined using petroleum ether (60–80 ^oC boiling point) in a soxhlet extractor. Filter paper was weighed (W_1). Mass of 2.0 g of sample was put into the filter paper and weighed (W_2), then pushed down into the soxhlet extractor, which was fitted into a flask filled with petroleum ether up to two-third. The solvent was boiled gently by adjusting the heat source so that it could siphon over the barrel. The filter paper was then removed. The filter paper plus the sample was placed in an oven at 100 ^oC and dried to a constant weight. It was cooled in a desiccator and then weighed (W_3). The percent fat extruded was calculated using equation 4.

$$\% \text{ fat} = \frac{W_2 - W_3}{W_2 - W_1} \quad (4)$$

➢ *Crude Protein*

Crude protein determination was carried out in three (3) steps. The first step involved digestion. 1.0 g of dried grinded sample and 15 ml of concentrated H_2SO_4 and 0.8 g of digestion catalyst mixture (400 g of Na_2SO_4, 16 g of hydrated $CuSO_4$ and 3 g selenium dioxide) were placed in the digestion flask. The mixture was heated gently until it no longer froths. The heat was increased for the contents of the flask to boil briskly. The mixture was digested until the solution lost its dark colour and became a clear blue solution. The flask was allowed to cool, after which the solution was diluted with water to 100 ml, of which 10 ml was transferred into Kjedahl distillation flask.

The second stage involved neutralization. The digestion flask is connected to a receiving flask by a tube, and the solution in the digestion flask is then made alkaline by addition of 10 ml of 40 % sodium hydroxide, which converted ammonium sulphate into ammonia gas. The NH_3 gas that was formed was liberated from the solution passed through the digestion flask into the receiving flask which contained an excess boric acid. The low pH of solution in the receiving flask converted the ammonia gas into the ammonium ion, and simultaneously converted the boric acid to borate ion.

The third stage involved titration process. where the nitrogen content was estimated by titration of the ammonium borate formed with standard hydrochloric using 0.06 g of methyl red and bromocresol green indicators to produce a pink solution.

➢ *Carbohydrate*

The total carbohydrate (TCHO) was estimated by difference, using equation 7.

TCHO = 100 – (% moisture + % ash + % crude fat + % crude fibre + % crude protein) (7)

➢ *Energy Estimation*

The energy of the samples was obtained by multiplying the values of crude fat, carbohydrate and crude protein by factors of 9,4,4 respectively. Sum of their product was calculated and the result was expressed in Kcal.

- *Determination of Vitamins*

Vitamins B_1 (Thiamin), B_2 (Riboflavin), B_3 (Niacin) and vitamin C were determined. The determinations were carried out as follows:

- *Determination of Vitamin B_1*

A mass of 5 g of the sample was measured and homogenised with 50 ml ethanoic sodium hydroxide. The mixture was filtered into a 100 ml conical flask, after which 10 ml of the filtrate was pipetted and added to 10 ml of potassium dichromate for colour development. Absorbance was read at 360 nm [15].

- *Determination of Vitamin B_2*

A mass of 5 g of the sample was measured and extracted with 100 ml of 50 % ethanol by shaking for 1 hr. This was filtered into 100 ml flask. 10 ml of the extract was pipetted into 50 ml volumetric flask. 10 ml of 5 % potassium permanganate and 10 ml of 30 % H_2O were added and was placed over a hot water bath for 30 minutes, followed by the addition of 2 ml of 40 % sodium sulphate. This was made up to 50 ml mark and the absorbance was measured at 510 nm [15].

- *Determination of Vitamin B_3*

A mass of 5 g of the sample was measured and treated with 50 ml of 0.5 M H_2SO_4. The mixture was agitated for 30 minutes. 3 drops of ammonia solution were added to the mixture and filtered. The filtrate was pipetted into a 50 ml volumetric flask and 5 ml of potassium cyanide was added. This was acidified with 5 ml of 0.01 M H_2SO_4 and the absorbance was measured at 470 nm [15].

- *Determination of Vitamin C*

The vitamin C content was determined using ascorbic acid as the reference compound. 200 µl of the extract was pipetted and mixed with 300 µl of 13.3 % of trichloroacetic acid and 75 µI of di-phenylpica hydrazine. The mixture was incubated at 37 ^oC for 3 hrs. 500 µI of 65 % H_2SO_4 was added and the absorbance was read at 520 nm [16]. Vitamins in the samples were calculated using equations 8 and 9.

$$\frac{Absorbance\ of\ sample}{\text{Conc.of sample}} = \frac{Absorbance\ of\ standard}{\text{Conc.of standard}} \quad (8)$$

$$\text{Conc. of sample} = \frac{Absorbance\ of\ sample \times Conc.\ of\ std}{\text{Conc.of standard}} \quad (9)$$

➢ *Determination of Anti-Nutritional Contents*

- *Determination of Tannin*

A mass of 0.2 g of finely grinded sample was weighed into a 50 ml sample bottle. 10 ml of 70 % aqueous acetone was added and properly covered. The bottle was put in an ice

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bath shaker and agitated for 2 hrs at 300 ºC. Each solution was then centrifuged and the supernatant was stored in ice cube. 0.2 ml of each solution was pipetted into test tube and 0.8 ml of distilled water was added. Standard tannin acid solutions were prepared from a 0.5 mg/ml of the stock and the solution made up to 1 ml with water. 0.5 ml of folin ciocatean reagent was added to both sample and standard, followed by 2.5 ml of 20 % Na_2CO_3. The solution was then incubated for 40 minutes at room temperature. Its absorbance was read at 725 nm against a reagent blank concentration of the same solution from a standard tannic acid. Calculation using the equation of a straight line, y = mx+c was done. m = slope of the graph of absorbance against concentration, y = absorbance, x = concentration [17].

