

1 **Phytochemicals, In-vitro Bioavailability of Beta carotene and Anti nutrient**
2 **Composition of Some Neglected Underutilized Green Leafy Vegetables and Fruits**
3 **in South East Geo-Political Zone of Nigeria.**
4
5
6

7 **ABSTRACT**
8

Background/Objective: Vegetables and fruits are important sources of protective substances, which are highly beneficial for the maintenance of good health and prevention of diseases. Phytochemicals are non-nutritive plant chemicals that have protective or disease preventive properties. The study was designed to determine the phytochemicals, *in-vitro* bioavailability of beta carotene and anti nutrient composition of some neglected underutilized fruits and vegetables in Southeast geopolitical zone of Nigeria.

Methodology: The frequently occurred underutilized fruits and vegetables were selected for the study. The food crops were harvested and identified at the Herbarium in the Department of Plant Science and Biotechnology, University of Nigeria Nsukka. Twenty underutilized fruits and vegetables each were cleaned and analysed for phytochemicals, *in-vitro* bioavailability of beta carotene and anti nutrients composition using standard methods. Data were presented using descriptive statistics, percentage, mean, standard deviation and frequency. **Results:** The result shows that 0 - 40% of beta carotene were bioavailability in the fruits studied. The antinutrient levels in fruits were cyanide (0.02-3.47 mg), oxalate 1.22-12.38 mg and phytate traces- 12.60 mg. The range of phytochemicals in the fruits were tannins trace-10.40 mg, flavonoids 0-0.10 %, saponins trace-0.051 mg, lycopene trace-94.20 mg, and phenol 0-4.01mg. The antinutrient levels in vegetables were cyanide 0.35-13.20 mg, oxalate 2.27-24.69 mg and phytate traces- 2.57 mg. : The result shows that 22- 68.80% of beta carotene were bioavailability in the vegetables studied. The phytochemicals in the vegetables were tannins 0.10-10.30 mg, flavonoids trace-0.20 %, saponins trace-0.10 mg, lycopene trace-31.20 mg and phenol 0.01-3.31 mg. **Conclusion:** The use of these neglected fruits and vegetables is imperative because of their health benefit.

Comment [D1]: Check the language..

Comment [D2]: Check the language.

9
10 *Keywords: phytochemicals, beta-carotene, neglected, vegetables and fruits.*
11

12 **1. INTRODUCTION**

13 The indigenous knowledge of the health promoting and protecting attributes of vegetables and
14 fruits are clearly linked to their nutritional and non- nutrient bioactive properties. More recent
15 reports have shown that they also contain non- nutrient bioactive phytochemicals that have been
16 linked to protection against cardiovascular and other degenerative diseases. Phytochemicals are
17 non-nutritive plant chemicals that have protective or disease preventive properties (1). Orech,
18 Akenga, Ochora, Friis, & Aagaard-Hansen (2) observed that some of these phytochemicals
19 found in some vegetables consumed may pose toxicity problems when consumed in large
20 quantities or over a long period of time.

21 The inclusion of vegetables in the diets has provided basic nutritional requirements for man and
22 also protection against incidence of chronic, degenerative and age-related disorder diseases, due
23 to the presence of phytochemical and antioxidants (3).

24 Fruits and vegetables are packed with essential vitamins, minerals and fiber. **Because** of this,
25 eating plenty of fruits and vegetables everyday can help reduce risk of heart disease, high blood
26 pressure, Type II diabetes and certain cancers . Fruits and vegetables have many important
27 phytochemicals that help "fight" diseases to protect health. Phytochemicals are usually related to
28 colour. Fruits and vegetables of different colours — green, yellow-orange, red, blue-purple, and
29 white — contain their own combination of phytochemicals and nutrients that work together to
30 promote good health. Most phytochemicals have antioxidant activity and protect the cells
31 against oxidative damage and reduce the risk of developing certain types of cancer.
32 Phytochemicals with antioxidant activity include allyl sulfides (onions, leeks, garlic), carotenoids
33 (fruits, carrots), flavonoids (fruits, vegetables), polyphenols (tea, grapes) (1).

Comment [D3]: As a result

34 Bioavailability of food is defined as the fraction of an ingested nutrient from food that is
35 available for absorption in the intestine and metabolic process and storage (4). Beta-carotene and
36 other carotenoids that can be converted by the body into retinol are referred to as provitamin A
37 carotenoids. Hundreds of different carotenoids are synthesized by plants, but only about 10% of
38 them are provitamin A carotenoids (5). Vitamin A is essential for maintaining normal vision,
39 gene expression, reproduction, embryonic development, growth and immune function (6).
40 Mason (7) reported that there is accumulating evidence that **VAD** increases risk of developing
41 respiratory diseases and the children who are vitamin A deficient are more likely to suffer from
42 chronic ear infections. Emphasis on prevention of VAD by dietary improvement, fortification
43 and/or supplementation is aimed at ameliorating infectious diseases through effects on immunity
44 and or epithelial tissue (8).

Comment [D4]: present in

Comment [D5]: Spell out the full meaning of VAD since it is appearing in the text for the first time.

45 Antinutrients are natural or synthetic compounds that interfere with the absorption of nutrients (9). One
46 common example is phytic acid, which forms insoluble complexes with calcium, zinc, iron and copper
47 (10). Proteins can also be antinutrients, such as the trypsin inhibitor and lectins found in legumes (11).
48 However, polyphenols such as tannins have anticancer properties, so foods such as green tea that contain
49 large amounts of these compounds might be good for the health of some people despite their antinutrient
50 properties (12). Many traditional methods of food preparation such as fermentation, cooking, and malting
51 increase the nutritive quality of plant foods through reducing certain antinutrients such as phytic acid,
52 polyphenols, and oxalic acid (13).

