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Nutrient, phytochemical and carotenoid profiles of two cultivars of Pterocarpus santalinoides (nturukpa) as affected by selected processing methods

Immaculata I Okparauka
Federal Polytechnic Uwana, Afikpo, Ebonyi State, Nigeria
Philippa C Ojimelukwe
philippaco60@gmail.com
Michael Okpara (Federal) University of Agriculture, Umudike https://orcid.org/0000-0002-0263-0597

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Abstract

Two cultivars of *Pterocarpus santalinoides* (*Nturukpa)* (light green *Avuo* and dark green *oseleukwu)* were investigated for their nutrient composition, phytochemical content and carotenoid profiles. The effects of oven-drying at 55^{0}C for 1h 20 min; sauteeing in palm oil for 3 min and blanching in boiling water for 5 min on the nutrients and phytochemicals were evaluated. The nutrient content showed that the leaves were rich in protein (14.0%) and vitamin B6 73mg/100g). The leaves are also moderate sources of iron (6.2-7.4%), magnesium (42-44%), zinc (1.2%) and potassium (45.0-55.0%). Raw light green Avuo contained the highest amount of folate (vitamin B_9). The pheolic contents, cyanogenic glycosides, anthocyanins, and phytates of the two *P. santalinoides* cultivars were statistically similar (p>0.05). Steroids, oxalate, tannins and alkaloids (7.7%) were higher in the light coloured cultivar (Avuo) while saponins and flavonoids (1.1%) were higher (p <0.5) in the dark green cultivar (Oseleukwu). The α-carotene, trans-β-carotene, and total β-carotene contents of the two *P.santaniloides* cultivars were statistically similar (P> 0.05). The most predominant peak in the chromatogram of the *P. santalinoides* was trans-beta-carotene. The nutrient and phytochemical composition of the two cultivars of *P. santalinoides* indicate that they are good sources of micronutrients and possess medicinal value.

Introduction

Pterocarpus santalinoides L' Herit ex DC., is a deciduous tree found in the wild in West Africa which belongs to the family Papilinoidea (Ngwa and Nnam, 2018). It is also found in South. America - Paraguay, Brazil, Bolivia, Peru, Ecuadoe, Colombia, Venezuela, the Guyanas; and the Caribbeean (Agidew, 2022). .The young leaves are used as cuilinary vegetable .in Nigeria. The raw seed is toxic but can be eaten when roasted. Its common names include nturukpa (Igbo), gbengbe (Yoruba), gunduru (Hausa), ikyarakwa or kereke (Tiv), and uturukpa. Available literature suggest that *P. santalinoides* (Igede).possess significant antioxidant and hypolipidemic activities. Further studies may be needed to demonstrate the importance of *P. santalinoides* in the treatment of diseases associated with oxidative stress and hyperlipidemia. In traditional settings in rural Nigeria, *P. santalinoides* bark, roots and leaves are commonly used in medicinal preparations. They may be taken to treat bronchial complaints, amoebic dysentery, stomach-ache and sleeping sickness; to prevent abortion and ease childbirth, and as a tonic. The leaf is used for treatment of stomach ache, diarrhea, and diabetes mellitus and to enhance wound healing (WHO, 2022). *Pterocarpussantalinoides* is commonly used in Cameroonian traditional medicine for the treatment of cardiovascular diseases, including hypertension (Rahman, 2022). Previous researches revealed that the presence of some bioactive compounds such as flavonoids, tannins, saponins, steroids, alkaloids and triterpenoids which could be responsible for the ethnobotanical uses of *Pterocarpus santalinoides* (Madubuike *et al.,* 2020; 2021). The role of underutilized green leafy vegetables in combating hidden hunger (micronutrient deficiencies) and promoting food securitycannot be overemphasized (Ojimelukwe and Okpalanma 2023) This underutilized food source with additional health benefits requires further research to justify its utilization. The present research addresses the need for in-depth compositional analysis of the nutrient, phytochemicals, carotenoid profile of two cultivars of *P. santalinoides* leaves which will scientifically ascertain their traditional uses and suggest their potential use as food and as medicine. The effect of selected processing methods on the nutrients will also be investigated.