- *Determination of Phytate*

A mass of 4.0 g of sample was soaked in 100 ml of 2 % HCl for 3 hrs and filtered through a No.1 Whatman filter paper. 25 ml of the filtrate was taken and placed inside a conical flask. 5 ml, 0.3 % of ammonium thiocyanate solution was added as indicator after which 53.5 ml of distilled water was added for acidification. This was titrated against 0.00566 g per milliliter of standard iron (III) chloride solution that contained about 0.00195 g of iron per milliliter until a brownish yellow colouration persisted for 5 minutes [17].

$$\text{Phytate} = T \times 8.24 \quad (10)$$

Where T is the titre value.

- *Determination of Oxalate*

A mass of 1.0 g of the sample was soaked in 75 ml 0.75 M H_2SO_4 for 1 hr and filtered through No. I Whatman filter paper. 25 ml of filtrate was transferred into a conical flask. This was titrated hot about (80 – 90 ºC) against 0.1 M $KMnO_4$ until a pink colour persisted for 15 seconds [18].

$$\text{Oxalate content} = T \times 0.9004 \quad (11)$$

Where T is the titre value

- *Determination of Saponin*

A mass, 2.0 g of finely grinded sample was weighed into a 250 ml beaker and 100 ml of isobutyl alcohol was added. The mixture was shaken for 5 hrs to homogenise and then filtered with No 1 Whatman filter paper into 100 ml beaker containing 20 ml, 40 % saturated solution of magnesium carbonate ($MgCO_3$). The resulting mixture was filtered through No 1 Whatman filter paper and a clean colourless solution was obtained. 1.0 ml of the colourless solution was pippeted into 50 ml volumetric flask and 2 ml of 5 % iron (III) chloride ($FeCl_3$) solution was added, and made up to the mark with water. It was allowed to stand for 30 minutes for the colour to develop. The absorbance was read against the blank at 380 nm. Equations 12 and 13 were used to calculate the saponin content.

$$\frac{Absorbance\ of\ sample}{\text{Conc.of sample}} = \frac{Absorbance\ of\ standard}{\text{Conc.of standard}} \quad (12)$$

$$\text{Conc. of sample} = \frac{Absorbance\ of\ sample \times Conc.of\ std}{\text{Conc.of standard}} \quad (13)$$

➢ *Determination of Antioxidant Contents*

- *Determination of Total Flavonoid*

Total flavonoid content (TFC) of the extract was determined using a colorimeter assay developed by [19]. 2 g of the sample was soaked in 100 ml of distilled water and left for 24 hrs. the mixture was filtered, and 0.2 ml of the extract was added to 0.3 ml of 5 % $NaNO_3$ at zero time. After 5 mins, 0.6 ml of 10 % $AlCl_3$ was added. After 6 minutes, 2 ml of 1M NaOH was added to the mixture followed by the addition of 2.1 ml of distilled water. Absorbance was read at 510 nm against the reagent blank. Flavonoid content was determined and expressed as mg equivalent.

- *Determination of Total Phenol*

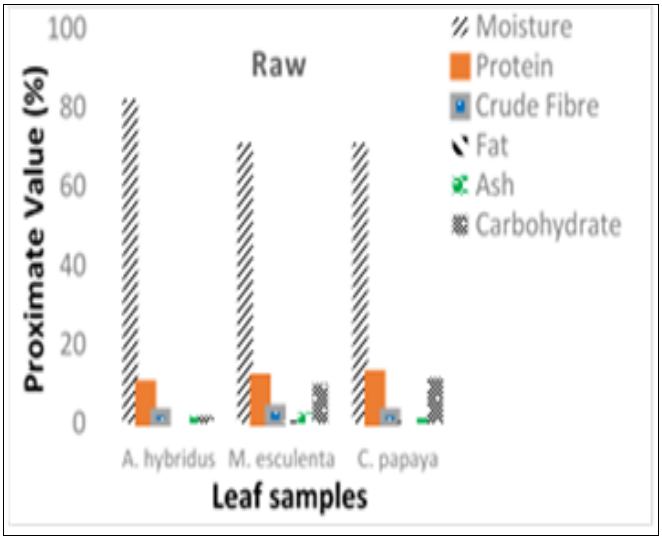
Total phenol content (TPC) of the extract was determined by using the method of [20]. A volume of 0.2 ml of the extract was mixed with 2.5 ml of 10 % Folin ciocaltean's reagent and 2 ml of 7.5 % sodium carbonate. The reaction mixture was subsequently incubated at 45 ºC for 40 minutes, and the absorbance was measured at 700 nm using spectrophotometer. Garlic acid was used as standard phenol.

- *Determination of Ferric Reducing Property*

The reducing property of the extract was determined by using the method adopted by [21], A volume of 0.25 ml of the extract was mixed with 0.25 ml of 2 M of sodium phosphate buffer (pH 6.6) and 0.25 ml of 1 % potassium ferrocyanide. The mixture was incubated at 50 ºC for 20 minutes. Thereafter, 0.25 ml of 10 % trichloro acetic acid was added and centrifuged at 2000 rpm for 10 minutes. Volume 1.0 ml of the supernatant was mixed with 1 ml of water and 0.1 % of $FeCl_3$ and the absorbance was measured at 700 nm.

III. RESULTS AND DISCUSSIONS

Results from the analysis of leaf samples and discussions are presented as follows: Fig. 1 represents the proximate composition of the raw, sun dried and oven dried (40 ºC and 60 ºC) leaf samples.