54 **2. MATERIALS AND METHODS**

55
56 **2.1 Study Area/ Study Design**

57 The study was carried out in South East Nigeria. The study design used was experimental study.

58
59 **2.2 Identification of Samples**

60 The plants harvested were identified at the Herbarium in the Department of Botany, University of Nigeria
61 Nsukka, Nigeria. Some samples were randomly selected and used for further study.

62
63 **2.3 Chemical analysis**

64 Phytochemicals, *In-vitro* bioavailability of beta carotene and anti nutrients of both underutilized
65 vegetables and fruits were determined in triplicate using standard methods |.

Comment [D6]: Cite the methods please!

66
67 **3. RESULTS**

68 Table 1 shows the list of underutilized vegetables selected for analysis.

69 Table 2 shows the list of underutilized fruits selected for analysis.

70
71 Table 3a shows phytochemicals composition of underutilized indigenous vegetables. The
72 flavonoid content of the underutilized vegetables varied from traces to 0.20%/100g on wet
73 weight basis. The vegetable with the highest level (0.10mg/100g) of saponin was *Vitex doniana*
74 and the ones with the lowest content (traces) of saponin were *Ficus elsticoides* and *Blinghia*
75 *unijugata*. The vegetable with highest content (10.30mg/100g) of tannin was *Moraceae spp*
76 while *Ceiba pentandra* had the lowest (0.10mg/100g) value of tannins. *Blinghia unijugata* had
77 the highest Lycopene content of 31.20mg/100g while *Ficus elsticoides* had traces of Lycopene.
78 The alkaloid contents of the vegetables varied from 0.10-0.50%/100g on wet weight basis. The
79 vegetable with the highest level (3.31mg/100g) of phenol was *Ficus vogaliana* and the one with
80 the lowest content (0.19mg/100g) of phenol was *Portulence oleraceae*. The vegetable with the
81 highest content (6.08%/100g) of glycoside was *Ipomea batata* while *Psychotria viridis* had
82 0.0%/100g of glycoside.

83
84 Table 3b shows phytochemicals composition of underutilized indigenous fruits. The flavonoid
85 content of the underutilized fruits varied between trace level-0.10%/100g on wet weight basis.
86 The fruit with the highest level (0.051mg/100g) of saponin was *Cola gingatean* and the one with
87 traces of saponin were *Napolean imperialist* and *Cola pachycarpa*. The fruit with the highest
88 content (10.40mg/100g) of tannin was *Afromomium daniella* while *Cola gigantean* and *parkia*
89 *clappatonia* had traces of tannins. *Cola pachycarpa* had the highest Lycopene content of
90 94.20mg/100g while *Cola gigantean*, *Napolean imperialist* and *Hippocretae myrint* had traces

91 of Lycopene. The alkaloid contents of these fruits varied between 0.03 in *Irvingia gabonensis* to
92 0.80%/100g in *Landolfolia dulcis* on wet weight basis. The fruit with the highest level
93 (4.01mg/100g) of phenol was *Olax viridis* and the one with traces of phenol was *Hippocretae*
94 *myrint*. The fruit with the highest content (3.04%/100g) of glycoside was *Hippocretae myrint*
95 while *Afromomium daniella* and *Cola parchycarpa* had traces of glycoside.

96 Table 4a shows *in-vitro* bioavailability of beta-carotene in some underutilized vegetables. The
97 bioavailability of beta-carotene for the studied underutilized vegetables ranged from 6.07-942.33
98 RE/100g. *Boerhavia diffusa* had the highest bioavailability of beta-carotene while *Ficus*
99 *elsticoides* had the least value. The percentage availability ranged from 24-68.80%.

100 Table 4b shows the *in-vitro* bioavailability of beta-carotene of some underutilized fruits. The
101 bioavailability of beta-carotene for the studied underutilized fruits ranged from 4.50-
102 2068.33RE/100g. The fruit with the highest bioavailability of beta-carotene (2068.33RE/100g)
103 was *Myristicaceae spp* while *Olax viridis* had the least value of 4.50RE/100g. The percentage
104 availability ranged from 21-40%.

105 Table 5a shows the anti-nutrient composition of some underutilized vegetables. The cyanide
106 content of these underutilized vegetables varied between 0.35-13.20mg/100g on wet weight
107 basis. The vegetable with the highest level (24.69mg/100g) of oxalate was *Ficus elsticoides* and
108 the one with the lowest content (2.27mg/100g) of oxalate was *Berlinia grandflora*. The vegetable
109 with the highest level (2.57mg/100g) of phytate was *Blinghia unijugata* while some of the
110 vegetables had traces of phytate.

111 Table 5b shows the anti-nutrient composition of some underutilized indigenous fruits. The
112 cyanide content of these underutilized fruits varied between 0.02-3.47mg/100g on wet weight
113 basis. The fruit with the highest level (12.38mg/100g) of oxalate was *Landolfolia dulcis* and the
114 one with the lowest content (1.22mg/100g) of oxalate was *Afromomium daniella*. *Landolfolia*
115 *dulcis* had the highest phytate content of 12.60mg/100g while majority of the fruits studied had
116 traces of phytate.

