International Journal of Food Science and Nutrition
ISSN: 2455-4898; Impact Factor: RJIF 5.14
Received: 15-08-2020; Accepted: 30-08-2020; Published: 16-09-2020
www.foodsciencejournal.com
Volume 5; Issue 5; 2020; Page No. 09-18

Identification and Quantification of Phenolic compounds in African bush mango (*Irvingia wombolu*) fruit, Free-radical scavenging activity and the Nutritive values of Its peel and pulp extracts

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Abstract
The phenolic constituents, Proximate, vitamin (A and C), and mineral compositions of African bush mango (*Irvingia wombolu*) fruit (peel and pulp) were evaluated. Their total phenolic, flavonoids, (TAC), FRAP, DPPH, NO, OH^-, and lipid peroxidation radical scavenging activity were also determined. Samples were analyzed using standard assay procedures for all determinations. Concentrations of minerals such as iron, copper, potassium, zinc and manganese were higher in peel than pulp. The peel and pulp of *I. wombolu* showed almost similar pattern of scavenging activities. The IC_{50} showed that the peel extract has a higher free radical scavenging activity than pulp. The proximate, vitamin A and C compositions, concentrations of antinutrients (oxalates, phytates and tannins), and the quantity of the identified phenolic compounds from the fruit of *I. wombolu* were higher in the peel extract than pulp. However, the peel and pulp extracts of *I. wombolu* fruit could significantly impact the health of populace if properly harnessed and utilized.

Keywords: *Phenolic constituents, proximate composition, vitamins, antioxidant activity*

1. Introduction

A fruit is the mature ovary of a plant or the succulent edible part of woody plants, the sweet and fleshy product of a tree or other plant that contains seed and can be eaten as food [Hung 2012, Boakye 2013] [32, 16]. Nutritionally, fruits are energy-dense foods containing vitamins, minerals, fibre and other bioactive compounds (FAO 2017). Fruits have been a part of human diet and food supplement over the years. They contain high quantity of water, carbohydrate, vitamins and minerals such as Ca, Mg, Zn, Fe, and K (organic compounds) which are required in small amounts, to make the body function properly [Abdelazim 2011, Ameh *et al.* 2015] [1, 6]. Many fruits are used to make beverages, such as fruit juice (orange, apple, grape, mango etc.) or alcoholic beverage such as wine, brandy or vinegar. It has been considered that wild fruits are rich sources of various vitamins, minerals, dietary fibres and polyphenols which could provide several health benefits, and consumption of fruits and green leafy vegetables reduces the risk of several diseases like diabetes, cancer, coronary heart disease, neurodegenerative ailments and aging as well [Stadlmayr *et al.* 2013] [56]. Wild plants, a source of natural antioxidants is valid as a healthier and cheaper alternative to the synthetic ones, which have been perceived as toxic and carcinogenic [Boakye 2013, Morah and Achu 2018] [16, 40].

Irvingia wombolu commonly called bush/wild mango, or dika nut, is an edible African indigenous fruit tree that produces edible fruits and seeds [Moral *et al.* 2013, Oduntan *et al.* 2019] [46]. *Irvingia* belongs to the family Irvingiaceae; the fruit of *I. wombolu* is sour and is consumed locally and the edible kernels are used for culinary purposes [Chah *et al.* 2014, Vihotogbe *et al.* 2015]. The only way to easily differentiate the bitter fruited from sweet fruited is by assessing the bitterness versus sweetness of the mesocarp because there are limited morphological differences between the two varieties [Moral *et al.* 2013]. The *I. wombolu* seeds are smaller in size but are preferable in soup making because of their greater slimy nature in soup. It also gives stronger flavor to the soup. The *I. wombolu* seed has higher protein and ash content while *I. gabonensis* has very high crude lipid content and lower ash content [Morah and Achu 2018; Oduntan *et al.* 2019] [40, 46].

The chemical composition of *I. wombolu* kernel have been well-studied [Ainge and Brown 2001, Leakey *et al.* 2005, Ekpo *et al.* 2007, Etebu 2012, Oduntan *et al.* 2019] [3, 34, 25, 46, 26], since it has been the most economically valuable part of an *Irvingia* tree. However, there is scarce information on the nutritional composition of the pulp and peel, which constitute the larger portion of the fruit. In view of this, there is need to ascertain the nutritive status of the peel and pulp of this valuable fruit, and also to investigate the antioxidant, anti-nutritional properties and inherent phenolic compounds in *I. wombolu* fruit. According to Oduntan *et al.* [2019] [46], *I. wombolu* pulp and peel contained appreciable levels of methionine and lysine, hence it could be supplemented into poultry diets to reduce the cost of animal feed production. Also, the incorporation of the *I. wombolu* pulp and peel in human food will help to meet the body's demand for nutrients and enhance the flow through required metabolic pathways to maintain optimum body structure and function.

2. Materials and Methods

2.1 Sample preparation

Matured fruits of African bush mango (*I.wombolu*) were purchased from a Local Market in Ikare, Akoko city of Nigeria lies on the geographical coordinates of 7.5248° N, 5.7669° E. It was authenticated by Prof. Jonathan Onyekwelu of the Department of Forestry and Wood Technology, Federal University of Technology, Akure. African bush mango fruits were thoroughly washed, peeled and sliced horizontally into tiny pieces with a sharp knife, kernels were removed from the fruit cavities. The peels were separated from the pulp. The peels was washed to remove adhering flesh. 1000 g each of the pulp and peel samples was oven dried at temperature of 35 °C for 6 days. The dried peels and pulp were finely ground with a warring blender and stored at 4 °C until analysis.

2.2 Preparation of extracts
The fruit peel and pulp powder (0.5 g each) were separately macerated in 10 mL of distilled water for 24 h at room temperature. The mixtures were centrifuged at 5000 rpm for 10 min, and the supernatant obtained filtered through Whatman No.1 filter paper. The filtrates were referred to as water extracts of *I. wombolu* peel and pulp.

2.3 Proximate Analysis
Proximate analyses which include moisture, total ash, crude fibre, crude protein, crude fat, carbohydrate, vitamin and mineral contents were done according to the methods of AOAC, [2010]. The mineral contents which include Na, K, Ca, Mg were analyzed on flame photometer (Model 405, Corning, U.K) while heavy metals which include Zn, Cu, and Mn were analyzed on atomic absorption spectrophotometer (Hitachi model 170.10).

2.4 Antioxidant Activity of African Bush Mango
The reducing property of the extracts of *I. wombolu* were determined according to the method of Pulido *et al*. [2000] [54]. Free radical scavenging ability of the extract against DPPH (1, 1- diphenyl-2-picryhydrazyl) using the method of Barriada-Bernal *et al.* [2014] [14]. Total phenolic content of the extracts was carried out as described by McDonald *et al.* [2006]. Total flavonoid content of the extracts was determined using a colorimetric assay developed by Bao [2005] [13]. Total antioxidant capacity and scavenging activity of nitric oxide of African bush mango peel and pulp extracts were assayed by the phosphomolybdenum method as described by Prieto *et al*. [1999] [53] and Kumaran and Karunakaran [2007] [33] respectively. The hydroxyl radical scavenging activity of the fruit pulp and peel samples was determined as described by Halliwell *et al*. [1987] [30]. Homogenate of liver was prepared from male wistar rats, and lipid peroxidation inhibition activity was carried out according to the method of Auddy *et al*. [2003].