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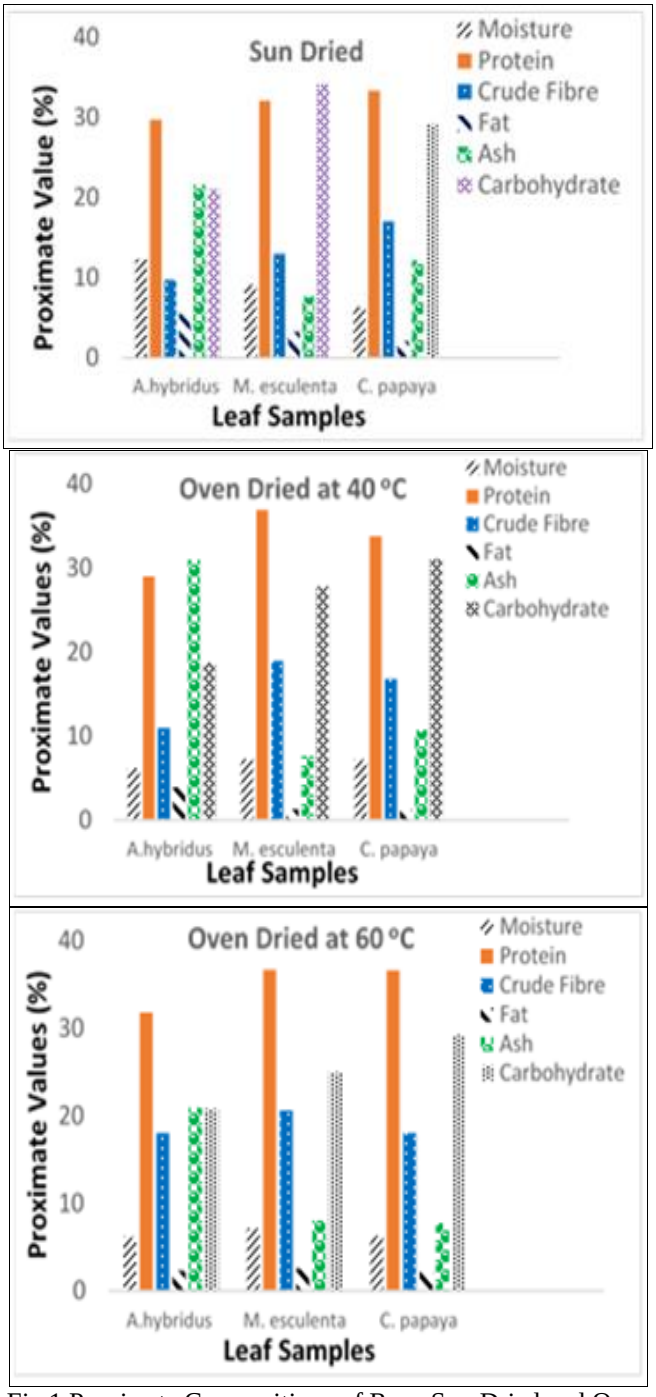

Fig 1 Proximate Compositions of Raw, Sun Dried and Oven Dried Leaf Samples

Fig. 1 shows the moisture contents of raw leaf samples ranging from 71.00 % in *C. papaya* to 82.15 % in *A. hybridus*. Moisture levels in sun dried samples ranged from 6.30 % in *C. papaya* to 12.32 in *A. hybridus*, indicating significant reduction in the moisture of all the leaf samples. Oven dried samples at 40 ºC and 60 ºC showed a further moisture reduction ranging from 6.25 % in *A. hybridus* to 7.30 % in *M. Esculenta* and 6.16 % in *A. hybridus* to 7.10 % in *M. Esculenta* respectively. Moisture generally reduced in all the dried samples. This could be due to higher heating effects offered by the oven. [1] and [22–25] reported similar observations of higher moisture content in fresh/raw leafy vegetables than the dried ones with values from 83.55 – 94.36 % > 8.07 – 16.27 %, 73.38 % > 12.8 – 20.40 %, 130.79 g/100 g d.m > 2.51 g/100 g d.m, above 6.93 % > 6.93 % and 72.43 % > 6.41 – 8.93 % respectively. [26] and [27] reported decreased moisture levels from 9.66 % raw/unfermented pawpaw seeds to 7.67 % treated/fermented seeds and 66.83 % raw/unfermented cassava flour to 49.55 % of fermented flour respectively. High levels of moisture indicates that the leaves are liable to perish within a short time due to microbial actions [27].

The protein content of the raw leaves ranged from 9.99 % in *A. hybridus* to 12.63 % in *C. papaya* leaves (Fig. 1). Protein content in sun dried samples increased with a range from 29.70 % in *A. hybridus* to 33.35 % in *C. papaya*. Oven dried samples at 40 ºC and 60 ºC showed a further increase in protein content with a range from 29.01 % in *A. hybridus* to 36.93 % in *M. esculenta* and 31.81 % in *A. hybridus* to 36.67 % in *M. esculenta* respectively. There was a general higher protein contents in oven dried samples than sun dried samples, except in *A. hybridus* at 40 ºC recording 29.01 % value less than 29.70 % from sun dried counterpart. This showed that increased temperature has caused increase in the protein component of the leaf samples. [1] reported similar observation of higher protein content in dried leafy vegetables than the raw vegetables in the range 1.36 raw – 23.62 % shade dried samples. [26] reported similar results of treated/fermented pawpaw seeds with a higher protein content of 24.50 % than the 22.32 % for raw/unfermented seeds. The result from this study however, disagrees with report from [27], where protein level of 2.333 % in raw cassava flour was higher than 1.367 % of treated cassava mash, and that from [23] with 15.54 g/100 g d.m protein in fresh *K. oblonga* leaves higher than 11.74 g/100 g d.m in the dried sample. This disagreement may be due to different drying method, the Parabolic Shaped Solar Dryer and microwave assisted used respectively.

In Fig. 1, Crude fibre components of the raw leaves from this study ranged from 2.91 % in *C. papaya* leaves to 3.90 % in *M. Esculenta* leaves. In sun dried samples, crude fibre increased with a range from 29.70 % in *A. hybridus* to 33.35 % in *C. papaya*. Crude fibre increased in all leaf samples oven dried at 40 ºC and 60 ºC with a range from 11.00 % in *A. hybridus* to 18.99 % in *M. Esculenta* and from 18.01 % in *A. hybridus* to 20.61 % in *M. Esculenta* respectively. [1] reported similar observation of higher crude fibre content in dried leafy vegetables than the raw vegetables in the range 1.87 – 39.36 % from raw to oven dried samples, just as [23] reported higher fibre 60.83 g/100 g d.m in dried *K. oblonga* leaves than 41.99 g/100 g d.m fresh. There was a general higher crude fibre contents in treated dried samples than the raw samples. Same trend was observed by [22] who reported higher fibre (3.54 – 4.02 %) in dried bitter leaf than the 1.62 % raw. However, [27] reported contrary observation of raw/wholesome cassava flour having a higher protein content of 5.850 % than the 2.200 % treated cassava mash. The oven dried samples at 60 ºC however, showed the highest fibres. This suggests that increased temperatures increase the fibre contents of the samples with the exception of *C. papaya* oven dried at 40 ºC recording 16.79 % value slightly lower than 17.00 % from its sun dried leaf. Presence of high crude fibre in leaves eases nutrient absorption and helps bowel movement [28].