117
118
119
120
121
122

123 4. DISCUSSION

124 Phytochemicals

125 **Tannins:** Tannin which usually gives rise to a dry, pickery, astringent sensation in the mouth
126 was in the range of 0.10-10.30% in the vegetables studied. Tannin act as antinutrient when the
127 value is above safe level but below safe level (0.15-0.20%) it functions as phytochemicals. The
128 range of values obtained for tannins in some of the vegetables were higher than the safe level of
129 tannins (0.15-0.20%) as recommended by Schiavone *et al.* (14). *Ficus elasticoides* (0.20mg),
130 *Ceiba pentandra* (0.10mg), *Pterocarpus santalinoides* (0.10mg), *Uvaria chamea* (0.20mg) and
131 *Berlinia grandiflora* (0.10mg) were within the safe level. The range of tannins obtained for the
132 fruits were between traces to 10.40mg. Fruits such as *Vitex doniana* (0.20mg), *Parkia*
133 *clappatonia* (Trace), *Gongronema spp* (0.12mg), *Sterculiar spp* (0.05mg), *Myristicaceae*
134 *spp*(0.10mg), *Artocarpus altilis*(0.11mg), and *Cola gingatean* (Trace) had tannin levels below
135 the safe level. Consumption of adequate amount of the fruits and vegetables could be useful in
136 prevention and treatment of cancer because of the antioxidant property of tannin. Other fruits
137 with tannin higher than the safe level should be subjected to different food processing methods to
138 reduce the tannin level and extend their food uses. Holz and Gibson (13) suggested that many
139 traditional methods of food preparation such as fermentation, cooking and malting increases the
140 nutritive quality of plant foods through reducing certain anti nutrients such as phytic acid,
141 tannins, polyphenols and oxalic acid. Subjecting the vegetables to these processes will reduce
142 the toxic level and at the same time boast the phytochemical properties of the vegetables (14).
143 Tannins may be employed medically in anti-diarrheal, hemostatic and anti-hemorrhoidal
144 treatment. The anti inflammatory effects of tannins help to control all indications of gastric
145 enteritis and irritating bowel disorders. Tannins not only heal burns and stop bleeding, but they
146 also stop infection while they continue to heal the wound internally.

147 **Flavonoids:** The flavonoid values obtained for the vegetables were between traces to 0.20%.
148 The values obtained for the fruits were between traces to 0.10%. Consumption of some
149 vegetables and fruits like *Ipomea batata* leaves (0.20%) and *Landofolia dulcis* (0.10%) in
150 significant quantity could be of health benefit due to their flavonoid constituents. Flavonoids
151 lower high blood pressure and have strong anti-inflammatory properties (15). Flavonoids are
152 potent anti-oxidants. They also inhibit low density lipoprotein (LDL) by free radicals and reduce

153 the risk of cancer & Cardiovascular diseases (16). Flavonoids are also involved in platelet
154 aggregation, antimutagenic and antiproliferative properties (17).

Comment [D7]: Ampersand should not be used in constructing a sentence.

155 **Saponin:** The saponin contents of the vegetables (traces- 0.10mg) and fruits (traces-0.10mg)
156 were appreciably below 3.00mg which was reported by Kumar (18) to be responsible for cattle
157 losses when they grazed on *alfonibrilla*. Saponins have expectorative, anti-inflammatory, and
158 immune stimulating activity. They also demonstrate antimicrobial properties particularly against
159 fungi, bacteria and protozoa (19). There is evidence of the presence of saponins in traditional
160 medicine preparations (20; 21; 22). Saponins are bitter and reduce the palatability of food and
161 increase excretion of cholesterol concentration by free radicals that are bond with cholesterol
162 and other pathogens in the body. Saponin decreases tumor size and improves cognitive ability
163 (23).

164 **Cardiac glycosides:** The cardiac glycosides values for the vegetables were traces- 6.08%. The
165 range of cardiac glycoside value obtained for the fruits were between traces to 3.04%.
166 Consumption of *Daniella olivera* (0.20%), *Afromomium daniella* (trace), *Cola parchycarpa*
167 (trace), *Ficus vogaliana* (0.64%), *Ceiba pentandra* (0.60%) and *Gssampelus mucanta* (0.67%)
168 should be encouraged because they contain appreciable quantities of cardiac glycosides which
169 could help in the treatment of congestive heart failure and cardiac arrhythmia. Cardiac glycosides
170 may also be used to strengthen a weakened heart and allow it to function more efficiently.

171 **Bioavailability of beta-carotene:** The result of the *in-vitro* bioavailability of beta-carotene in
172 the vegetables and fruits were between 6.07-940.33RE and 4.50-2068.32RE, respectively as
173 against 15.20-1933.33RE and traces to 5666.67RE, respectively. This represents 22-68.80% and
174 traces to 40% availability respectively. Bioavailability of nutrient is the proportion of the nutrient
175 that when ingested, actually is absorbed in the body. The remaining amount cannot be
176 metabolized and is removed as waste. Generally, fruits and vegetables are good sources of beta
177 carotene but not all the beta-carotene are absorbed by the body. Adding cooking oil to vegetables
178 while cooking could help in bioavailability of beta carotene. Consumption of 100g of majority
179 of vegetables and fruits as shown in the pictorial record for *Vitex doniana* (580.00), *Ceiba*
180 *pentandra* (653.33), *Pterocarpus santaloides* (629.00), *Ficus vogaliana* (588.00), *Cola*
181 *parchycarpa* (2068.32), *Myristicaceae spp* (996.67), *Spondian mombin* (580.00) and *Boerhavia*
182 *diffusa* (940.33) could provide the RNI (400RE) for provitamin A (24). Beta-carotene serves as

183 powerful antioxidant, fights against heart diseases, improves absorption of iron, prevents iron
184 deficiency anemia, reduces the risk of cancer (lung and stomach), protects skin from sun
185 damage, promotes eye health, protects against cancer, stroke and high blood pressure (25).