MATERIALS AND METHODS

Procurement of samples

The fresh tender leaves of two cultivars of *Pterocarpus santalinoides* (*Nturukpa*) were bought from Eke Market Afikpo North Local Government of Ebonyi State, bagged separately in polythene bag.

Sample preparation

At the laboratory, the two varieties of *P. santalinoides* twigs were destalked, and the tender leaves selected, washed in potable water, drained and sliced into 1.5 m pieces. The sliced leaves were divided into four 500g portions and each portion was subjected to a different processing method (oven drying at 50^0C for 1h 20 min; sauteeing with 20 ml of palm oil for 3 min; blanching at 100 ^{0}C boiling water). The raw samples were used as the controls.

3.2 Determination of nutrient content

The moisture content, ash, protein, fat, crude fibre and carbohydrate were determined according to the •standard methods of Association of Official Analytical Chemists (AOAC), (2000). The values obtained for protein, fat and carbohydrate were used to calculate the energy content of the samples. Calcium and magnesium contents of the sample extract were determined by the Versanate EDTA complexiometric titration method, described by AOAC (2000). The atomic absorption spectrophotometer (AAS) was used to determine the concentration of trace elements as described by AOAC (2000). The iodine value of the samples was determined by Wijs method (Mary and Adeniyi, 2012). Vitamins B_1, B_2, B_3, $B_{6,}$ and vitamin E were determined according to the method described by AOAC (2000). The vitamin C content of the samples was determined using 2, 4-dinitrophenyl hydrazine (DNPH) method as described by AOAC (2000).

3.2 Determination of Phytochemicals:

Preliminary qualitative phytochemical screening of extract was carried out to determine the presence of secondary metabolites using the method described by Harbone (1998). Alkaloids were qualitatively detected by dragendroff reagent (potassium bismuth iodide), flavonoid by Benedict’s solutions, and saponin by frothing test, tannin by Wohler’s test and phenol by Ferric chloride solution as described by Ajuru *et al*. (2017). Saponins, total phenol and tannins in the leaves of *Pterocarpus santalinoides* were determined spectrophotometrically (Okwu, 2005) by Folin-Ciocalteu method (Jahan *et al*., 2011). The method described by AOAC (2000) was used for the determination of phytic acid. Alkaloid content was determined using the alkaline precipitation gravimetric method (AOAC, 2000). The Folin- Dennis colorimetric method as described by Kirk and Sawyer (1998) was used to determine tannin content in the sample. Flavonoid content was determined according to the method by AOAC (2000). Oxalate was determined by the method as described by Iwuoha and Kalu (1995). The alkaline titration method of AOAC (2000) was used for the determination of cyanogenic glycoside in the sample

3.3 Protocol for carotenoid analysis of vegetables:

Only the raw and sautéed leafy green vegetables were used for the determination of the carotenoid profile. Chromatographic peaks were identified based on the standards available.

Sample Extraction

A portion of about 10 g of homogenous sample was weighed into a mortar and about 3 g of hyflosupercel (celite) was added. The mixture was ground with 50 ml of cold acetone. After proper maceration in the mortar, the mixture was filtered with suction using a Buchner funnel with filter paper. The mortar, pestle, funnel, and residue were washed with small amounts of acetone, receiving the washings in the suction flask through the filter paper. Extraction was repeated 3-4 times until the final residue washed with acetone until it was devoid of color.

Partition to petroleum ether

The extract was *trans*ferred into a chromatographic column which was previously packed with Alumina and made wet with petroleum ether (to remove chlorophylls and other esters that could interfere with the analysis). The collected fraction was then *trans*ferred to 500 ml separating funnel with Teflon stop cock. Twenty (20) ml of petroleum ether (PE) was added, followed by addition of 300 ml of distilled water slowly along the walls of the funnel without shaking to avoid formation of an emulsion. The two phases were allowed to separate, and the aqueous lower phase was discarded.