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Fat content from Fig. 1 in of *A. hybridus* raw leaf samples ranged from 0.15 % to 5.57 % in sun dried. Same trend was recorded for raw *M. esculenta*, which ranged from 0.58 % to 3.25 % in sun dried. In raw *C. papaya*, fat content ranged from 0.53 % to 2.14 % in 60 ºC oven dried. Lowest values of fats were recorded in all the raw leaf samples. This implied that temperature increases the fat content of the leaf samples, and even appreciably in sun dried *A. hybridus* leaves. [1] reported similar observation of higher lipids content in dried leafy vegetables than the raw vegetables in the range 0.25 – 7.66 % from raw to shade dried samples, just as [22] and [23] reported 1.84 – 2.64 % and 2.73 g/100 g d.m lipids respectively in dried bitter leaf and dried *K. oblonga* leaves respectively higher than in 0.62 % and 2.50 g/100 g d.m fresh respectively. [26] and [27] reported similar trend, in which treated/fermented pawpaw seeds recorded higher fat content than raw/unfermented seeds from 40.29 – 42.60 % and raw/wholesome cassava flour 1.100 – 3.88 % treated cassava mash respectively. Generally, leafy vegetables are poor sources of fat [29–30] as observed in this study.

Ash content of the leaf samples as in Fig. 1 ranged from 1.34 % in raw *C. papaya* to 31.00 % in 40 ºC oven dried *A. hybridus*. Raw samples of all the leaves recorded lowest ash contents. This means that application of heat increased the ash component of the leaf samples. This could be attributed to the fact that heat does not destroy the inorganic component of food but destroys the organic counterparts. [22–23] and [1] reported 10.38 – 11.20 %, 7.45 g/100 g d.m and 6.68 – 21.81 % ash respectively in dried bitter leaf, *K. oblonga* leaves and dried leafy vegetables respectively higher than in 2.56 %, 6.71 g/100 g d.m and 0.38 – 1.51 % fresh respectively. [26] reported ash content being higher, 7.46 % in treated/fermented pawpaw seeds than the 6.41 % raw/unfermented seeds. Conversely, [27] reported a higher value 7.430 % raw/wholesome cassava flour than the 1.667 % treated cassava mash.

Carbohydrate contents are generally higher in *C. papaya* for all treatments, with the values ranging from 11.59 – 31.02 %, except in sun dried *M. esculenta* with 34.08 % (Fig. 1). *A. hybridus* recorded lowest values which ranged 2.06 – 21.03 %. Sun dried samples showed the highest carbohydrate content, especially in *M. esculenta* and *C. papaya* with the order sun dried > 40 ºC oven dried > 60 ºC oven dried > raw. These observations implied that heating effect increased the carbohydrate content of leaves. [1] and [24] reported similar observations of higher carbohydrate content in dried leafy vegetables in the range 2.59 – 59.74 % from raw to shade dried samples, and 95.38 % in dried vegetable samples respectively. This also agrees with lower value of 14.787 % raw/wholesome cassava flour than the 58.767 % treated cassava mash reported by [27]. This trend however, deviates from report by [26], that carbohydrate level in treated/fermented pawpaw seeds (11.00 %) was lower than in untreated ones (15.85 %) and that reported by [23] of 17.25 g/100 g d.m carbohydrate lower in dried *K. oblonga* leaves than 33.26 g/100 g d.m fresh. Difference in carbohydrate compositions of the studied leaf samples may be due to their physiological and structural differences.

Energy evaluation of the leaf samples was determined. The results are presented in Table 1.

Table 1 Energy Content of Leaf Samples with Different Drying Methods

Leaf Samples	Treatment	Energy (cal)
A. hybridus	Raw	51.95
	Sun dried	253.05
	Oven dried (40^0C)	215.00
	Oven dried (60^0C)	230.67
M. esculenta	Raw	92.06
	Sun dried	296.87
	Oven dried (40^0C)	290.76
	Oven dried (60^0C)	249.90
C. papaya	Raw	101.65
	Sun dried	268.45
	Oven dried (40^0C)	270.15
	Oven dried (60^0C)	282.66

The energy content of the leaves ranged from 51.95 in raw *A. hybridus* to 290.76 cal. in sun dried *M. esculenta* (Table 1). The energy values of the leaf samples correspond relatively to their carbohydrate/fat compositions in the order sun dried > 60 ºC oven dried > 40 ºC oven dried > raw for both *A. hybridus* and *M. esculenta*. However, the energy value is least in the raw leaves of all the samples, and *M. esculenta* recorded the lowest energy content for all sample treatments. The result obtained in this research is similar to that reported by [1] of higher energy content in dried leafy vegetables than the raw vegetables in the range 15.41 – 300.59 kcal from raw to shade dried samples.

Anti-nutrient analysis of the selected leaf samples was carried out. The results are as presented in Fig. 2.