186 **Antinutrients.**

187 **Phytate :** The range of phytate values (trace-2.57mg) for all the vegetables studied were below
188 the toxic limit for phytate (5.00mg/100g) (26). The low level of phytate in the vegetables studied
189 suggests that phytic acid concentration in the vegetables studied may not chelate important
190 minerals such as calcium, magnesium, iron and zinc in the diet containing the vegetables (27).
191 The diet will however protect the body against cancer because of its phytochemical properties
192 (28). The range of phytate values for all the fruits studied were (trace-12.06mg). *Landolfolia*
193 *dulcis* (12.60mg), *Phyllanthus debilis* (10.18mg) and *Gongronema spp* (8.20mg) had high
194 levels. There may be need to reduce the antinutrient content of the fruits, since most fruits are
195 eaten raw.

196 **Oxalate:** The oxalate values for all the vegetables studied were within the range 2.27-24.69mg.
197 The values obtained in this study were higher than the toxic limit for oxalate (2.20mg) (26). Holz
198 and Gibson (13) suggested that many traditional methods of food preparation such as
199 fermentation, cooking and malting increases the nutritive quality of plant foods through reducing
200 certain anti nutrients such as phytic acid, polyphenols and oxalic acid. The result of the fruits
201 studied showed 1.22-12.38mg/100g of oxalate. Majority of the fruits had oxalate level higher
202 than the toxic limit while fruits such as *Phyllanthus debilis* (1.88mg), *Irvingia gabonensis*
203 (1.44mg), *Afromomium daniella* (1.22mg) *Hippocretae myrint* (1.89mg), *Icacina trichatha olive*
204 (2.01mg) and *Napoleana imperialist* (1.37mg) had oxalate levels lower than toxic limit. Since
205 most fruits are eaten raw, the high oxalate level of some of the fruits may pose a problem when
206 the fruits are consumed raw. The fruits could be processed into fruit juice or drink to reduce the
207 oxalate level to acceptable level thereby extending the food uses of the fruits.

208 **Toxicant**

209 **Cyanide:** The cyanide levels (0.35-13.20mg) and (0.02-3.47mg) in the vegetables and fruits
210 were below the toxic limit for cyanide (35mg) (26). Cyanide is a toxin affecting the host when

211 consumed in large quantity. The low levels of cyanide in the vegetables and fruits studied
 212 suggest that cyanide content of these vegetable may not pose a threat to the consumers.

213 **Table 1: List of underutilized vegetables randomly selected for analysis.**

Common name	Igbo name	Scientific name
Vegetable		
Fig tree	<i>Ogbu ike</i>	<i>Ficus elasticoides</i>
Hog weed	<i>Azuigwe</i>	<i>Boerhavia diffusa</i>
-	<i>Ogbu</i>	<i>Ficus vogaliana</i>
Black plum	<i>Uchakiri</i>	<i>Vitex doniana</i>
-	<i>Uturukpa</i>	<i>Pterocarpus santalinoides</i>
-	<i>Anyazu</i>	<i>psychotria viridis</i>
Water leaf	<i>Ntioko</i>	<i>Portulace oleraceae</i>
-	<i>Agba</i>	<i>Daniella olivera</i>
Jute	<i>Arira/Elegule</i>	<i>Corchorus olitorius</i>
-	<i>Akwokwo akpu</i>	<i>Ceiba pentandra</i>
-	<i>Okwuruezikemba</i>	<i>Moraceae spp</i>
-	<i>Ogwuazu</i>	<i>Bombaceae spp</i>
-	<i>Okpokoko</i>	<i>Uvaria chamea</i>
-	<i>Akuokoro</i>	<i>Ficus fur</i>
-	<i>Ububa</i>	<i>Berlinia grandiflora</i>
Akee/Ackee	<i>Uso</i>	<i>Blighia unijugata</i>
Huckleberry	<i>Ewa</i>	<i>Vaccinium parvifolium</i>
-	<i>Obuako-enwe</i>	<i>Gssampelus mucanta</i>
-	<i>Agbolu-uku</i>	<i>Brillantaisi nitens</i>

Potato leaves *Akwukwo ji nnu* *Ipomea batata*

214

215

216 **Table 2: List of fruits randomly selected for analysis.**

Common name		Scientific name
Fruits	Igbo name	
Hog plum	<i>Echikara</i>	<i>Spondian mombin</i>
Black plum	<i>Mbembe</i>	<i>Vitex doniana</i>
-	<i>Icheku</i>	<i>Velvet tamarind</i>
-	<i>Osisiiike/Karagu</i>	<i>Myristicaceae spp</i>
-	<i>Urumbia</i>	<i>Icacina trichatha olive</i>
-	<i>Mkpuruamunwaebule</i>	<i>Hippocretae myrint</i>
-	<i>Aku okoro</i>	<i>Ficus sur</i>
-	<i>Ose ohia</i>	<i>Afromomium daniella</i>
-	<i>Uvuru</i>	<i>Nauclea diderrichii</i>
-	<i>Uvurunwamkpi</i>	<i>Artocarpus altilis</i>
White rubber vine	<i>Utu</i>	<i>Landolfolia dulcis</i>
West African locust bean	<i>Nkpuru ugba</i>	<i>Parkia clappatonia</i>
-	<i>Achicha</i>	<i>Cola parchycarpa</i>
Bush mango	<i>Ujuru</i>	<i>Irvingia gabonensis</i>
-	<i>Oji-eyi</i>	<i>Cola gingatean</i>
-	<i>Osenga</i>	<i>Olox viridis</i>
-	<i>Aodo</i>	<i>Gongronema spp</i>
Gooseberry	<i>Akpuru</i>	<i>Phyllanthus debilis</i>
-	<i>Nkwukpo</i>	<i>Sterculiar spp</i>