2.5 Determination of Anti-nutrients
Tannin concentration of the peel and pulp extracts of *I. wombolu* fruit was determined using the method of Makkar and Goodchild [1996] [36]. Phytate content was determined according to the method of Wheeler and Ferrel [1974]. Oxalate content was estimated according to the procedure of Day and Underwood [1986]. Also, alkaloid and saponin contents were determined according to the methods of Henry [1973] and Brunner [1984] [18].

2.6 HPLC-UV Methodology
The separation of phenolic compounds in the peel and pulp extracts of *I. wombolu* fruit was performed using an Agilent HPLC series 1200 system (Agilent, Waldbronn, Germany) equipped with Chem Station software, with detector model: AGILENT 1260, column model: CHROMSPHERE 5 C18, dimension: 5 micrometer, 3 mm x 250 mm with Hamilton microliter syringe, column temperature: 40 °C. 100 µL of each extract was injected, the flow rate was 0.7 ml/min, pressure: 180 x 105 Pa, and carrier: acetonitrile / water (80:20, v/v) and isocratic elution was done using 2% acetic acid in water – methanol mixture (82:18, v/v) and column temperature of 40 °C. Quantification was performed by measuring all the investigated phenolics 320 nm UV-vis wavelength. Individual compounds were identified by their retention times and UV-vis spectra and quantified using a calibration curve of the corresponding standard compound. When reference compounds were not available, the calibration of structurally related substances was used including a molecular weight correction factor [Brito *et al*. 2014] [17].

2.7 Statistical Analysis
All the analyses were run in triplicates. Results were then computed using Microsoft Excel software (Microsoft Corporation, Redmond, WA) and followed by one-way Anova Duncan's Multiple Range Test (DMRT) to compare the means that showed significant variation by using SPSS 11.09 for windows. The significance level was set $P < 0.05$.

3. Results
3.1 Proximate, Vitamin and Mineral Compositions of I. *Wombolu* fruit Peel and Pulp
The results of the proximate, vitamin and mineral compositions of *I. wombolu* fruit peel and pulp are summarized in Table 1(a), (1b), and 1(c) respectively. The moisture content of both extracts were found to be very high (74.1 g/100g and 81.33 g/100g) for peel and pulp of *I. wombolu* respectively. The mineral ash, crude fibre, crude protein, fat and carbohydrate of the fresh extracts (peel and pulp) were found ranged from 0.69 - 0.92 g/100g, 8.67-11.08 g/100g, 3. 38 - 5.55 g/100g, 3.14 – 4.11 g/100g, and 3.72 - 4.32 g/100g/FW respectively as shown in Table 1(a). The results of the vitamin (A) and vitamin (C) contents of *I. wombolu* fruit are summarized in Table 1(b). It was observed from the results that African Bush Mango fruit is a unique source of vitamins. The vitamin A content of *I. wombolu* fruit peel and pulp were 3.57 mg/100g and 1.13 mg/100g respectively. The vitamin C content of the fruit peel and pulp extracts ranged from 16.00 mg/100g – 24.00 mg/100g FW.

Table 1(a): Proximate composition of *I. wombolu* fruit

Parameter	Peel	Pulp
Moisture	74.10 ± 0.36^a	81.33 ± 2.78^b
Mineral ash	0.92 ± 1.23^a	0.69 ± 0.99^b
Crude fibre	11.08 ± 0.89^a	8.67 ± 1.24^b
Crude protein	5.55 ± 1.23^a	3.38 ± 0.15^a
Crude fat	4.11 ± 0.92^a	3.14 ± 1.24^b
Carbohydrate	4.32 ± 0.98^a	3.72 ± 0.98^a

Values with different superscript letters along the same row are significantly different (P < 0.05)
The experiment was repeated three times, and each value is given as the mean ± standard deviation.

Table 1(b): Vitamin Composition of *I. wombolu* Fruit Peel and Pulp

Parameter	Peel	Pulp
Vitamin A	3.57 ± 0.16^a	1.13 ± 0.08^b
Vitamin C	24.00 ± 0.75^a	16.0 ± 0.51^b

Data represent the mean ± standard deviation of replicate readings (n = 3). Values with different superscript letters along the same row are significantly different (P < 0.05)

Table 1(c): Mineral composition of *I. wombolu* Fruit (Peel and Pulp)

Mineral	Peel	Pulp
Ca	25.50 ± 0.55[a]	27.13 ± 1.04[b]
Cu	0.17 ± 0.03[a]	0.14 ± 0.05[a]
Fe	1.10 ± 0.08[a]	1.05 ± 0.03[a]
K	26.50 ± 0.72[a]	20.2 ± 0.88[b]
Mg	2.57 ± 0.05[a]	2.81 ± 0.66[b]
Zn	1.45 ± 0.03[a]	0.81 ± 0.08[a]
Na	10.90 ± 1.12[a]	13.50 ± 0.07[b]
Mn	0.74 ± 0.03[a]	0.52 ± 0.05[a]

Data represent the mean ± standard deviation of replicate readings (n = 3). Values with different superscript letters along the same row are significantly different (P < 0.05)

3.2 Antioxidant and Antinutrient Properties of I. wombolu fruit (peel and pulp) extracts

The antioxidant and antinutrient properties of *I. wombolu* fruit (peel and pulp) extracts are presented in Table 2. The antioxidant properties of *I. wombolu* fruit extract were determined by assessing the total phenolic and flavonoid contents, ferric reducing activity in African Bush Mango peel and pulp. The result indicates that the peel extract showed a higher antioxidant activity than pulp. Similarly, the antinutritional component such as oxalates, alkaloids, phytates, saponins and tannins of the fruit extracts were determined and are also shown in Table (2). *I. wombolu* fruit peel was higher in tannins, phytates and oxalates than pulp.

Table 2: Antioxidant and Antinutrient constituents of *I. wombolu* Fruit Peel and Pulp

Constituent (mg/100g)	Peel	Pulp
Total phenol	3.77 ± 0.30[a]	10.45 ± 0.64[b]
Total flavonoid	0.23 ± 0.06[a]	1.58 ± 0.08[b]
Frap	32.59 ± 2.50[c]	86.58 ± 1.64[b]
Alkaloids	19.73 ± 0.29[a]	24.73 ± 0.11[b]
Oxalates	2.89 ± 0.15[a]	2.25 ± 0.20[b]
Phytates	10.7 ± 0.82[a]	4.94 ± 0.12[b]
Saponins	5.59 ± 0.30[a]	15.64 ± 0.18[b]
Tannins	7.5 ± 0.12[a]	5.61 ± 0.08[b]

Data represent the mean ± standard deviation of replicate readings (n = 3).
Values with different superscript letters along the same row are significantly different (P < 0.05)

3.3 Free radical Scavenging Activity of I. wombolu Peel and Pulp Extracts

In this study, the DPPH, NO, TAC and OH -radical scavenging shown by the extracts was concentration dependent. With increasing concentration, the radical scavenging activity increases in the extracts of African Bush Mango fruit as depicted in Figures (1- 4) respectively. The peel extract showed a higher radical scavenging activity than pulp with the least IC_{50} value. The summary of the result is presented in Table 3. The lipid peroxidation inhibition effect of the peel and pulp extracts of *I. wombolu* fruit is presented in Figures (5 -8). The IC_{50} (the concentration of the extracts at 50% inhibition) is summarized in Table 4. On the basis of IC_{50} values pattern of lipid peroxidation inhibition activity of the extracts and various fractions can be arranged as peel > pulp using Fe^{2+} and SNP.