About 200 ml of distilled water was added for about 4 times to wash and remove any residual acetone. During the last washing, it was ensured that the lower phase was completely discarded while the upper phase was retained. The petroleum ether phase was collected in a 25 ml volumetric flask making the solution pass through a small funnel containing anhydrous Sodium sulfate (about 15 g) to remove residual water. The funnel is washed with petroleum ether and collecting washings into the volumetric flask. Volume was made up to mark using Petroleum ether and the total carotenoids was determined spectrophotometrically. The total carotenoids (TC) content was calculated using the formula:

TC (µg/g) = A× volume (ml) × 10^4 /$A^{1\ \%}$ 1cm × sample weight (g)

Where A = absorbance;

Volume = total volume of extract: 25ml

$A_{1\ \%cm}$ = absorption coefficient of carotene in PE (2592)

Identification of the carotenoid

High performance Liquid Chromatograph (HPLC) technique was used. Separation of carotenoids in samples was carried out using Waters e2695 HPLC systems equipped with a photodiode Array (PDA) Detector. The Petroleum ether extract in the extraction steps above was concentrated and dried under nitrogen gas. It was reconstituted in 1mL of dichloromethane: methanol (50:50), and filtered through 0.22 mm PTFE syringe filter (Millipore) directly into injection vials and 10μL was injected into the system.

High performance Liquid Chromatograph (HPLC) conditions were:

Mobile phase: 50 % Methyl-tert-butyl ether (MTBE): 50 % Methanol

Column: Polymeric YMC $C_{30,}$ 5μm, 4.6 × 250mm

Isocratic elution for 10 min

Flow rate: 1ml / min

Equilibration: 10 min

Injection volume: 20μl

Identification and Quantification

Chromatograms were generated at 450 nm and identification of Lutein, α-carotene and ***β***-carotene (cis and *trans* isomers) were done using external standards based on the calibration curve and verification of absorption spectrum and co-elution with available authentic standards. .

3.4 Statistical Analysis

Data were analyzed using Statistical Package for Social Sciences (SPSS) version 23 (IBM SPSS) Incorporated, Chicago, IL, USA). One way analysis of Variance (ANOVA) was used to analyze the results. Mean of duplicate values were obtained and separation of means were carried using Duncan Multiple Range test. Means were separated at ($p<0.05$) confidence level.

RESULT AND DISCUSSION

Morphological description of *Pterocarpus santalinoides* leaves

Two cultivars of *Pterocarpus santalinoides (Nturukpa)* leaves (light green cultivar locally known as *Avuo* and dark green cultivar with a harder texture, locally known as *Oselukwu* were used for this research work. They are both forest trees.

Effect of processing methods on the proximate composition of two cultivars of *Pterocarpus santalinoides*

The effect of processing methods on proximate composition of two cultivars of *Pterocarpus santalinoides* (Light green Avuo and Dark green Oseleukwu) is shown in table 1. All the proximate parameters of the leaves were significantly affected by processing. Oven dried samples had higher fibre, ash and protein contents. Sauteed samples had higher fat content.

Pterocarpus santalinoides leaves have high amounts of crude protein (14.44-14.75%) enhanced by sautéing and oven drying (15.88-16.01 and 16.27-16.42% respectively). They also increased the ash, crude fibre; carbohydrate and energy contents. Blanching led to the highest reduction in all the nutrients. The protein concentration in this study was higher than that reported for fresh *P. santalinoides* (7.12 %) by Ike *et al*. (2015). Fat content was 1.96-2.76% in the leaf samples, while the ash content was 3.73-3.88%. However, these values are relatively high when compared with the data obtained by Agiang *et al*. (2016) for fresh *P. santalinoides.*

Effect of processing methods on the vitamin content of two cultivars of *Pterocarpus santalinoides*.

The effect of processing methods on the vitamin content of two cultivars of *P. santalinoides* is shown in table 2. Pro-vitamin A and vitamin E were improved by sauteeing; vitamin B_6 was improved by blanching in *Avuo*. Also oven drying retained moderately some vitamins like vitamin B_6, and vitamin C of the cultivars of *Pterocarpus santalinoides* (*Nturupka*) leaves.

There were no significant variations ($p<0.05$) in Pro-vitamin A content of *P. santalinoides* in the raw and other processing method apart from sautéing that was statistically different. Alpha carotene, trans-beta-carotene, and total beta-carotene contents of the leaves were statistically similar.