217

218 **Table 3a: Phytochemicals composition of some underutilized vegetables on wet weight**
 219 **basis.**

Scientific name	Flavonoids (%)	Saponins (mg)	Lycopenes (mg)	Alkaloids (mg)	Tannins (mg)	Phenols (mg)	Glycosides (%)
<i>V. doniana</i>	Trace	0.100±0.25	10.40±0.03	0.20±0.06	6.30±0.72	2.80±0.03	0.71±0.65
<i>F. elsticoides</i>	0.001±0.40	Trace	Trace	0.61 ±0.00	0.20±0.12	0.19±0.26	1.60±0.12
<i>F. vogaliana</i>	0.031±0.18	0.002±0.01	8.80±0.11	0.11±0.13	3.20±1.24	3.31±0.18	0.64±0.23
<i>C. pentandra</i>	0.011±1.21	0.003±0.01	26.10±0.01	0.24±0.17	0.10±0.14	1.10±0.33	0.60±0.41
<i>P. oleraceae</i>	0.001±0.35	Trace	Trace	0.10±0.06	2.49±1.00	0.01±0.11	1.00±0.09
<i>D. olivera</i>	Trace	0.030±0.29	10.10±0.04	0.30±0.24	3.10±0.23	1.03±0.32	0.20±0.06
<i>P. santalinoides</i>	0.090±0.08	0.010±0.01	10.70±0.13	0.121±1.02	0.10±0.01	0.57±1.27	1.62±0.84
<i>p. viridis</i>	0.009± 0.64	0.080±0.04	13.00±0.01	0.47±0.18	1.30±0.35	3.20±1.12	Trace
<i>H.crinite</i>	0.010±0.11	0.013±0.72	2.40±0.12	0.40±0.02	2.04±0.47	3.01±0.14	1.24±0.17
<i>Moraceae spp</i>	Trace	0.005±0.25	1.24±0.03	0.15±0.06	10.30±0.72	0.93±0.55	1.80±0.10
<i>Bombaceae spp</i>	0.003±0.40	0.047±0.00	3.20±0.2	0.40±0.34	3.10±0.12	1.16±0.26	3.25±0.92
<i>U. chamea</i>	0.010 ±0.22	0.024±0.00	9.10±0.01	0.32±0.32	0.20±0.09	2.40±1.08	4.98±0.72
<i>Ficus sur</i>	0.051±0.18	0.011±0.01	12.70±0.14	0.43±0.03	0.43±0.03	1.55±0.64	1.25±0.83
<i>B. grandiflora</i>	0.030 ±1.21	0.006±0.01	4.70±0.01	0.27±0.91	0.10±0.14	1.26±0.01	5.57±0.88
<i>B. unijugata</i>	0.060±0.35	0.0	31.20±0.06	0.50±0.01	4.68±1.00	3.00±0.02	2.67±0.16
<i>B. nitens</i>	0.020±0.29	0.010±0.04	6.10±0.24	0.47±0.22	0.30±0.23	1.20±0.07	3.36±0.18
<i>G. mucanta</i>	0.040± 0.64	0.031±0.04	3.10±0.01	0.33±1.23	2.61±0.35	2.40±0.36	0.67±0.29
<i>I.batata</i>	0.200± 0.72	0.001±0.12	1.13±0.02	0.27±0.65	7.43±0.47	1.80±0.13	6.08±0.49