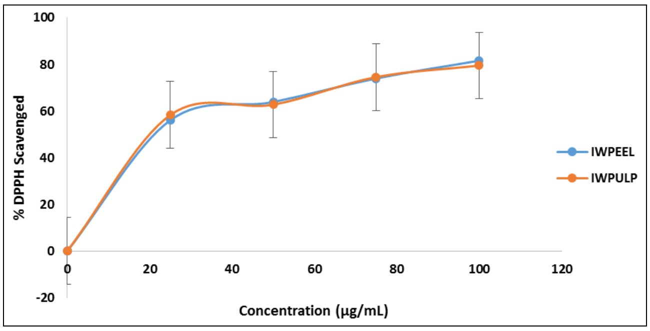

Fig 1: DPPH scavenging activity of *I. wombolu* Fruit Peel and Pulp

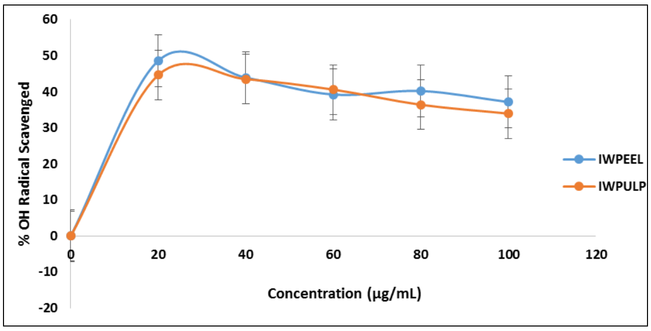

Fig 2: Hydroxyl radical scavenging activity of peel and pulp extracts of *I. wombolu* Fruit

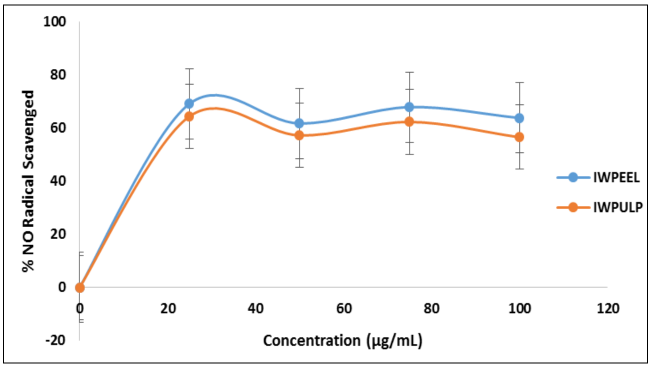

Fig 3: NO radical scavenging activity of *I. wombolu* Fruit Peel and Pulp

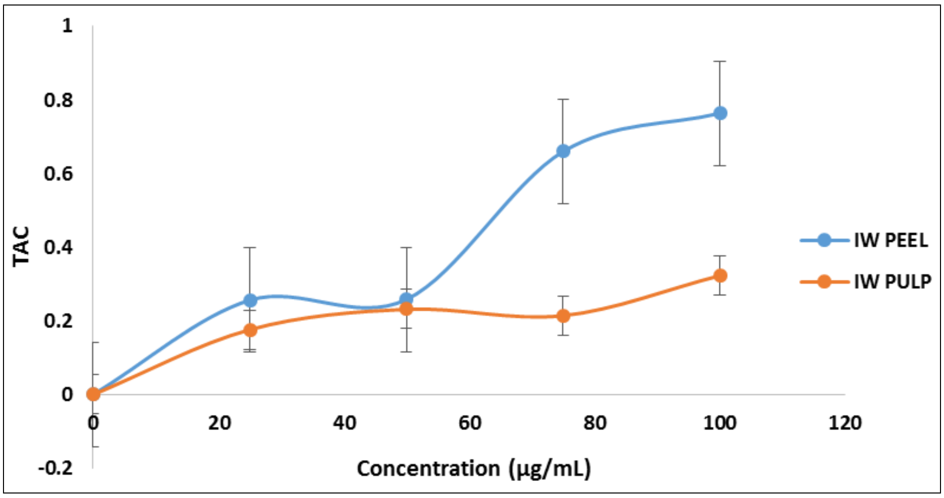

Fig 4: Total Antioxidant capacity of *I. wombolu* Fruit Peel and Pulp

Table 3: Inhibitory Concentration (IC_{50}) of Antioxidant Activity of the Peel and Pulp Extracts of *I. wombolu*

IC_{50}				
Sample	**OH**	**NO**	**DPPH**	**TAC**
I. wombolu Peel	117.90 ± 2.86^{a}	45.08 ± 3.75^{c}	42.80± 2.45^{c}	58.57 ± 1.65^{a}
I. wombolu Pulp	132.71 ± 1.69^{b}	77.69 ± 1.46^{d}	42.93 ± 4.65^{c}	30.64 ± 1.65^{b}

Data represent the mean ± standard deviation of replicate readings (n = 3).
Values with different superscript letters along the same row are significantly different ($P < 0.05$)

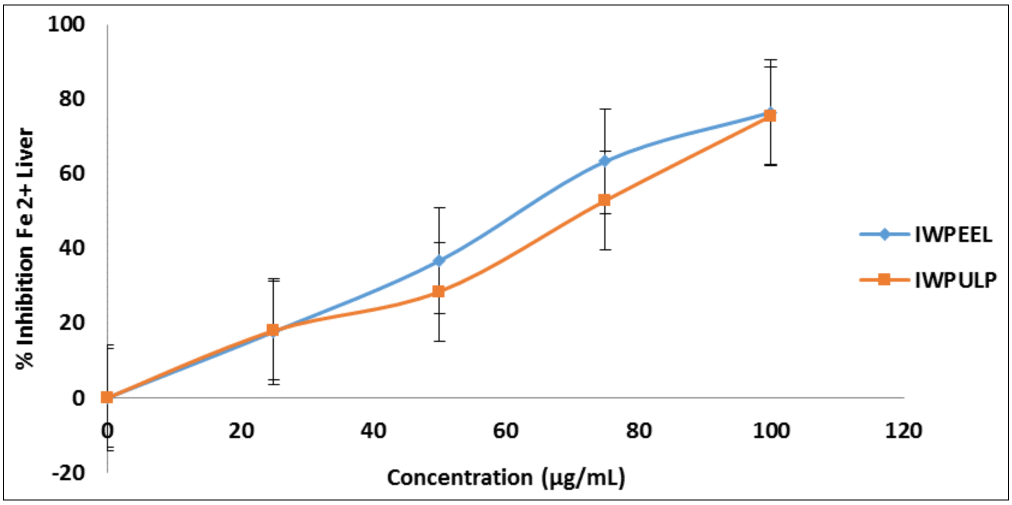

Fig 5: Inhibitory effect of *I. wombolu* on Fe^{2+}-Induced lipid peroxidation in rat's liver homogenate

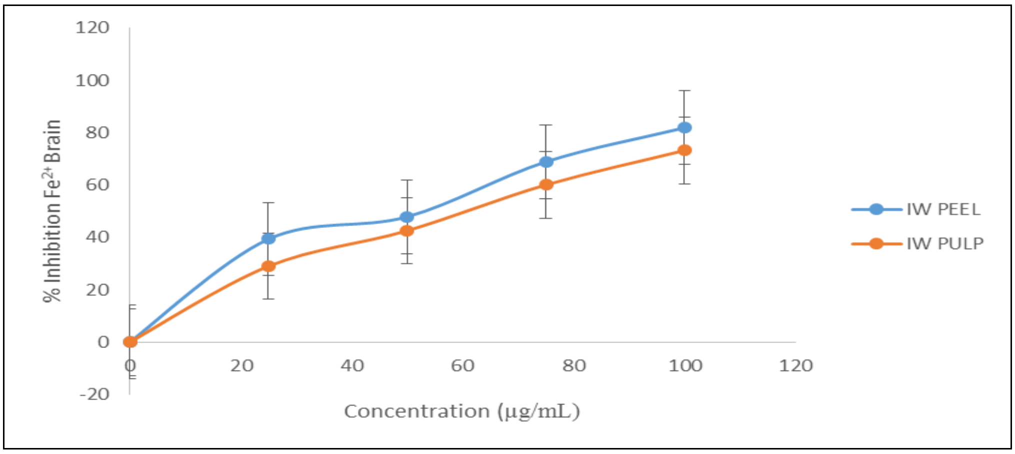

Fig 6: Inhibitory effect of *I. wombolu* on Fe^{2+}-Induced lipid peroxidation in rat's brain homogenate