Pro-vitamin A acts in the body as an antioxidant, regulates metabolic reactions, maintains ocular health and immune function (Craft and Wise, 1993). The vitamin has integral role in regulating total metabolic reaction in the body. The highest concentration of Pro-vitamin A (243.72µg) in this study is lower than the RDA required for pregnancy and lactation according to WHO (2018), which is 800µg. Raw Avuo contained the highest amount of folate (3.69mg/100g), while raw dark green Oseleukwu contained the highest amounts of vitamin B_2 (0.33mg/100g) and vitamin B_a (87.35mg/100g).

The vitamin C content of *P. santalinoides* was significantly lower ($p<0.05$) than *Gnetum africanum* (36.22 mg/100g), *Talinium triangulare* (65.34 mg/100g) and *Telfairia occidentalis* (86.20 mg/100g) reported by Oladejo, (2019). Vitamin C is an antioxidant which also regenerates the active antioxidant form of vitamin E and enhances non-haem iron absorption (Duraipandiyan 2017). It helps cells adhension, quick healing of wounds and cuts and also fights mouth infection.

The highest concentration of vitamin C (20.39 mg) in this study is lower than the RDA during pregnancy and lactation according to WHO (2018) which is 55.0 mg/100g.

The highest concentration of vitamin E (4.30 mg) in the study is also lower than the RDA during pregnancy and lactation according to WHO 2018 which is 15.0mg.

Albeit, *Pterocarpus santalinoides* (*Nturukpa* leaves) is a good source, providing at least 25% of the daily requirement of provitamins A, B_6, vitamin C, Vitamin B_1 and vitamin E.

Effect of processing methods on mineral content of two cultivars of *Pterocarpus santalinoides*.

The effect of processing methods on the mineral content of two cultivars of *P. santalinoides* is shown in table 3. Some of them were actually improved by processing like calcium retention in oven drying and sautéing, potassium retention in sautéing, also magnesium content was also improved in oven dried *Avuo*; therefore sauteeing is considered as a better processing followed by oven drying as regard the mineral composition in this study.

The raw vegetables contained the highest amount of zinc (1.22-126 mg/100g) which were enhanced by oven-drying and sauteeing. Raw Oseleukwu contained the highest amount of iodine (63.3mg/100g). The highest concentration of iron (7.75 mg/100g) in this study is lower than the RDA required during pregnancy and lactation according to WHO (2018) which is 27.0 mg/100g. The highest concentration of zinc was found to be 1.29 mg/100g. Marginal zinc deficiency can impact immunity. Those deficient in zinc particularly children are prone to increased diarrheal and respiratory problems.

Calcium concentration in the leaves was found to be in appreciable amounts. The highest concentration of calcium was 4.09 mg/100g. There was a higher potassium concentration in Oseleukwu (55 mg/100g) compared to Avuo cultivar (45.00 mg/100g). The iodine concentration in this study is lower than that reported by Ujowundu *et al.* (2011) that Uziza had a concentration of (95.66 mg/100g), Tomatoes (66.06 mg/100g) and Oha (117.66 mg/100g) only the result obtained in Tomatoes (66.06 mg/100g) is slightly compared to raw Osw (63.33mg/100g). From the results, the different processing methods used in this study did not affect the iodine concentration greatly. Iodine is an essential component of the thyroid hormones, thyroxine (T_4) and triiodothyronine (T_3), necessary for normal growth, development, and metabolism during pregnancy, infancy and throughout life (Michael, 2012). When the physiological requirements for iodine are *not* met, a series of functional and developmental abnormalities occur. Severe iodine deficiency results in hypothyroidism, endemic goiter and cretinism, endemic mental retardation, decreased fertility, increased prenatal death, and infant mortality (Michael, 2012). The iodine in the sample was in appreciable amount. For all the minerals analyzed in these leafy vegetable, magnesium, potassium and iodine were predominant, iron, calcium were moderately available while zinc and selenium a trace element were not present in appreciable amounts.. The highest concentration of iodine (63.33 mg/100g) in this study is lower than the RDA during pregnancy and lactation according to WHO 2018 which is in the range of 150.250 µg.