220 Mean ± Standard deviation

221

222

223

224

225

226

227

228

229 Table 3b: Phytochemical composition of some underutilized fruits on wet weight basis.

Scientific name	Flavonoids (%)	Saponin (mg)	Lycopene (mg)	Alkaloids (mg)	Tannins (mg)	Phenols (mg)	Glycoside (%)
<i>H. myrint</i>	Trace	0.021±0.90	Trace	0.57±0.01	1.50±0.25	0.07±0.16	3.04±0.92
<i>N. diderrichii</i>	0.001±0.92	0.030±0.06	1.20±0.24	0.26±0.12	1.30±0.17	2.34±0.59	1.34±0.02
<i>I. trichatha olive</i>	0.005 ±0.87	0.020± 0.02	0.10±1.06	0.10±0.16	1.40±0.79	1.21±0.28	1.90±0.74
<i>N. imperialist</i>	0.010± 0.59	Trace	Trace	0.20±0.01	1.20±0.06	0.23±0.22	2.10±0.25
<i>A. daniella</i>	0.030±0.74	0.001± 0.43	8.30±1.08	0.43±0.01	10.40±0.08	3.22±0.08	Trace
<i>V.tamarind</i>	0.020±0.06	0.004±0.09	11.80±0.22	0.51±1.23	1.40±1.08	2.13±0.09	0.22±0.07
<i>Myristicaceae spp</i>	0.010±0.01	0.031±0.28	5.00±0.09	0.23±1.45	0.10±0.07	2.74±0.03	3.11±0.18
<i>Olex viridis</i>	0.001± 0.02	0.009±0.07	2.10±0.47	0.40±0.22	1.30±0.04	4.01±0.09	1.24±0.23
<i>A. altilis</i>	0.030±0.25	0.011±0.03	22.40±0.06	0.27±0.98	0.11±0.72	1.10±0.12	1.40±0.21
<i>C. gingatean</i>	Trace	0.051±0.29	Trace	0.54±0.04	Trace	4.00±0.11	2.10±0.60
<i>Ficus sur</i>	0.002 ±0.08	0.036±0.01	4.40±0.13	0.20±0.52	0.12±0.01	Trace	0.96±0.88
<i>P. debilis</i>	0.003 ± 0.64	0.010±0.04	27.04±0.01	0.14±0.0	2.41±0.35	0.87±0.26	2.41±0.15
<i>Sterculiar spp</i>	0.050± 0.72	0.031±0.12	18.16±0.02	0.30±0.12	0.05±0.47	2.41±0.18	2.40±0.10
<i>L. dulcis</i>	0.100 ±0.40	0.030±0.00	1.80±0.06	0.80±0.76	3.40±0.12	1.96±0.00	1.92±0.11
<i>C. parchycarpa</i>	0.070±0.18	Trace	94.20±0.01	0.30±2.01	1.30±1.24	3.26±0.24	Trace
<i>Gongronema spp</i>	0.004 ±1.21	0.043±0.01	7.00±0.01	0.60±0.17	0.12±0.14	2.01±0.59	0.11±0.01
<i>S.mombi</i>	0.040± 0.43	0.031±0.03	3.10± 0.21	0.32± 0.10	0.40± 0.13	3.30± 0.00	0.48± 0.08
<i>V.doniana</i>	0.020± 0.01	0.004± 0.28	11.80±0.16	0.51± 0.06	0.20± 0.17	3.93± 0.23	3.03± 0.12
<i>P.clappatoniana</i>	Trace	0.001± 0.11	50.20±1.12	0.36± 0.98	Trace	1.04± 0.54	0.06± 0.18
<i>I.gabonensis</i>	0.050± 0.72	0.031± 0.13	18.16±0.22	0.03± 1.15	1.55± 0.64	2.24± 0.33	1.22± 1.52

230 Mean±Standard deviation

231

232

233

234

235

236

237

238

239

240

241

242

243 **Table 4a: In-vitro Bioavailability of Beta- carotene in some underutilized vegetables**

Scientific name	B- carotene (RE) as Determined	B-carotene (RE) available	(%) Availability
<i>Vitex doniana</i>	1933.33±21.59	580.00	30
<i>Ficus elsticoides</i>	15.20±0.29	6.07	40
<i>Corchorus olitorius</i>	16.00±0.35	6.24	39
<i>Ficus vogaliana</i>	1633.33±8.74	588.00	36
<i>Ceiba pentandra</i>	1866.67±18.17	653.33	35
<i>Portulace oleraceae</i>	31.20±0.14	12.23	39
<i>Daniella olivera</i>	22.40±0.11	8.74	39
<i>Pterocarpus santalinoides</i>	1233.33±6.18	629.00	51
<i>Uvaria chamea</i>	200.00±0.35	56.00	28
<i>Ficus sur</i>	356.67±2.74	217.33	22
<i>Berlinia grandiflora</i>	356.67±1.17	117.00	33
<i>Blinghia unijugata</i>	591.67±1.14	142.00	24
<i>Brillantaisi nitens</i>	700.00±0.11	259.00	37
<i>Vaccinium parvifolium</i>	451.67±2.18	176.15	39
<i>Gssampelus mucanta</i>	266.83±0.01	72.58	27.20
<i>Ipomea batata</i>	701.67± 0.19	213.66	30.45
<i>psychotria viridis</i>	25.67±0.01	10.13	39.40
<i>Boerhavia diffusa</i>	1366.67± 0.19	940.33	68.80
<i>Moraceae spp</i>	450.00±0.59	130.50	29
<i>Bombaceae spp</i>	6161.67±1.29	565.83	35

244 Mean and percentage bio-accessible.

245

246

247

248

249

250

251 **Table 4b: In-vitro Bioavailability of Beta- carotene in some underutilized fruits.**

Scientific name	B-carotene (RE) as determined	B-carotene (RE) available	(%) Availability
<i>Hippocretae myrint</i>	Trace	—	—
<i>Nauclea diderrichii</i>	1233.33±6.62	394.67	32
<i>Icacina trichatha olive</i>	16.67±0.94	6.67	40
<i>Napoleana imperialist</i>	Trace	—	—
<i>Spondian mombin</i>	2000.00±9.71	580.00	29
<i>Vitex doniana</i>	1333.33±0.76	392.00	29.41
<i>Afromomium daniella</i>	566.67±0.73	170.00	30
<i>Vevet tamarind</i>	Trace	—	—
<i>Myristicaceae spp</i>	4333.33±11.03	996.67	23
<i>Olax viridis</i>	16.67± 0.09	4.50	27
<i>Irvingia gabonensis</i>	416.67±2.14	132.32	32
<i>Cola ginatean</i>	46.67±0.11	9.33	20
<i>Ficus sur</i>	665.00±1.18	259.33	39
<i>Phyllanthus debilis</i>	141.67±0.01	35.42	25
<i>Sterculiar spp</i>	60.00± 0.19	12.60	21
<i>Artocarpus altilis</i>	199.83±4.59	51.96	26
<i>Landfolia dulcis</i>	48.33±0.29	11.12	23
<i>Parkia clappatonia</i>	970.67±1.35	371.57	38.28
<i>Cola parchycarpa</i>	5666.67±2.74	2068.32	36.5
<i>Gongronema spp</i>	17.5±0.17	5.25	30