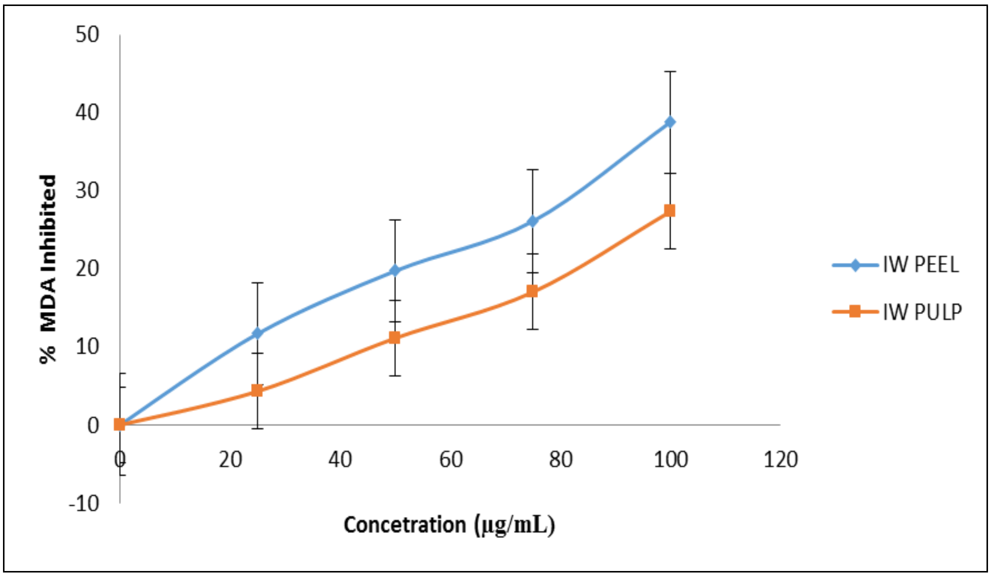

Fig 7: Inhibitory effect of *I. wombolu* on SNP-Induced lipid peroxidation in rat's Liver homogenate

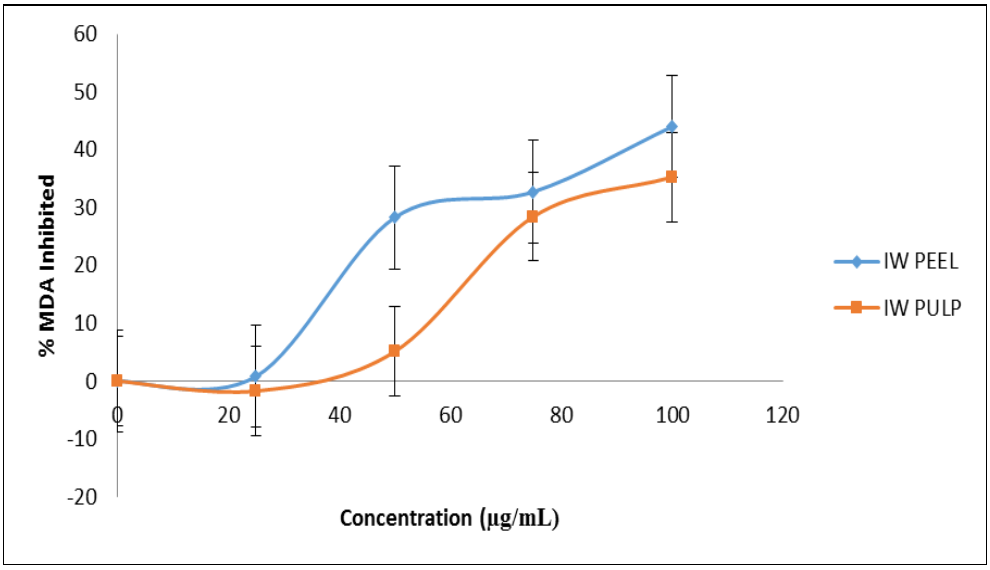

Fig 8: Inhibitory effect of *I. wombolu* on SNP-Induced lipid peroxidation in rat's brain homogenate

Table 4: Inhibitory concentration (IC_{50}) of the Peel and Pulp extracts of *I. wombolu* fruit on Fe^{2+} and SNP- induced lipid peroxidation in rat's brain and liver homogenates

IC_{50}				
Sample	**Fe^{2+}- Induced brain**	**Fe^{2+}- Induced liver**	**SNP-Induced brain**	**SNP-Induced liver**
I. wombolu Peel	38.45 ± 2.36^a	25.20 ± 1.29^c	28.46 ± 1.63^a	36.86 ± 1.56^a
I. wombolu Pulp	46.30 ± 2.86^b	39.65 ± 1.65^d	36.32 ± 2.36^b	19.82 ± 1.75^b

Data represent the mean ± standard deviation of replicate readings (n = 3).
Values with different superscript letters along the same row are significantly different ($P < 0.05$)

3.5 Phenolic Constituents of I.wombolu Peel and Pulp

The HPLC–UV analysis revealed a total of 42 phenolic compounds in the peel and pulp of *I.wombolu* analyzed (the respective chromatograms are shown in Figures 9 (a) and (b). The most predominant among them include: catechin (0.22 mg/100g), procatechuic acid (82.0mg/100g); coumaric acids (1.929 mg/100g); vanillic acid (1.456 mg/100g); gallic acid (68.54 mg/100g); caffeic acid (14.11 mg/100g); ferulic acid (2.192 mg/100g); kaempferol (3.936 mg/100g); ellagic acid (111.1 mg/100g); quercetin (7.783 mg/100g); myricetin (0.23 mg/100g); chlorogenic acid (30.01 mg/100g); and epigallocatechin (0.045 mg/100g) for peel while pulp gave catechin (0..46 mg/100g), procatechuic acid (1.27 mg/100g); coumaric acids (0.025 mg/100g); vanillic acid (0.912 mg/100g); gallic acid (4.21 mg/100g); caffeic acid (0.45 mg/100g); ferulic acid (16.88 mg/100g); kaempferol (0.01 mg/100g); ellagic acid (0.027 mg/100g); quercetin (0.02 mg/100g); myricetin (0.05 mg/100g); chlorogenic acid (2.41 mg/100g); and epigallocatechin (0.10 mg/100g). The respective retention time and concentration of each phenolic compound found in the different analyzed extracts are shown in Table 5.