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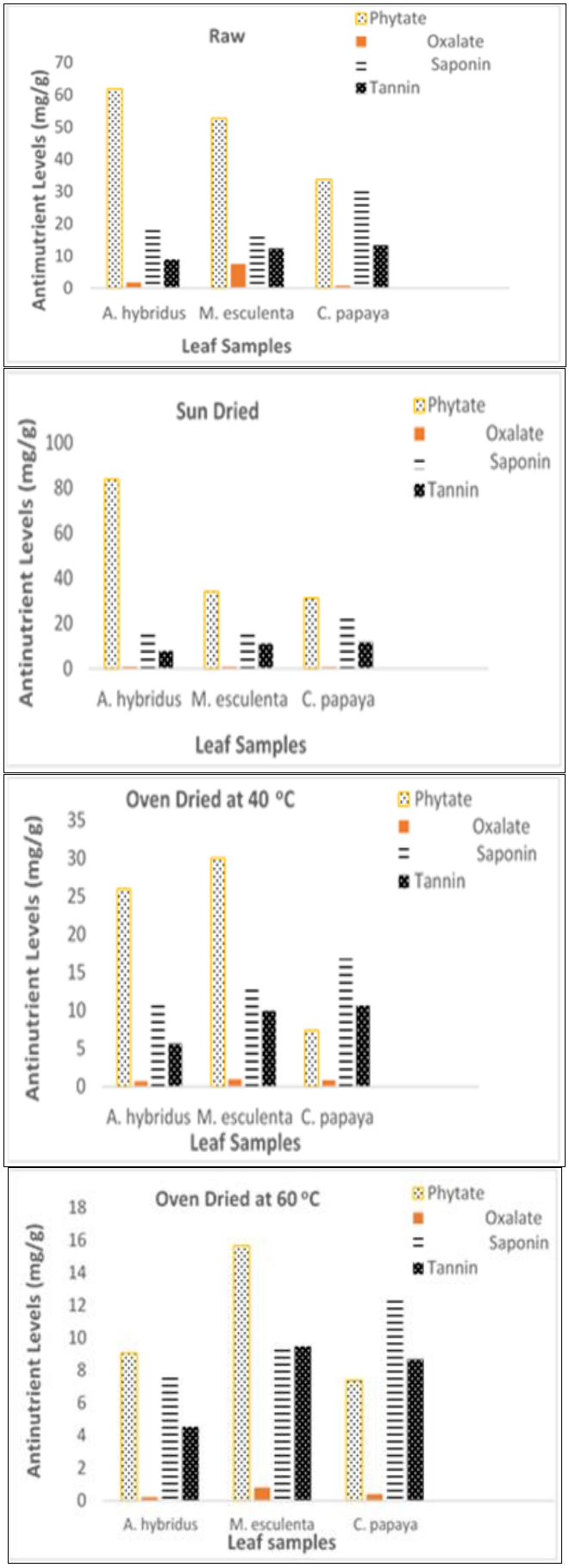

Fig 2 Anti-nutrient Levels of Raw, Sun Dried and Oven Dried Leaf Samples

Fig. 2 revealed that the drying methods reduced antinutrient contents of the samples. Phytates are least found in *C. papaya* leaves regardless of treatment methods. Phytates values of raw samples ranged 33.78 – 61.80 mg/g from *C. papaya* leaf to *A. hybridus*. Phytate concentrations in dried samples ranged from 7.39 – 83.78 mg/g. These values are much higher than the values of 3.63 – 11.41 mg/100 g and 22.18 – 35.29 mg/100 g reported for raw and dried leafy vegetables respectively by [1]. All drying methods are revealed to have caused loss of phytates (7.39 – 34.20 mg/g), more significantly with oven drying, except in sun dried *A. hybridus* (83.78 mg/g). This observation contradicts the report from [1], where the levels of phytates increased in the dried samples of leafy vegetables. [31] also reported higher phytates in dried sweet (2.33 – 4.12 mg/kg) and bitter (1.64 – 2.89 mg/kg) cassava leaves than the fresh leaves 2.16 mg/kg and 1.84 mg/kg respectively. Phytates level also increased in dried *A. hybridus* to 25.39 – 34.39 mg/100 g as reported by [32] from 19.42 mg/100 g in the wet samples. The disparity in values may be due to the varietal differences of the samples and the methods of drying.

Oxalate content of the raw leaf samples ranged 0.86 – 7.58 mg/g from C. *papaya* to *M. esculenta* (Fig. 2). [1] reported lower values of 37.04 – 93.48 mg/100 g oxalates for raw leafy vegetables. Oxalate levels in all the leaf samples in this study decreased with sun drying, and further reduction was observed with oven drying at 40 ºC and 60 ºC. Oven drying at 60 ºC recorded the lowest oxalate values. This however, contradicts the findings by [1] who reported increased concentration of 163.40 – 914.30 mg/100 g oxalates in dried samples of leafy vegetables. In the same vein, [32] also reported higher oxalates in dried sweet (1.12 – 1.23 mg/kg) and bitter (1.48 – 1.62 mg/kg) cassava leaves than the fresh leaves 0.77 mg/kg and 0.94 mg/kg respectively. Oxalates level reportedly increased in dried *A. hybridus* to 6.17 – 14.18 mg/100 g from 2.14 mg/100 g in the wet samples [32]. High oxalates in human body are known to be harmful as it binds to calcium and prevent its absorption [33].

Fig. 2 showed that saponin composition in the raw leaf samples ranged 16.09 – 31.45 mg/g from *M. esculenta* to *C. papaya*. Variations in values obtained may probably be due to agronomic factors and method of analysis. The drying methods employed in this study caused reduction in saponin content of the samples, with oven drying being more effective. This agrees with the findings of [32] who reported lower saponin level of 4.00–8.34 mg/100 g in dried *A. hybridus* than the 8.40 mg/100 g in the wet samples, and that of [34] having saponin levels in oven dried *A. hybridus* as 1.37 – 1.46 mg/100 g lower than 1.76 mg/100 g fresh samples. Decrease in saponin contents signifies its degradable sensitivity to increased temperatures [34]. Conversely, findings by [35] revealed higher values (1.62 – 1.68 mg/100 g) of saponin in dried *A. hybridus* than in the fresh samples (1.59 mg/100 g). Disparity could arise from varied samples processing and treatment methods. However, [35] reported reduction in saponins content after the drying methods were variedly doubled.