252 Mean and percentage bio-accessible

253

254

255

256

257 **Table 5a: Antinutrient composition of some underutilized vegetables on wet weight basis**
 258 **(mg/100g).**

Scientific name	Cyanide	Oxalate	Phytate
<i>Vitex doniana</i>	12.14±0.25	10.02±0.03	1.90±0.06
<i>Ficus elsticoides</i>	11.59±0.40	24.69±0.00	1.40±0.06
<i>Corchorus olitorius</i>	3.24 ±0.22	9.21 ±0.00	0.30±0.01
<i>Ficus vogaliana</i>	4.71±0.18	13.02±0.01	Trace
<i>Ceiba pentandra</i>	13.20±1.21	11.97±0.01	1.20±0.01
<i>Portulacae oleraceae</i>	3.91±0.35	14.16±0.06	0.40±0.01
<i>Daniella olivera</i>	5.20±0.29	23.12±0.04	1.54±0.24
<i>Pterocarpus santalinoides</i>	6.23 ±0.08	17.02±0.01	1.10±0.13
<i>psychotria viridis</i>	2.14 ± 0.64	3.24±0.04	1.07±0.01
<i>Boerhavia diffusa</i>	4.47± 0.72	4.96±0.12	1.24±0.02
<i>Moraceae spp</i>	0.67±0.25	2.70±0.03	2.30±0.06
<i>Bombaceae spp</i>	0.57 ±0.40	2.38±0.00	Trace
<i>Uvaria chamea</i>	0.47 ±0.22	5.91±0.00	Trace
<i>Ficus sur</i>	2.04±0.18	4.28±0.01	Trace
<i>Berlinia grandiflora</i>	0.52 ±1.21	2.27±0.01	1.10±0.01
<i>Blinghia unijugata</i>	0.35±0.35	4.56±0.06	2.57±0.01
<i>Brillantaisi nitens</i>	0.45±0.29	3.78±0.04	1.90±0.24
<i>Vaccinium parvifolium</i>	1.94 ±0.08	3.87±0.01	10.01±0.13
<i>Gssampelus mucanta</i>	0.45 ± 0.64	3.52±0.04	2.34±0.01
<i>Ipomea batata</i>	0.98± 0.72	2.84±0.12	0.82±0.02

259 Mean ± Standard deviation

260
 261
 262
 263
 264
 265
 266
 267
 268
 269
 270
 271
 272

273

274 **Table 5b: Anti-nutrient composition of some underutilized fruits on wet weight basis**
 275 **(mg/100g).**

Scientific name	Cyanide	Oxalate	Phytate
<i>Hippocretae myrint</i>	1.07±0.90	1.89±0.01	Trace
<i>Nauclea diderrichii</i>	0.82 ±0.92	3.10 ± 0.06	Trace
<i>Icacina trichatha olive</i>	1.20 ±0.87	2.01± 0.02	Trace
<i>Napoleana imperialist</i>	3.24± 0.59	1.37±0.01	Trace
<i>Spondian mombin</i>	2.71±0.02	4.30±0.03	1.20±0.25
<i>Vitex doniana</i>	3.01±0.19	2.26±0.04	2.88±0.28
<i>Afromomium daniella</i>	1.77±0.74	1.22± 0.43	3.40±1.08
<i>Vevet tamarind</i>	1.53±0.06	2.77±0.09	Trace
<i>Myristicaceae spp</i>	2.20±0.01	3.08 ±0.28	Trace
<i>Otax viridis</i>	1.24± 0.02	4.03± 0.07	Trace
<i>Artocarpus altilis</i>	0.30±0.25	12.08±0.03	4.02±0.06
<i>Irvingia gabonensis</i>	2.23±0.35	1.44±0.06	1.64±0.01
<i>Cola gingatean</i>	1.22±0.29	3.87±0.04	1.10±0.24
<i>Ficus sur</i>	0.05 ±0.08	12.02±0.01	10.18±0.13
<i>Phyllanthus debilis</i>	3.47 ± 0.64	1.88±0.04	0.21±0.01
<i>Sterculiar spp</i>	0.14± 0.72	6.16±0.12	5.15±0.02
<i>Landolfolia dulcis</i>	0.27 ±0.40	12.38±0.00	12.60±0.06
<i>Parkia clappatonia</i>	0.34 ±0.22	9.02 ±0.00	1.20±0.01
<i>Cola parchycarpa</i>	1.98±0.18	7.11±0.01	2.72±2.01
<i>Gongronema spp</i>	0.02 ±1.21	12.22±0.01	8.20±0.01