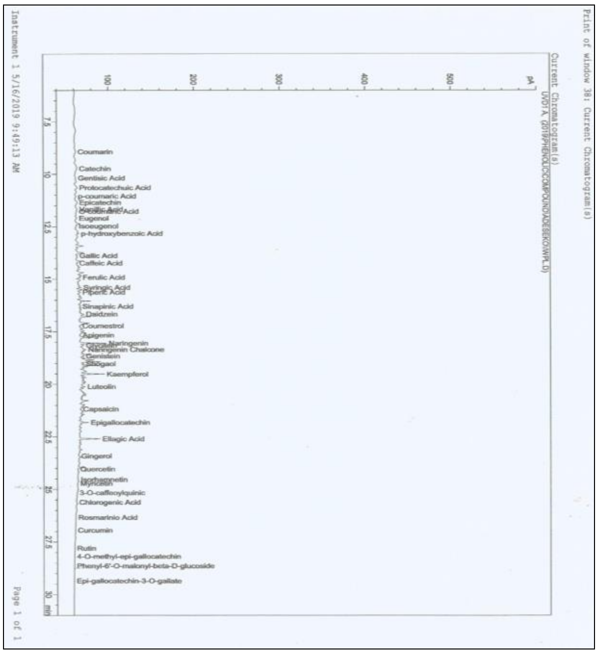

Fig 9a: HPLC-UV Spectra of *I. wombolu* Peel extract

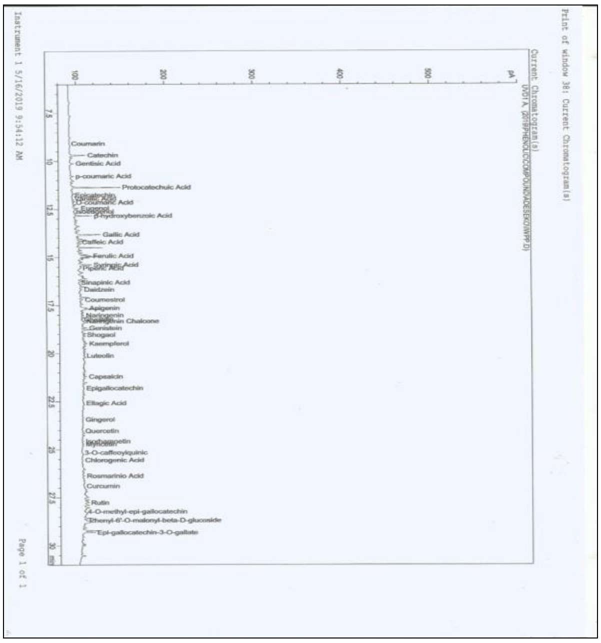

Fig 9b: HPLC-UV Spectra of *I. wombolu* Pulp extract

Table 5: Retention times of Constituent Peak in HPLC-UV Spectra

Identified	***I.wombolu***	**peel**	**extract**	***I.wombolu***	**pulp**	**extract**
Constituent	Retention	Area	Height	Retention	Area	Height
Catechin	9.740	25.27781	0.220	9.687	52.70000	0.046
Procatechuic	10.647	37.39469	82.00	10.510	0.802916	1.270
p-coumaric Acid	11.042	20.91961	0.861	11.027	8.28151	0.341
o-coumaric Acid	11.773	24.23651	1.929	11.750	0.554255	0.025
Vanillic Acid	11.664	31.01845	1.456	11.694	5.60171	0.912
Gallic Acid	13.884	14.09288	68.540	13.819	86.58865	4.211
Caffeic Acid	14.242	11.74016	14.11	14.206	8.37311	0.454
Ferulic Acid	14.925	27.71804	2.192	14.926	28.16913	16.88
Kaempferol	19.518	97.00559	3.936	19.483	17.61580	0.011
Ellagic Acid	22.599	94.21912	111.1	22.579	5.59084	0.027
Quercetin	24.033	9.87508	7.783	24.088	0.47827	0.019
Myricetin	24.724	20.25312	0.234	24.699	4.56909	0.053
Chlorogenic Acid	25.521	8.64494	30.01	25.599	0.29653	2.407
Epigallocatechin	29.277	0.68650	0.015	29.300	45.84109	0.100

4. Discussion and Conclusion

4.1 Discussion

Proximate, Vitamin and Mineral Compositions of I. Wombolu fruit Peel and Pulp

The nutritional composition of African bush mango (*I. wombolu*) in this study compared well with other commonly consumed fruits. High moisture content values of 79.40 and 81.33 g/100g FW were obtained for the peel and pulp of *I. wombolu* respectively. Boakye [2013] [16] had earlier reported a high moisture content in the mesocarp of edible fruits including: African Bush Mango (84.07%); breadfruit (67.89%); soursop (82.37%) and sweetsop (73.19%). This result is also in consistence with Onimawo *et al*. [2003] [49] who reported 80.0% moisture content for African Bush Mango pulp. The high moisture content obtained in this present study is also corroborated with 67.86% for sweetsop, 81.2% for soursop [Folorunso and Modupe 2007] [27] and 60.5% for breadfruit [Asibey-Berko and Tayie 1999] [10]. Okokon and Okokon [2018] [48] had reported a high moisture content which ranged from 76.92% to 92.93 % for apple, banana, and watermelon.

The high moisture content in *Irvingia* fruits makes it ideal for fruit juicing as a supplement to whole fruits [Abdelazim *et al*. 2011] [1]. Nevertheless, in terms of natural products stability, high moisture content tends to promote microbial contamination and chemical degradation because it promotes a medium for many reactions to occur [Msogoya and Kimaro 2011; Ogunsina 2012] [43, 47].

The crude protein values of (3.38 - 5.55 g/100g FW) obtained for the peel and pulp compared well with some commonly consumed fruits. Proximate analysis reported by Ositadinma and Ogodo [2015] [50] on three different fruits: pawpaw, banana and watermelon given protein values range of 0.56 g/100g - 1.22 g/100g. However, the seed of *I. wombolu* was reported with higher level of crude protein Onimawo *et al*. [2003] [49]. Reported protein content of sweetsop (1.2 - 2.4) % by Pinto *et al*. [2005] [52] and soursop 1.21% by Amusa *et al*. [2003] [7] are in agreement with the values obtained in this research. African bush mango fruit protein content recorded in the current study compared favorably with the values obtained by Boakye [2013] [16], with African Bush Mango (2.63%); breadfruit (2.87%); soursop (4.61%), and sweetsop (3.26%). Generally, the fruit of *I.wombolu* had protein contents comparatively higher than literature values for some common fruits. Significant among than as reported by Lozano [2006] [36] include, 1.3% for banana, 0.9% for oranges and 0.3% for apples.

Reported carbohydrate content of (3.72 - 4.32 g/100g FW) obtained in this study (Table 1a) is consistent with the 3.33 % values obtained by Boakye [2013] [16] from the fruit pulp of African Bush Mango, but lower than 12.83% from breadfruit, and also, 14.98%, for soursop [Amusa *et al*. 2003] [7]. The relatively lower values obtained for peel and pulp in this study is in harmony with the work of Boakye [2013] [16], who suggested the potential use of *I.gabonensis* fruit as an industrial energy food drink. *I.* wombolu fruit peel and pulp contained high level of total ash up to 5.76 - 9.20% and crude fibre ranged from 8.67 -11.08 g/100g. The values were significantly higher for the peel than pulp.

Moreover, this study is in agreement with the work of Morais *et al*. [2017] [42] on avocado, pineapple, papaya, passion fruit and watermelon. He reported a crude fiber content ranged values of 1.9 ± 0.3 to 56.7 ± 0.5%. The pulp extract presented the lower values range (1.9 ± 0.3 to 12.2 ± 0.4%). The obtained values (8.67- 11.08 g/100g) showed that *I. wombolu* fruit is a good source of dietary fibre. The result of this work compared higher than the report of Boarkye [2013], with African Bush Mango (4.15 %); breadfruit (2.09%); soursop (4.81%) and sweetsop (4.35%). According to Anderson *et al*. [2009] [8], crude fibre content of foods gives an indication of its dietary fibre as it measures one-half to one-seventh of the total dietary fibre component of the food. Considering the health benefits of dietary fibre in diets as elaborated by Champ *et al*. [2003] [20], the relatively high crude fibre content observed in the studied fruit is much desired. Compared with the fibre content of some common fruits such as common mango with values ranging from 1.6% - 4.5% and apple with 0.86 - 1.81% [Boakye 2013] [16].