Effect of processing on the phytochemical composition of *Pterocarpus santalinoides*

The effect of processing methods on the phytochemical content of two cultivars of *P. santalinoides* is shown in table 4. There were no statistically significant variations ($p>0.05$) in the phenolic content, cyanogenic glycosides, anthocyanins, and phytates in the two *P. santanoloides* cultivars. Sterol, oxalate tannin and alkaloids were higher in Avuo, while saponins, and flavonoids were higher in the Oseleukwu cultivar.

P. santalinoides leaves are edible and their phytochemical contents were less than 5g or above which has been reported as an indication of phytochemical toxicity (Messina and Messina, 1999). The low tannin (sautéed Osw and oven dried Osw) content in this study implies that the leaves have little or no astringent properties (Praven and Kumad, 2012). Tannins are water soluble phenolic compounds which precipitate proteins from aqueous solution. They occur in all vascular plants. Tannins bind to proteins making them biologically unavailable (Sotel *et al.*, 1995). They protect the kidney and have antiviral, antibacterial and anti-parasitic potentials (Praveen and Kumad, 2012). Leaves that have tannins are used for the treatment of intestinal disorders such as diarrhea and dysentery (Akindahunsi and Salawu, 2005). Tannins hasten the healing of wounds and inflamed mucous membranes (Praveen and Kumad, 2012).

4.6: Effect of processing on the carotenoid profile of two cultivars of *Pterocarpus santalinoides*

The effect of processing methods on the carotenoid profile content of two cultivars of P. santalinoides is shown in table 5. Carotenoid content was improved maximally by sautéing irrespective of the cultivar. Therefore sauteeing is considered as a better processing method for carotenoid retention. Oven drying retained minimally but not significantly, the carotenoid content of the cultivars of *P. santalinoides* (nturupka) leaves.

Increase in carotenoids concentration in the sautéed samples may be due to dehydration of the cellular matrix and improved extractability of carotenoids from the vegetables. This process involved the addition of minimal or no water in the sautéed process (Nwedi and Ogendi, 2020).

Carotenoids are lipophilic; they tend to be more bioavailable in fats. Moderate levels of α-carotene was found in both cultivars of *Pterocarpus santalinoides* vegetables, which may be related to the "channeled" conversion of α-carotene to lutein in the biosynthetic pathway through hydroxylase enzymes, (Djuikwo *et al.,*2011).

Increase in carotenoids concentration in the sautéed samples may be due to dehydration of the cellular matrix and improved extractability of carotenoids from the vegetables. This process involved the addition of minimal or no water (Nwedi and Ogendi, 2020).

Raw Avuo contained statistically higher 13-cis-**β**-carotene (6.01 μg/g) than the raw Osw (4.77 μg/g). Sautéed Avuo (86.31 μg/g) was statistically higher than sautéed Oseleukwu (76.71 μg/g). The 13-cis **β**-carotene data in raw and blanched sample in the study is moderately lower than *Telferia occidentalis* raw (26.47 μg/g) and cooked *Telferia occidentalis* (50.78 μg/g) reported by Okpalanma *et al.* (2013).

Available literature suggest that the consequences of trans- cis- isomerization are changes in bioavailability and physiological activity (Okpalanma et al., 2016). Trans **β**-carotene is also an isomer of **β**-carotene Okpalanma et al. (2013). Sautéeing may have caused the denaturation of carotene binding proteins releasing the carotenoids so that they can be extracted more easily (Nwedi and Ogendi, 2020).

