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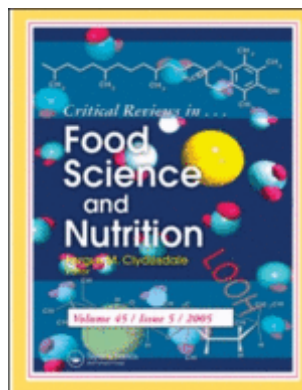
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(Article begins on next page)



Food applications of *Irvingia gabonensis* (Aubry-Lecomte ex. O'Rorke) Baill., the "wild mango": a review

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2 1 **Food applications of *Irvingia gabonensis* (Aubry-Lecomte ex. O'Rorke) Baill., the “wild**
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4 2 **mango”**: a review
5

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26 12
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28
29 13 **Abstract**
30

31
32 14 *Irvingia gabonensis*, also known as ‘wild mango’ is a multipurpose fruit tree that is native to tropical
33
34 15 Africa. It is recognized as a priority indigenous fruit tree in western and central Africa since its wood
35
36 16 is used for making utensils and fruits are mostly used as food and medicinal. The fruit mesocarp
37
38 17 contains various phytochemicals and a concentration of ascorbic acid higher than some vitamin C
39
40 18 rich fruits then it is consumed fresh or dried or is used for the production of juice and wine or as a
41
42 19 flavourant. The *I. gabonensis* fruit kernel is rich in oil (63%-69% crude fat), which is mainly
43
44 20 composed of myristic and lauric acids. Moreover, the content of carbohydrates and protein is very
45
46 21 high. Seeds can be dried and milled, and the cake obtained can be used directly or after degreasing as
47
48 22 a thickener in ‘ogbono soup’. The kernel fats are instead used as a pharmaceutical excipient as well
49
50 23 as for margarine production. The objective of this work is to provide an update review of the available
51
52 24 knowledge about the characteristics of the *I. gabonensis* fruit in order to evaluate its potential use in
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54 25 the food industry.
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60 26

27 Keywords: bush mango, ogbono soup, dika nut, polyphenols, carotenoids

28

1. Introduction

31 *Irvingia gabonensis* (Aubry-Lecomte ex O'Rorke) Baill., also known as 'African mango tree', 'bush
32 mango', 'sweet bush mango', 'wild mango', 'dika nut', 'rainy season bush mango', 'dika bread tree',
33 'odika', 'manguier sauvage', 'chocolatier', or 'ogbono', is a multipurpose fruit tree native to tropical
34 Africa, and more specifically to Angola, Cameroon, Central African Republic, Congo, Cote d'Ivoire,
35 Democratic Republic of Congo, Equatorial Guinea, Gabon, Ghana, Guinea-Bissau, Liberia, Nigeria,
36 Senegal, Sierra Leone, Sudan, and Uganda (National Research Council 2006; Singh 2007). This
37 traditional tree is common in dense evergreen rain forests but is also found near riverbanks (Atangana
38 et al. 2001); it has been reported to be used as a source of timber and to make utensils, and also as
39 food and medicine (Okoronkwo et al. 2014; Fungo et al. 2016; Ofundem et al. 2017).

40 The fruits are available from May to September with the peak harvesting period being June/July
41 (Onimawo et al. 2003). The fruit is a broad, ellipsoid drupe with a thin epicarp, an edible fleshy
42 mesocarp (pulp) (when ripe) and a hard, stony, nut encasing a soft, oil rich, dicotyledonous kernel
43 wrapped inside a brown seed-coat (Ogunsina, Koya and Adeosun 2008^a; Ogunsina, Koya and
44 Adeosun 2008^b; Ogunsina et al. 2012; Ogunsina, Olatunde and Adeleye 2014). This kernel, which is
45 also referred to as seed, is widely used as food (Omoniyi et al. 2017). Thus, *I. gabonensis* is included
46 in the FAO/INFOODS biodiversity list and is recognized by the International Centre for Research in
47 Agroforestry as a priority indigenous fruit tree for West and Central Africa (Franzel, Jaenicke and
48 Janssen 1996; Leakey et al. 2005; National Research Council 2006; Ruth Charrondière et al. 2013;
49 Stadlmayr et al. 2013; Vihotogbe', van der Berg and Sosef 2013; Bvenura and Sivakumar 2017;
50 Shaheen, Ahmad and Haroon 2017). Due to this, ethnobotanical and economical researches focussed
51 on *I. gabonensis*, have emerged in recent years (Ladipo, Fondoun and Ganga 1996; Ayuk et al. 1999;
52 Leakey et al. 2000; Atangana et al. 2001; Leakey and Page 2006; Singh 2007; Vihotogbé, van der