The values of macro and micro elements of the peel and pulp extracts of *I.wombolu* is shown in Table 1(c). As with many foods, the mineral content of fruits is highly varied. There are many minerals that are essential for a normal healthy body. Generally plants have a good mix of minerals, and their fruiting bodies are characterized by high levels of minerals [Czech *et al*. 2019] [22]. The calcium content in the fruit extracts ranged from 25.50 – 27.13mg/100g. The concentration of magnesium ranged from 2.57 to 2.81 mg/100g. The potassium concentration ranged from 20.20 to 26.50 mg/g while for sodium (10.90 to 13.50 mg/100g). Calcium, sodium and potassium were abundant in the fruit species studied. The results showed that the fruit studied is a good source of mineral elements. Calcium was the predominant elements among the macro minerals measured. Zinc and iron were the most abundant elements among the trace minerals analyzed, their concentrations were higher for peel than pulp. Similar observations on mineral content profiles have been reported by Morais *et al*. [2017] [42], who presented a higher mineral content in peel with calcium ranged (332.1 - 9770.9 mg/100g) than pulps (25.4 - 20.2.7 mg/100g) for watermelon, papaya, passion fruit, pineapple and avocado. The mineral concentrations of fruits can be influenced by a number of factors including fruit species and strain types, age of the fruit, part of the fruit used, the composition of the growth substrate and the environment (water, temperature and humidity).

Similar observations have been made by Czech *et al*. [2019] [22] and Barros *et al.* [2012] [15], who also found that the minerals such as potassium, phosphorus, magnesium and manganese contents in the peel of orange, lemon and red grapefruit were significantly higher than pulp, which contained only trace amounts. Therefore, the removal of this part of the fruit greatly reduces its nutritional value and also allows this element to enter the environment. Research has shown that minerals of fruit and vegetable origin are well absorbed from the human digestive tract [Yang *et al*. 2012] [61], so losses of it should be limited by using *I. wombolu* peels for consumption.

Antioxidant and Antinutrient Properties of I.wombolu Fruit Peel and Pulp extracts

The phytochemical analysis of *I. wombolu* fruit (peel and pulp) extracts as revealed in Table 2, showed that *I.wombolu* fruit peel and pulp contained low levels of tannins and oxalates, which ascertained its possible use as a source of antioxidants to prevent oxidative damage in food products. At moderate concentration, tannins are acclaimed for their free-radical scavenging activity, antimicrobial, antiviral and anti-inflammatory properties [Murillo *et al.* 2012] [44]. Thus, the detection of tannins in both extracts indicates the potential health benefits of the fruits. It is worth ascertain that the tannin content of these fruits when ripe is just adequate to prevent the astringent and bitter taste imparted by tannins to some plant-based foods [Adekunle and Oyerinde 2004; Etebu 2012] [22, 25]. Saponins are common in most plants and have been postulated to have a wide range of biological activity including antioxidant, anticarcinogenic as well as having immune stimulant properties thereby exhibiting its potential to cure a number of diseases [Wolfe *et al*. 2010, Nange *et al*. 2011] [60].

Aqueous extracts of the peel and pulp of *I. wombolu* showed their capacities to significantly scavenge DPPH free radicals while there was a slight difference between the two extracts. The studied fruit showed fairly high free radical scavenging (antioxidant) activities against 1, 1, diphenyl-1-dipicrylhydrazyl radical (DPPH), Ferric Reducing Activity Power (FRAP), Nitric oxide (NO^-), Hydroxyl radical (OH^-) and lipid peroxidation compared to the activity of the standards used as revealed in Figures (1-8). However, the peel extract of African mango showed a higher free radical scavenging activity than pulp extract is consistent with other reports that fruit peels exhibited higher values of antioxidant activity compared to pulp. Ali and Naz [2017] [4] reported higher radical scavenging activity in potato, turnip and bitter gourd peels than pulp extract while Giomarol *et al*. [2014] reported the peel of a rare apple having higher DPPH radical scavenging activity than pulp.

The measure of DPPH, OH^-, NO and TAC inhibitory activity versus different concentration helped us to evaluate the IC_{50} (concentration that inhibited 50% of free radical) Tables (3 and 4). The lower the IC_{50} value, the higher the radical scavenging activity. IC_{50} results revealed that the peel extract has a higher scavenging activity than the pulp extract of *I.* wombolu. The nitric oxide radical scavenging activity of the peel (IC_{50} = 45.08 μg/mL) has scavenging effect than pulp (IC_{50} = 77.69 μg/mL) respectively. Addition of *I. wombolu* extracts reduces the carbonyl products like malondialdehyde (MDA) produced by the reaction of hydroxyl radical with polyunsaturated fatty acid moieties of cell membrane. The presence of sodium nitroprusside also caused a significant increase in the rat's homogenate malondialdehyde (MDA) content. However, the extract of *I. wombolu* inhibited MDA production content in a dose-dependent manner. The antioxidant properties of the peel and pulp extracts of *I. wombolu* against sodium nitroprusside-induced lipid peroxidation in the tissue homogenates could be because of the antioxidant/phytochemicals present in the extract to quench/scavenge the nitrous radical and iron produced from the decomposition of sodium nitroprusside (Hung 2012) [32].

Phenolic Constituents of *I. wombolu* Fruit Peel and Pulp extracts

The results obtained in this study revealed a higher concentration of phenolic compounds in the peel of *I.wombolu* than pulp. Several authors including Chang *et al*. [2000], Gorinstein *et al*. [2002] [29], and Maldonado-Celis *et al*. [2019] [38] have earlier reported "a peel having higher level of phenolic compounds than pulp". The current study is also in agreement with Balasundram *et al*. [2005] [12], who found that the total phenolics in peels of lemons, oranges, and grapefruit were higher than those in the fleshy portion of these fruits. Similarly, Li *et al*. [2005] have reported that pomegranate peels contain 249.4 mg/g phenolics compared to just 24.4 mg/g phenolics in the pulp. Apple peels were found to contain up to 3300 mg/100 g dry weight of phenolics higher than pulp [Wolfe and Liu 2003] [60]. Sanchez-Mesa *et al.* [2020] reported the identification of phenolic compounds such as gallotannins, flavonoids, gallic acid and xanthones from mango peel (mangifera indica I.var.).

Phenolic compounds have been associated with the health benefits derived from consuming high levels of fruits and vegetables [Altemimi *et al*. 2017] [5]. The beneficial effects derived from phenolic compounds have been attributed to their antioxidant activity [Brito *et al*. 2014] [17]. Phenolic acids consist of two subgroups, i.e., the hydroxybenzoic and hydroxycinnamic acids. The predominant phenolic compounds identified from the fruit peel and pulp of *I. wombolu* are available in the two subgroups stated above. However, gallic acid, procatechuic acid are examples of hydroxybenzoic acid while p-coumaric acid, caffeic acid, ferulic acid belong to the second subgroup.

According to the report of Balasundram *et al*. [2005] [12], there are wide variations in total phenolics of the different fruits or vegetables, or even for the same fruits or vegetables reported by different authors. These differences may be due to the complexity of these groups of compounds, and the methods of extraction and analysis [Sanchez-Mesa *et al*. 2020]. Moreover, phenolic compounds present in fruits are found in both free and bound forms (mainly as b-glycosides), but as the latter are often excluded from analyses, the total phenolics contents of fruits are often underestimated [Sun *et al.* 2002]. Besides, the phenolic contents of plant foods depend on a number of intrinsic (genus, species, cultivars) and extrinsic (agronomic, environmental, handling and storage) factors [Balasundram *et al*. 2005] [12].