Many geometric isomers of carotene trans-, 9-cis, 13-cis- and 15-cis isometric farms exist in food and human tissues (Okpalanma et al., 2016). The major carotene isomers in the circulation of humans is trans-carotene, with small amount of 13-cis- and 9-cis- carotene. However, circulating levels of the cis-isomers of **β** –carotene are not responsive to increased consumption of their isomers (Okpalanma et al., 2016). Besides, literature data suggest that each carotenoid shows an individual pattern of absorption, plasma transport and metabolism (Okpalanma *et al.,* 2016). The levels of cis-isomers of carotene are much higher in leafy vegetables. The consequences of trans-cis-isomerization are changes in bioavailability and physiological activity (Okpalanma *et al.,* 2013). **9-cis-β carotene**: The 9-cis- **β**-carotene level was significantly higher in sauteed Avuo (38.01μg/g) and sautéed Oseleukwu (33.89 μg/g), (Okpalanma *et al.,* 2016) reported that 9-cis-**β**-carotene of *Pterocarpus mildbraedii* raw had 12.30 μg/g was significantly higher than result obtained in this study (4.45, 2.54) but the sauteed samples of the two cultivars in this study (38.01 μg/g, and 33.89 μg/g) were higher than the cooked sample of *Pterocarpus mildbraedii* (27.25 μg/g) reported by Okpalanma *et al.* (2016). The 9-cis-**β** carotene in this study was lower than that in raw and cooked *Talinum triangulare* (8.53 μg/g, and 44.29 μg/g) reported by Ojimelukwe *et al.* (2018) and Solanum melongena (eggplant) (1.48 μg/g) reported by Djuikwo *et al.* (2011). Increase in carotenoids concentration in the sautéed process may be due to dehydration of the cellular matrix and improved extractability of carotenoids from the vegetables ((Nwedi and Ogendi, 2020). 9-cis-**β** carotene is an isomer of total **β**-carotene (Okpalanma *et al.* 2013).

Total β-carotene:

Sauteeing significantly improved ($p<0.05$) total **β**-carotene concentrations of the green vegetables than other processing methods. The total **β**-carotene (T**β**-c) content was significantly higher in sauteed leaves- Avuo (232.46 μg/g,) and sautéed Oseleukwu- 225.23μg/g) than in raw leaf Avuo (27.26 μg/g), and raw Oseleukwu (17.87μg/g), because denaturation of carotene binding proteins releases the carotenoids so that they can be extracted more easily (Nwedi and Ogendi, 2020). Total **β**-carotene isomerizes into 13 and 9-cis-**β**-carotenes and to quantify the **β**-carotene, it is necessary to add all the isomers. Therefore Avuo cultivar of *P. santalinoides* is a better source of the carotenoids.

Carotenoid profile of the raw Light green Pterocarpus santalinoides (Avuo cultivar)

The carotenoid profile of the raw Light green *P. santalinoides* is shown in fig 4.2a. The chromatogram shows up to four major peaks and several minor peaks. 13-cis-**β**-carotene eluted at about 5.2 min, œ-carotene eluted at 5.4 min. Trans-**β**-carotene eluted 6.15 min (and was the highest peak), while 9-cic-**β**-carotene eluted after 7 min. The other peaks were not identified due to lack of standards (see Fig. 4.2a).

Carotenoid profile of the sauteed Light green Pterocarpus santalinoides

The carotenoid profile of the sautéed sample is shown in fig 4.2b. Up to 7 peaks with broader peaks areas than the raw samples were observed. While 13-cis-**β**-carotene eluted within 5 min: œ-carotene eluted within 5.4 min. Trans –**β**-carotene eluted within 6 min while 9-cis-**β**-carotene eluted after 6.8 min.

There were about four other small but broad peaks which were not identified due to lack of calibration standards.

Carotenoid profile of the raw Pterocarpus santalinoides (Oseleukwuw cultivar)

The Carotenoid profile of the raw dark green *P. santalinoides* (Oseleukwu cultivar) is shown in fig. 4.2c. The chromatogram shows four major peaks and several minor peaks. 13-cis-**β**-carotene eluted at about 5.2 min, œ-carotene eluted at 5.5 min. Trans-**β**-carotene eluted at 6.14 min (and was the highest peak) while 9-cis-**β**-carotene eluted after 6.91 min.

Carotenoid profile of the sautéed Dark green Pterocarpus santalinoides (Oseleukwu cultivar)