276 Mean±Standard deviation

277

278

279

280

281

282 **5. References**

- 283 1 Downey, M.O.; Harvey, J.S.; Robinson, S.P. The effect of bunch shading on berry
284 development and flavonoid accumulation in Shiraz grapes. *Australian Journal of Grape and*
285 *Wine Research* 10: 55-73. 2004.([www. Phytochemical.info](http://www.Phytochemical.info))
- 286 2 Orech, F.O., Akenga, T., Ochora, J., Friis, H. & Aagaard-Hansen, J.(2005). Potential toxicity
287 of some traditional leafy vegetables consumed in Nyang'oma Division, Western Kenya. *African.*
288 *Journal of Food Agriculture, Nutrition & Development.*, Online 2005, **5(1)** .
- 289
- 290 3 Ibiyinka, O., Gregory T., Ian F. & Adebayo O.(2009). Evaluation of antioxidant activity and
291 vitamin E profile of some selected indigenous vegetables in Nigerian diet. *Journal of Food,*
292 *Agriculture & Environment.*7 (2), 1 4 3 - 1 4 5 www.world-food.net.
- 293 4 Jackson, M.J. (1997). The assessment of bioavailability of micronutrients: introduction.
294 *European Journal of Clinical Nutrition.*, **51**: S1-S2.
- 295 5 Linus Pauling Institute, Oregon State University (2012) Vitamin A and skin healthy
296 ([www.oregonstate.edu.vit](http://www.oregonstate.edu/vit)).
- 297 6 Mc Gurie, J. (1993).Addressing micronutrient malnutrition ,SCN News No 9: 1-9.
- 298 7 Mason J. (1991) Vitamin A policies need rethinking. *International Journal of Epidemiology.*
- 299 8 Usha, U.K.R. (2002).Experiences and challenges in developing countries. Forging effective
300 strategies to combats iron deficiency. *Journal of Nutrition Science*, 32, 827-830.
- 301 9 Oxford Dictionary of Biochemistry and Molecular Biology.(2006) Oxford University Press.
302 ISBN_0198529171.(www.en.wikipedia.org/wiki/special).
- 303 10 Cheryan M. (1980) Phytic acid interaction in food systems, NCBI. *Crit. Rev. Food Sci*
304 *Nutr* 13 (4) 297- 297-335
- 305 11 Gilani, G.S., Cockell, K.A. & Sepehr, E. (2005). "Effects of antinutritional factors on
306 protein digestibility and amino acid availability in foods". *American Journal of clinical*
307 *Nutrition.* **88** (3), 967–87. [PMID 16001874](http://PMID_16001874).
- 308 12 Chung, K.T., Wong, T.Y., Wei, C.I. , Huang, Y.W & Lin, Y.(1998) .Tannins and human

Comment [D8]: Add the website url.

309 health: *Critical Review of Food Science Nutrition*, 8,21-464.

310 13 Hotz, C. & Gibson, R.S. (April 2007). "Traditional food-processing and preparation
311 practice to enhance the bioavailability of micronutrients in plant-based diets".*Journal of*
312 *Nutrition*, **137**(4), 1097–100. [PMID 17374686](#)

313 14 Schiavone, A., Guo, K., & Tassone, S.(March 2008). "[Effects of a natural extract of](#)
314 [chestnut wood on digestibility, performance traits, and nitrogen balance of broiler chicks](#)".
315 *Poultry Science* **87** (3), 521–7. [doi:10.3382/ps.2007-00113](#). [PMID 18281579](#).
316 <http://ps.fass.org/cgi/pmidlookup?view=long&pmid=18281579>

317 15 CSIRO (2004) Reduction of root flavonoid level and its potential (www.publish.csiro.au).

318 16 Verena, S., Mario, L. & Karl, S. (2006). The role of tea and tea flavonoids in
319 cardiovascular health. *Journal of Nutritional Food Resources*,50, 218-228.

320 17 Subramani, S. & Casimir, C. A. (2002). Flavonoids and antioxidant activity of Georgia.

321 18 Kumar, K. (1987). *Conducting focus group interviews in developing countries*. A.I.D.
322 Program Design and Evaluation Methodology Report No. 8. Washington, D.C. U.S. Agency for
323 International Development.

324 19 Abbot, W.S. (1925). A method of computing the effectiveness of an insecticide.
325 *J.Econ. Entomol.*18, 265-267, (www.rayahelian.com).

326

327 20 Asl, M.N. & Hosseinzadeh, H. (2008). Review of pharmacological effects of Glycyrrhiza spp
328 and its bioactive compounds. *Phytother Resources*. 22(6), 709-724.

329 21 Hostettan, K. & Marston, A. (1995). Saponins: chemistry and pharmacology of natural
330 products. Cambridge University Press, Cambridge, UK.

331 22 Hussain, Z. J., Muhammad, R. Ullah, F.U. Khan, I.U. Khan, N. Khan, J. Ali, & S. Jan (2010).
332 Evaluation of the chemical composition of *Sonchus eruca* and *Sonchus asper*, *Journal of*
333 *American science*. 6(9), 231-235.

334 23 Malinow, M.R., McNaughty, A.L. and Kohler, G.O. (1985). Effects of synthetic glycosides on
335 cholesterol absorption. *Ann. N.Y. Acad. Sci.*, 23: 454.

336 24 FNB (Food and Nutrition Board/IOM (Institute of Medicine). Dietary Reference Intakes for
337 vitamin A, vitamin K, arsenic, boron, chromium, copper, iodine, iron, manganese, molybdenum,

338 nickel, silicon, vanadium, and zinc. Washington, D.C., National Academy Press; 2001. p.82-
339 393.

340 25 Nnam, N.M. (2011). Bioactive compounds in plant foods with potential health benefits and he
341 double burden of malnutrition. *Proceedings of Federation of African Nutrition Society*
342 *Congress*.

343 26 Munro, A. & Bassir, O. (1969).Oxalate in Nigeria vegetables. *West African Journal of*
344 *Biological, Agriculture and Chemistry*, 12, 14-17.

345 27Committee on Food Protection, Food and Nutrition Board, National Research Council
346 (1973). "Phytates". *Toxicants Occurring Naturally in Foods*. National Academy of
347 Science, 363– 371. ISBN 9780309021173 (www.bookgoogle.com).

348 28 Seaman, J. C., Hutchison, J. M., Jackson, B. P. & Vulava, V. M. (2003), "In situ treatment
349 of metals in contaminated soils with phytate", *Journal of Environmental Quality*, **32** (1), 153–
350 161, PMID 12549554 .

351

352

UNDER PEER REVIEW