The fruit industry produces large quantities of peels and seed residue, which may account for up to 50% of the total fruit weight [Peng *et al*. 2019, Sanchez-Mesa *et al*. 2020] [51]. Fruit industry by-products, if utilized optimally could be major sources of phenolic compounds as the peels, in particular, have been found to contain higher amounts of total phenolics compared to the edible portions.

4.2 Conclusion

The evaluation of the peel and pulp extracts of *I. wombolu* in the present work revealed the nutritional status of the fruit. The presence of essential minerals and other macromolecules indicates that it can serve as a complement in food and feed materials that are limited in vitamins. The inherent phenolic compounds in the peel and pulp of *I. wombolu* justifies their use in herbal medicine for control of infectious and degenerative diseases. The antioxidant properties and higher content of flavonoids in the peels can make this waste material a good source of nutraceutical and healthy phenolic compounds, especially to be used as anti-ageing products, due to the high content of polyphenols. Nevertheless, further research is needed to explore other bioactive compounds in *I.wombolu* fruit peels to support their potential use in human diet.

5. Acknowledgements

The author thanks Prof. Mrs M. T. Olaleye, Department of Biochemistry, Federal University of Technology, Akure, Ondo State, Nigeria for providing a very conducive environment during the course of this research.

6. References

1. Abdelazim AM, Khalid SM, Gammaam AMO. Suitability of some Sudanese mango varieties for jam making. Am J Sci Ind Res. 2011; 2(1): 17- 23.
2. Adekunle VAJ, Oyerinde OV. Food potentials of some indigenous wild fruits in lowland rainforest ecosystem of South West Nigeria. J Food Technol. 2004; 2(3):125-130.
3. Ainge L, Brown N. *Irvingia gabonensis* and *Irvingia wombolu*. A State of knowledge report undertaken for the Central African Regional Program for the Environment, 2001.
4. Ali H, Naz N. Free Radical Scavenging Activity of Pulps and Peels of Some Selected Vegetables Commonly Used In Pakistan. Pakistan J Agric. Res, 2017, 30(1).
5. Altemimi A, Lakhssassi N, Baharlouei A, Watson DG, David A. Light foot Phytochemicals: Extraction, Isolation, and Identification of Bioactive Compounds from Plant Extracts. Plants, 2017, 6:42. doi: 10.3390/plants6040042
6. Ameh BA, Gernah AL, Obioha O, Ekuli GK. Production, quality evaluation and sensory acceptability of mixed fruit juice from pawpaw and lime. Food Nutr. Sci, 2015; 6:532-537.
7. Amusa NA, Ashaye OA, Oladapo MO, Kafuru OO. Preharvest deteriorations of soursop (*Annona muricata*) at Ibadan Southwestern Nigeria and it effect on nutrient composition. Afri. J Biotechnol. 2003; 2(1): 23-25. ISBN 1684-5315.
8. Anderson JW, Baird P, Davis RH, Ferreri S, Knudtson M, Koraym A, Waters V, *et al*. Health benefits of dietary fiber. Nutr. Rev. 2009; 67(4):188-205.
9. AOAC. Official methods of Analysis of Association of Official Analytical Chemists 18th ed., Published by AOAC International, Gaithersburg, Maryland, USA, 2010.
10. Asibey-Berko E, Tayie EAK. Proximate analysis of some underutilised Ghanaian vegetables. GJS, 1999; 39:91-96.
11. Auddy B, Ferreira M, Blasina F, Lafon L, Arredondo F, Dajas F, *et al*. Screening of antioxidant activity of three Indian medicinal plants traditionally used for the management of neurodegenerative diseases. J Ethanopharmacol, 2003; 84:131-138.
12. Balasundram N, Kalyana Sundram K, Samman S. Phenolic compounds in plants and agri-industrial by-products: Antioxidant activity, occurrence, and potential uses. Food Chem, 2006; 99:191-203.
13. Bao JY, Cai M, Sun G, Wang Corke H. Anthocyanins, Flavonoid and Free Radical Scavenging Activity of thinesBaybery (Myrialrubia) extracts and their colour properties and stability. J Agric. Food Chem, 2005; 53:2327-2332.
14. Barriada-Bernal LG, Almaraz-Abarca N, Delgado-Alvarado EA, Gallardo-Velázquez T, Ávila-Reyes JA, Torrres-Morán MI, *et al*, 2014.
15. Barros HR, de M Ferreira TAP, de C, Genovese MI. Antioxidant capacity and mineral content of pulp and peel from commercial cultivars of citrus from Brazil. Food Chem, 2012; 134:1892-1898.
16. Boakye AA. Assessment of Some Health Beneficial Constituents of Edible Portions of Four Underutilized Fruits. Trends Food Sci Technol, 2013; 21:475-482.
17. Brito A, Ramirez JE, Areche C, Sepúlveda B, Simirgiotis MJ. HPLC-UV-MS Profiles of Phenolic Compounds and Antioxidant Activity of Fruits from Three Citrus Species Consumed in Northern Chile. Molecules, 2014, 19:17400-17421. doi: .3390/molecules191117400
18. Brunner JH. Direct spectrophotometric determination of saponin. Anal Chem, 1984; 42:1752-1754.
19. Chah JM, Ani NA, Irohibe JI Agwu AE. Exploitation of Bush Mango (Irvingia wombolu and Irvingia gabonensis) Among Rural Household in Enugu State, Nigeria. Journal of Agricultural Extension, 2014, 18(2). December 2014 DOI: 10.4314/jae.v18i2.6
20. Champ M, Langkilde A, Brouns F, Kettlitz B, Collet YB. Advances in dietary fibre characterisation. Definition of dietary fibre, physiological relevance, health benefits and analytical aspects. Nutr. Res. Rev, 2003, 16:7182
21. Chang S, Tan C, Frankel EN, Barrett DM. Low density lipoprotein antioxidant activity of phenolic compounds and polyphenol oxidase activity in selected clingstone peach cultivars. J Agric Food Chem, 2000; 48:147-151.
22. Czech A, Zarycka E, Yanovych D, Zasadna Z, Grzegorczyk I, Kłys S, *et al*. Mineral Content of the Pulp and Peel of Various Citrus Fruit Cultivars. Biol. Trace Elem Res, 2019.
23. Day RA, Underwood AL. Quantitative Analysis.5thedn.Prentice–Hall Publication, 1986, 701.
24. Ekpo IW, Amor ID Morah FNI. Seed oils and nutritive studies on the seeds of *gabonensis* and *wombolu* varieties of *Irvingia*. The Nigerian Academic Forum. 2007; 13(1):1-3.
25. Etebu E. 2012. Differences in Fruit Size, Postharvest Pathology and Phytochemicals between *Irvingia gabonensis* and *Irvingia wombolu*. Sustain. Agric. Res 2 (1): 56 - 61.
26. FAO. The State of Food Security and Nutrition in the World. FAO News, 2017.
27. Folorunso AE, Modupe OV. Comparative study on the biochemical properties of the fruits of some *Annona species* and their leaf architectural study. Not. Bot. Hort. Agrobot. Cluj. 2007; 35(1):15-19.
28. Giomaro1 G, Karioti A, Rita Bilia A, Bucchini A, Giamperi L, Ricci D, *et al*. Polyphenols profile and antioxidant activity of skin and pulp of a rare apple from Marche region (Italy). Chem Cent J, 2014, 8:45.
29. Gorinstein S, Martı´n-Belloso O, Lojek ACˆ ı´z, M, Soliva-Fortuny R, Park YS. Comparative content of some phytochemicals in Spanish apples, peaches and pears. J Sci Food and Agric, 2002; 82:1166-1170.
30. Halliwell B, Gutteridge JMC, Aruoma OI. The deoxyribose method: a simple 'test tube'assayfor determination of rate constants for reaction of hydroxyl radicals. Anal. Biochem, 1987; 165:215-219.
31. Henry TA. Organic Analysis of Alkaloids, 1973; 6:163-187.
32. Hung ML. Antioxidant Effect of Mango Waste on Shelf life of Pork Products. An Abstract for Lincoln University Postgraduate Conference, 2012.
33. Kumaran A, Karunakaran RJ. In Vitro Antioxidant Activities of Methanol Extracts of Five Phyllanthus