The Carotenoid profile of the raw *P. santalinoides* (dark green cultivar) is shown in fig. 4.2d. The chromatogram contains four major peaks and several minor peaks. 13-cis-**β**-carotene eluted at about 5.1 min, œ-carotene eluted at 5.4 min. Trans-**β**-carotene eluted at 6.12 min (and was the highest peak) while 9-cis-**β**-carotene eluted after 6.92 min. Because there are such high concentrations of 13-cis **β**-carotene in both cultivars of sautéed processing of leafy vegetables under study, they could potentially be used to help alleviate deficiencies in vitamin A which are prominent in most developing countries (Djuikwo *et al*. 2011). Out of the several different geometric isomers of **β**-carotene that exist in food and human tissues, the major **β**-carotene isomers in the circulation of humans are trans- **β**-carotene, with small amount of 13-cis- and 9-cis- **β**-carotene. Okpalanma *et al*. (2013). The results showed that the identification of the carotenoids according to the standard protocol was precise. Two classes of carotenoids namely; xanthophylls and carotenes were identified and quantified under the HPLC conditions used. Only the carotenoids with major peaks areas were further identified. **β**-carotene is the most abundant carotenoid and exhibits numerous pharmaceutical properties including antioxidant, anti-obesity, anti-cancer, anti-aging, anti-atherosclerotic and anti-sunburn properties as well as hepatoprotective, neuroprotective and improved vision and night blindness prevention (Chiu *et al.,* 2019).

Conclusion

The results of this study revealed that *Pterocarpus santalinoides* leaves are good sources of macro and micro nutrients and carotenoids. The leaves are good sources of protein, potassium, calcium and iodine. The light green coloured cultivar contained significant amounts of folate while the dark green coloured cultivar contained significant amounts of flavonoids. The iodine and zinc content of these underutilized vegetables exceed the WHO recommended daily allowances for pregnant and lactating women. They are also moderate sources of iron. Of processing methods investigated, sauteeing and oven drying at 50 ^{O} C led to better retention of nutrients than blanching. Raw Oselukwu had iodine concentration more than raw Avuo. The leaves are good sources of major carotenoids. More so sautéing improved maximally the trans-**β**-carotene and other carotenoid profile of *Pterocarpus santalinoides*. Most of the carotenoids were better retained in Avuo leaf compared to Oselukwu leaf hence Avuo was a better source of major carotenoid.

Declarations

Competing interests: The authors declare no competing interests.

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Plate

Plate I is available in the Supplementary Files section.

Tables

Tables 1, 3, 4.2, 4.3, 4.4, and 4.5 are available in the Supplementary Files.

Figures

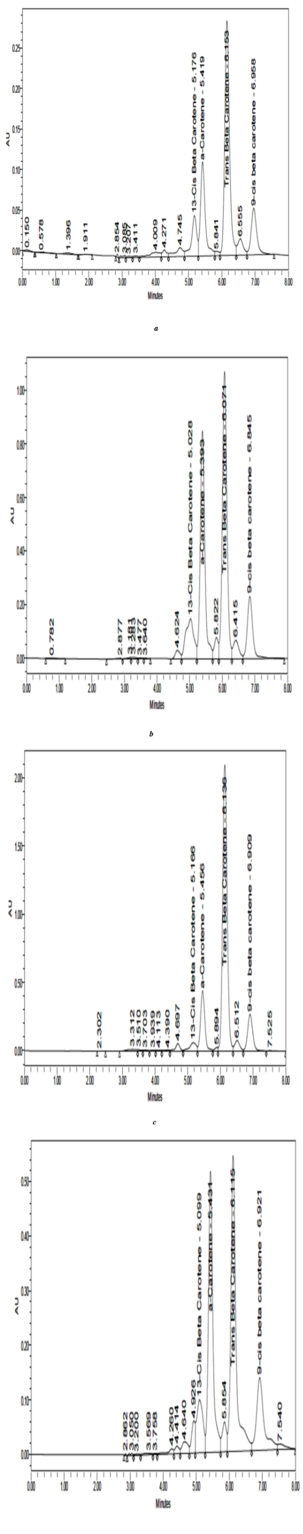

Figure 1

Fig. 4.2.a: Carotenoid Profile of raw Pterocarpus santalinoides (Light greencultivar).

Fig. 4.2.b: Carotenoid Profile of sautéed Pterocarpus santalinoides (Light greencultivar) leaf

Fig. 4.2.c: Carotenoid Profile of raw Pterocarpus santalinoides (Dark green cultivar) leaf.

Fig. 4.2.d: Carotenoid Profile of sautéed Pterocarpus santalinoides (Dark green cultivar).

Supplementary Files

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- Plate.docx
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