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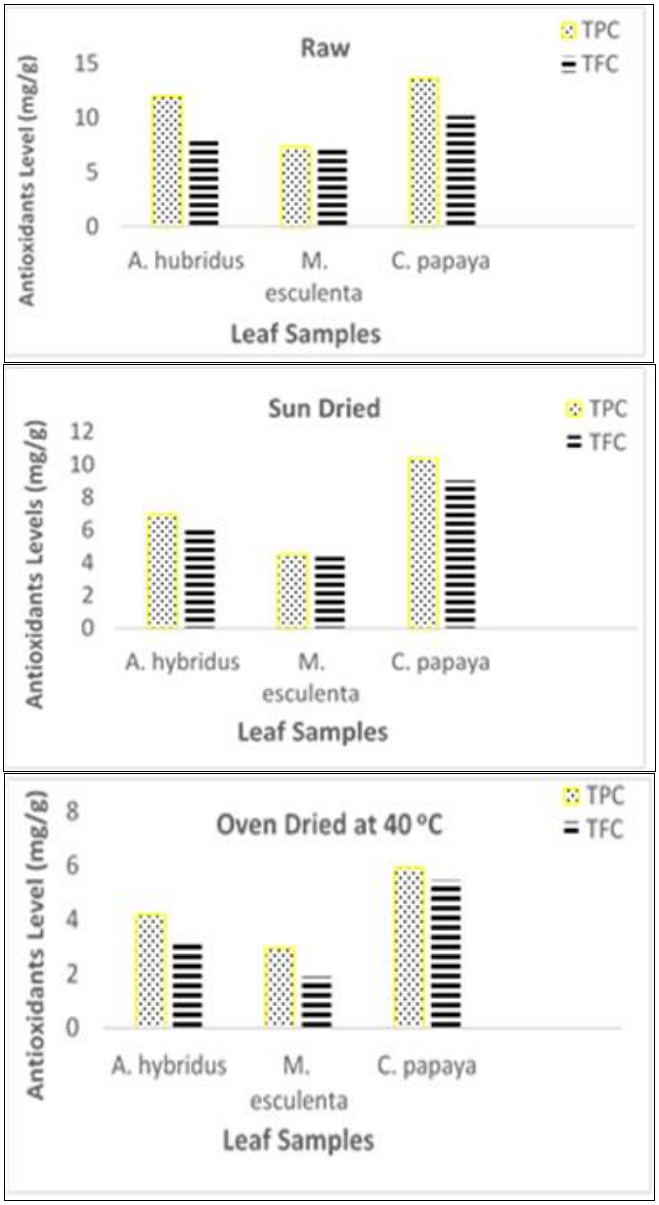
Tannin content of the studied leaves are presented in Fig. 2 with values ranging 8.91 – 13.41 mg/g from *A. hybridus* to *C. papaya* leaves. Tannins are least present in *A. hybridus* leaves among other samples, regardless of treatment methods. The different drying methods employed in this study reduced the levels of tannin in the samples, with oven drying being more effective with increased temperature. This observation differs from that reported in cassava leaves by [36] where sun dried leaves (7.60 mg TAE/mL) showed more loss of tannins than the oven dried leaves (8.35 mg TAE/mL). [31] also reported differing findings of lower tannin in fresh sweet (0.92 mg/kg) and bitter (0.85 mg/kg) cassava leaves than the dried leaves 0.98 – 1.52 mg/kg and 1.33 – 1.42 mg/kg respectively. Also, [32] reported increased tannin levels in dried *A. hybridus* to 3.60 – 3.90 mg/100 g from 1.69 mg/100 g in the wet samples. The difference in the findings may be due to difference in the drying temperatures and the leaves pretreatment methods.

Antioxidants examined in the leaf samples are phenols and flavonoids. Their concentrations in the samples are presented in Fig. 3.



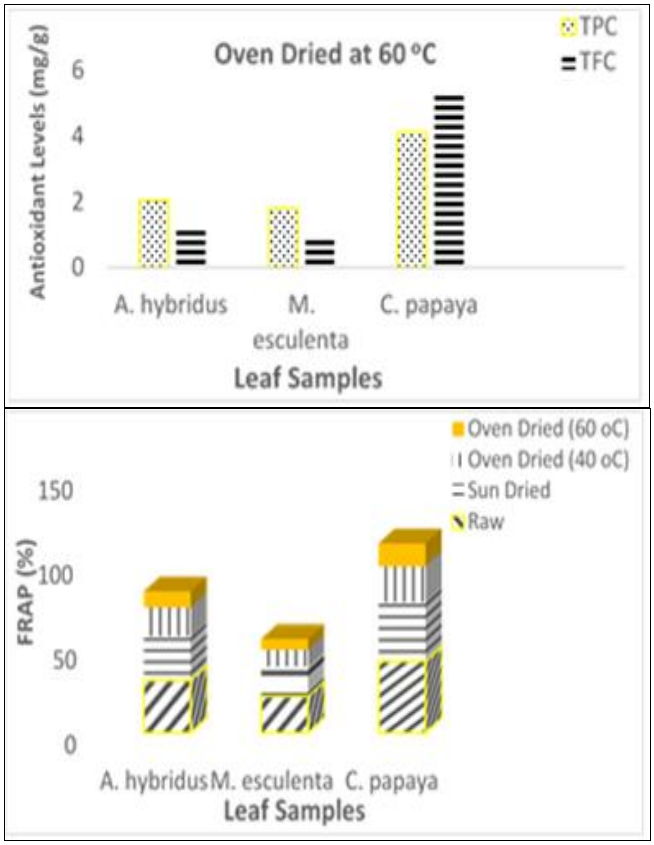


Fig 3 Antioxidant Levels and FRAP in Raw, Sun Dried and Oven Dried Leaf Samples

Considering Fig. 3, total phenol content (TPC) of the raw leaf samples vary. The TCP ranged 7.40 – 13.65 mg/g with highest value and lowest values recorded for *C. papaya* and *M. esculenta* leaves respectively. Sun dried samples showed reduction of TPC within the range 4.52 – 10.37 mg/g. Oven dried samples showed further TPC reduction as temperatures increased from 40 – 60 °C. This partially agrees with the lower phenol levels 19.03 and 22.25 mg RE/mL in sun and oven dried cassava leaves respectively, reported by Diniyah *et al.* (2024) against the 31.88 mg RE/mL fresh leaves: sun drying caused more loss of phenols. Conversely, results of dried *A. hybridus* leaves with higher phenols 0.30 – 0.35 mg/100 g than 0.23 mg/100 g of shredded samples was reported by Akubugwo *et al.* (2020). Variations in these findings may be as a result of storage condition, cultivar, agricultural practices and maturity (Akubugwo *et al.*, 2009).