Species from India, 2007.
34. Leakey RRB, Greenwell P, Hall MN, Atangana AR, Usoro C, Anegbeh PO, *et al*. Domestication of: 4. Tree-to-tree variation in food-thickening properties and in fat and protein contents of nut, 2005; 90:365-378.
35. Li Y, Guo C, Yang J, Wei J, Xu J, Cheng S. Evaluation of antioxidant properties of pomegranate peel extract in comparison with pomegranate pulp extract. Food chem, 2005. doi:10.1016/j.food chem.2005.02.033.
36. Lozano JE. Chemical composition of fruits and its technological importance: In Fruit Manufacturing, 2006. *ISBN* 978-0-387-30614-8.
37. MacDonald-Wicks LK, Wood LG, Garg ML. Methodology for the determination of biological antioxidant capacity *in vitro*: a review. J Sci. Food and Agric, 2000; 86:2046-2056.
38. Maldonado-Celis ME, Yahia EM, Ramiro B, Landazuri P, Aguillon J Restrepo B, Ospina JCG, 2019. Chemical composition of Mango (Mangifera indica L.) Fruit: Nutr Phytochem Compd. Front. Plant Sci. https://doi.org/10.3389/fpls.2019.01073
39. Marker AOS, Goodchild AV. Qualification of Tannis. A laboratory Manual. International Centre of Agricultural Research in Dry Areas (ICRDA). *Alleppo Syria*, 1996, 4:25
40. Morah FNI, Achu FD. Antibacterial activity of the stem barks of *Irvingia wombolu* and *Irvingia gabonensis*. Int J Adv Sci Res Vol. 2018; 3(6):52-54
41. Morah FNI, Ekpo IW, Amor ID. Seed oils and nutritive studies on the seeds of *gabonensis* and *wombolu* varieties of *Irvingia gabonensis*, Nigerian Academic forum. 2013; 13(1):1-3.
42. Morais DR, Rotta EM, Sargi SC, Bonafe EG, Suzuki RM, Souza NE, *et al*. Proximate Composition, Mineral Contents and Fatty Acid Composition of the Different Parts and Dried Peels of Tropical Fruits Cultivated in Brazil. J Braz. Chem. Soc. 2017; 28(2):308-318. http://doi.org/10.5935/0103-5053.20160178
43. Msogoya JT, Kimaro SE. Assessment and management of post-harvest losses of fresh mango under small- scale business in Morogoro, Tanzania. J Anim Plant Sci. 2011; 11(1):1358-1363.
44. Murillo E, Britton GB, Durant AA. Antioxidant activity and polyphenol content in cultivated and wild edible fruits grown in Panama. J Pharm BioAllied Sci, 2012; 4:313-317.
45. Nangue TJ, Womeni HM, Mbiapo FT, Fanni J, Michel L. Fat nutritional properties and effect of increasing amounts on the growth and lipid metabolism of young rats wistar sp, 2011, 10:43.
46. Oduntan AO, Babalola SO, Kenneth-Obosi O, Awe OF E, Olabode IA, Egbekunle K, *et al*. Evaluation of proximate, amino acid profile and oil characterisation of *Irvingia wombolu* fruit pulp and peel. Int Food Res J. 2019; 26(4):1371-1377.
47. Ogunsina BS, Bhatnagar AS, Indira TN, Radha C. The proximate composition of African bush mango kernels (*Irvingia gabonensis)* and characteristics of its oil. Ife J Sci. 2012; 14(1):177-183.
48. Okokon EJ, Okokon EO. Proximate analysis and sensory evaluation of freshly produced apple fruit juice stored at different temperatures and treated with natural and artificial preservatives. Global J Pure Appl Sci, 2019; 25:31-37.
49. Onimawo IA, Oteno F, Orokpo G, Akubor PI. Physicochemical and nutrient evaluation of African bush mango (*Irvingia gabonensis*) seeds and pulp. Plant Foods for Hum Nutr, 2003; 58:1-6.
50. Ositadinma CU, Ogodo AC. Microbial Flora, Proximate Composition and Vitamin Content of Juices of Three Fruits Bought from a Local Market in Nigeria. Int. J Chem. Eng. Appl, 2015, 6(6).
51. Peng D, Zahid HF, Ajlouni S, Dunshea FR, Suleria HAR. LC-ESI-QTOF/MS Profiling of Austalian Mango Peel By-Product Polyphenols and Their Potential Antioxidant Activities. Processes. 2019; 7(10):764. https://doi.org/10.3390/pr7100764
52. Pinto AC, de Q, Cordeiro de Andrade SRM, Ferreira FR, Filgueiras HA, de C, *et al*. *Annona species*. International Centre for Underutilised Crops, University of Southampton, Southampton, UK, 2005. ISBN 0854327851.
53. Prieto P, Pineda M, Aguilar M. Spectrophotometric quantitation of antioxidant capacity through the formation of a phosphomolybdenum complex: specific application to the determination of Vitamin E. Anal Biochem, 1999; 269:337-341.
54. Pulido R, Bravo L, Saura-Calixto F. Detemination of Antioxidant activity of dietary polyphenols. J Agric Food Chem, 2000.
55. Sanchez-Mesa N, Sepulveda-Valencia JU, Ciro-Velasquez HJ, Meireles MA. Bioactive compounds from mango peel (Mangifera indica I. var. Tommy atkins) obtained by supercritical fluids and pressurized liquids extraction. Food Eng, 2020, 19(2). https://doi.org/10.24275/rmiq/Alim657
56. Stadlmayr B, Charrondière UR, Eisenwagen S, Jamnadass R, Kehlenbeck K. Nutrient composition of selected indigenous fruits from Sub- Saharan. Afr. J Sci Food and Agric. 2013; 93(11):2627-2636.
57. Sun J, Chu YF, Wu X, Liu RH. Antioxidant and anti-proliferative activities of common fruits. J Agric Food Chem, 2002; 50:7449-7454.
58. Vihotogbé R, van den Berg RG, Missihoun AA, Sinsin B, Sosef MSM. Genetic diversity of bitter and sweet African bush mango trees (*Irvingia* spp., Irvingiaceae) in West and Central Africa. Afri. J Biotechnol. 2015; 14(45):3062-3074.
59. Wheeler EL, Ferrel RA. A method for phytic acid determination in wheat and wheat flour. Cereal Chem. 1971; 48:313-314.
60. Wolfe OA, Ijeoma UF. Effects of aqueous extracts of *Irvingia gabonensis* seeds on the hormonal parameters of male guinea pigs. Asian Pa.c J Trop. Med. 2010; 3(3):200-204.
61. Yang J, Punshon T, Guerinot ML, Hirschi KD. Plant calcium content: ready to remodel. Nutrients. 2012; 4:1120-1136.