Fig. 3 revealed the total flavonoid content (TFC) of the raw leaf samples ranging 7.28 – 10.19 mg/g from *M. esculenta* to *C. papaya* leaves. Further TFC reduction was caused in oven dried samples at 40 °C within the range 1.89 – 5.44 mg/g from *M. esculenta* to *C. papaya* leaves, which reduced further at 60 °C within 0.83 – 5.29 mg/g from *M. esculenta* to *C. papaya* leaves. This could imply thermal instability of flavonoids in the samples. These findings however, contradict flavonoid contents of dried *A. hybridus* (0.68 – 0.83 mg/100 g) reported by Akubugwo *et al.* (2020), as being higher than the shredded samples (0.46 mg/100 g), but partially agrees with the quote of lower flavonoid levels 105.6 and 113.31 mg RE/mL in sun and oven dried cassava leaves respectively reported by Diniyah *et al.* (2024) against the 133.41 mg RE/mL fresh leaves: sun drying caused more

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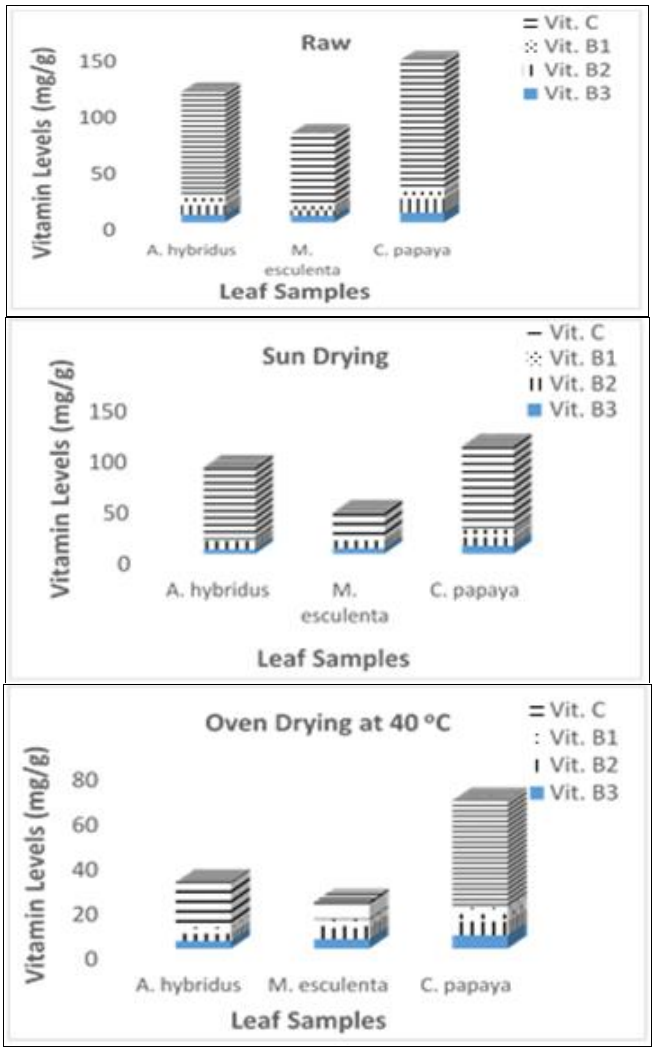
loss of flavonoids. TFC in the raw and dried leaf samples of this study follows the order *C. papaya* > *A. hybridus* > *M. esculenta*.

The iron reducing antioxidant property (FRAP) (Fig. 3) for the raw samples ranged from 21.51 – 42.12 % with highest values in *C. papaya* and lowest values in *M. esculenta*. Sun dried samples revealed reduction in the FRAP content within the range 17.39 – 34.79 %. Oven dried samples at 40 ºC showed further FRAP reduction (9.79 – 20.93 %), which even furtherly reduced within the range 6.53 – 13.59 % at 60 ºC oven drying. [36] reported FRAP value of 36.17 mg Fe^{2+}/mL in fresh cassava leaves. This value was slightly lower than the 34.37 mg Fe^{2+}/mL recorded in oven treatment. Further reduction to 30.32 mg Fe^{2+}/mL was recorded in sun dried cassava leaves. [37] reported 55.50 – 59.06 % FRAP for different varieties of *M. esculenta* leaves. Antioxidants at moderate levels are biologically useful for combating oxidative stress species. The FRAP results from this study revealed that heating or increased temperature is not suitable for retaining the antioxidant properties of the leaf samples.

Vitamins such as ascorbic acid, thiamin, riboflavin and niacin were determined. Vitamins composition of the raw, sun and oven dried leaf samples determined are presented in Fig. 4.



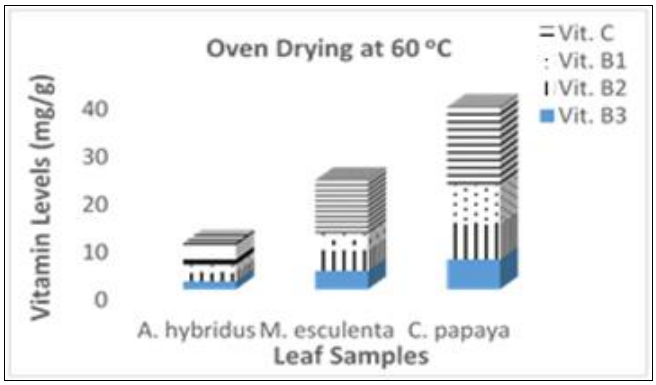


Fig 4 Vitamin Levels of Raw, Sun Dried and Oven Dried Leaf Samples

Fig. 4 at a glance, showed that drying treatments significantly reduced the levels of all vitamins understudied, at $P < 0.05$ in the order 60 ºC oven dried > 40 ºC oven dried > sun dried. Oven dried samples at 60 ºC, however, showed the lowest levels of vitamin C. In the raw, sundried, oven dried at 40 ºC and 60 ºC samples, the value of vitamin C ranged 63.72 – 116.19 mg/g from *M. esculenta* to *C. papaya* leaves, 25.61 – 80.33 mg/g from *M. esculenta* to *C. papaya* leaves, 7.66 – 47.68 mg/g and 4.62 – 16.38 mg/g both from *A. hybridus* to *C. papaya* leaves respectively. Loss of vitamin C could be attributed to its high proneness to oxidative destruction in the presence of heat [7]. In all, the leaves of *C. papaya* recorded the highest levels of vitamin C. Lowest level was recorded in *A. hybridus* oven dried at 60 ºC. [34] reported 36.25 mg/100 g vitamin C in raw *A. hybridus*, slightly lower than 37.85 mg/100 g at 40 ºC oven drying and higher than 33.80 mg/100 g at 60 ºC oven drying. [7] reported lower values of vitamin C ranging from 0.141 – 0.757 mol/cm for varieties of fresh vegetables than 0.346 – 1.854 mol/cm dried vegetables, irrespective of drying methods used, and [25] reported 29.25 % vitamin C retention in 40 ºC oven dried cassava leaves as against the 75.68 % recorded at 80 ºC from 100 % in the raw leaves. This could be due to differences in the drying durations. Recommended dietary allowance for vitamin C is 75 mg per day for women and 90 mg per day for non-smoking men [38]. Raw leaf samples in this study appears sufficient to meet the daily requirements for ingestion of vitamin C. For the dried samples, consumption of larger quantity of the leaves may be recommended.

Thiamin (vitamin B_1) as shown in Fig. 4 was low in *M. esculenta* for all drying treatments, and in *A. hybridus* oven dried at 40 and 60 ºC. Vitamin B_1 values ranged from 1.63 – 9.99 mg/g from *A. hybridus* oven dried at 60 ºC to the raw *C. papaya* leaves. Vitamin B_1 was affected by heating as indicated by its decrease in all the dried samples in the order oven dried 60 ºC > oven dried at 40 > sun dried > raw, except in 40 ºC oven dried *C. papaya* leaf, in which the decreasing pattern was distorted. [5] reported closely similar trends with values ranging 0.68 – 4.22 mg/100 g of thiamine irrespective of the fresh leafy vegetables and drying methods, higher than the range 0.31 – 3.98 mg/100 g irrespective of the dried leafy vegetables and drying methods. [39] reported 2.45 mg/100 g for *A. hybridus*. Recommended dietary allowance for vitamin B_1 is 1.2 mg per day for men, 1.1 mg per day for women. To

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this end, vitamin B_1 in the studied leaves is best recommended for consumption after oven drying.

Riboflavin (Vitamin B_2) in the samples under all conditions of treatments as recorded in Fig. 4 ranged 1.77 – 9.48 mg/g from *A. hybridus* oven dried at 60 ºC to the raw *C. papaya* leaf. All drying methods reduced the riboflavin contents in all the samples in the order sun > 40 ºC oven dried > 60 ºC oven dried, except for 7.30 mg/g, 40 ºC oven dried which was higher than 6.17 mg/g, 60 ºC oven dried in *C. papaya* leaf. [5] reported, though lower values compared to this study, but closely similar trends with values ranging 0.71–1.49 mg/100 g of riboflavin irrespective of the fresh leafy vegetables and drying methods, higher than the range 0.31 – 0.97 mg/100 g irrespective of the dried leafy vegetables and drying methods. [40] published values ranging from 0.12 mg/100 g to 0.15 mg/100 g for different cassava leaf varieties. [39] recorded 4.24 mg/100 g for *A. hybridus*. The recommended dietary allowance for riboflavin is 1.3 mg per day for men, and 1.1 mg per day for women [38]. Ingestion of vitamin B_2 through consumption of the studied leaves appears feasible only when dried.

Niacin (Vitamin B_3) acts as a coenzyme for oxidation/reduction reactions. Its concentrations in the samples ranged 1.66 – 8.64 mg/g from *A. hybridus* oven dried at 60 ºC to the raw *C. papaya* leaf. Vitamin B_3 recorded lowest values in *C. papaya* leaves irrespective of treatment methods, and in raw and sun dried *A. hybridus* leaves as well. All drying methods reduced the Vitamin B_3 contents in all the samples in the order sun > 40 ºC oven dried > 60 ºC oven dried, except in *C. papaya* leaf where value of 6.26 mg/g, 60 ºC oven dried was higher than 5.96 mg/g, 40 ºC oven dried. [40] recorded values from 0.35 mg/100 g to 0.43mg/100 g for varieties of cassava leaves. [39] recorded 1.54 mg/100 g for *A. hybridus*. The recommended dietary allowance for niacin is 16 mg per day for men and 14 mg per day for women [38]. The results obtained for raw samples in this study indicate meeting the daily requirements for the ingestion of vitamin B_3 by consuming the leaves freshly prepared.

Generally, vitamin C recorded highest values across all samples regardless of type of treatments. Vitamin B_1 and B3 recorded the lowest values in *M. esculenta* and *C. papaya* leaves respectively. All vitamins occur at highest levels in all raw samples, and are reduced by heat through the drying methods in the order of raw > sun dried > oven dried at 40 and > oven dried 60 ºC, except in few cases of irregularity between oven drying at 40 ºC and at 60 ºC.

IV. CONCLUSION

The findings from this study showed that proximate-nutrient, anti-nutrients, antioxidants and vitamins determined were present in the leaf samples and were affected at varied degrees by the drying methods. This resulted into reduction in the levels/concentrations of most of the parameters analysed, including the proximates, antioxidants and vitamins, which are considered as very important for proper functioning of the body. Sun drying had the best proximates, antioxidants and vitamins retention irrespective of the leaf samples, followed by oven drying at 40 ºC, while oven drying at 60 ºC is best suitable for the reduction of concentrations of the anti-nutrients. Except for the vitamins whose values are dangerously reduced by the drying methods. All treatments showed appreciable amounts of phytochemical constituents in the leaf samples, which makes them recommendable for consumption as food, herbs and medicines.

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