1
2 53 Berg and Sosef 2013); however, up until now, a comprehensive review summarising its applications
3
4 54 and the functional properties of *I. gabonensis* products in the food industry is lacking. The aim of this
5
6 55 review is thus to deepen the existing knowledge about the physico-chemical characteristics of *I.*
7
8 56 *gabonensis* pulp and kernels in order to verify their potential use in the food industry, especially in
9
10
11 57 functional products.
12

13 58

16 59 2. Fruits

17
18 60 The fresh fruits, that are similar to small mangoes, have a green-yellow colour and since their taste
19
20 61 varies between sweet and bitter they are divided into two groups, the “eating type” and the “cooking
21
22 62 type. The “eating type” comprises of the species *Irvingia gabonensis* which is fibrous, has a mesocarp
23
24 63 characterized by a sweet taste and is a yellow to orange colour while the “cooking type” is the *Irvingia*
25
26 64 *wombolu* species whose seeds are widely processed across West Africa but the mesocarp is bitter and
27
28 65 non-edible (Harris 1996).
29

30
31
32 66 The pulp of *I. gabonensis* has an elevated moisture content (Table 1), from 78.8% to 90.47%, and a
33
34 67 soluble solid content of around 10%, which indicates that this fruit is suitable for juice production.
35
36
37 68 The pH varies between 4.7 to 5.8 and acidity may be the reason behind the bitter taste of the pulp
38
39 69 (Onimawo et al. 2003). The ash content is low (0.8 – 1.8 %) but potassium (1114 mg/100 g dry
40
41 70 weight) and calcium (118 mg/100 g dry weight) contents are high in contrast to low sodium content
42
43 71 (12 mg/100 g dry weight) (Olayiwola et al. 2013). The high variability on reported fat content of this
44
45 72 fruit is due to the differences in sample extraction amongst different studies.
46
47

48 73 *I. gabonensis* fruits are well cited as antisickling products (Amujoyegbe et al. 2016). Etebu (2012)
49
50 74 compared the phytochemicals in *I. gabonensis* and *I. wombolu* documenting the presence of five
51
52 75 groups of phytochemicals (alkaloids, flavonoids, saponins, tannins and glucosides) in mesocarp from
53
54 76 both varieties. This finding is supported by other studies which investigated these components (Table
55
56 77 2). The fruit of *I. gabonensis* can be considered vitamin C rich (51-76 mg/100g) when compared with
57
58
59
60

1
2 78 other fruits like orange (about 50 mg/100g), and common mango (about 40 mg/100g) (USDA 2018).

3
4 79 Also, the carotenoid and the phenolic content of *I. gabonensis* fruits are very high (Table 2).

5
6 80 Emejulo et al. (2014) studied the effect of *I. gabonensis* fruit juice on serum lipid profile of sodium
7
8 81 fluoride-intoxicated rats by comparing with positive and negative control groups. They concluded
9
10 82 that the level of HDL-cholesterol was higher in the *I. gabonensis* group than in the positive control
11
12 83 group (20 mg/kg body weight of quercetin + 100 mg/kg body weight of alfa-tocopherol) and the fruit
13
14 84 juice of *I. gabonensis* was reported to have a lowering effect on LDL-cholesterol as compared to the
15
16 85 other groups tested. The author attributed this action to the presence of alkaloids, saponins, flavonoids
17
18 86 and polyphenols commonly known to reduce serum lipids in animals (Ezekwe and Obioha 2001). An
19
20 87 ameliorative effect was observed in NaF-induced lipidemia in rats when fed with *I. gabonensis* fruit
21
22 88 juice, which may be due to its reportedly rich vitamin C content and plant polyphenols. *I. gabonensis*
23
24 89 pulp is also used for diabetes treatment when coupled with *Ouratea turnarea* (Kuate and Efferth
25
26 90 2011).

27
28 91 As *I. gabonensis* kernels are more economically resourceful, the traditional post-harvesting
29
30 92 operations aim to remove the kernel in its optimum conditions. In most cases, the interest in the seed
31
32 93 results in the neglect of the potential of other parts of the fruit, including the pulp.

33
34 94 Fruit harvesting must be undertaken at an appropriate time, preventing the harvest of immature fruits,
35
36 95 but also ensuring a good shelf life (Ladipo 1999). Besides harvesting, the gathering of fallen ripe
37
38 96 fruits by women, children and young adults in many of the cultivated areas has also been reported
39
40 97 (Elah 2010; Nkwatoh et al. 2010). The fresh fruits of *I. gabonensis* have a shelf life of less than 2
41
42 98 days if picked when ripe and not more than 10 days if harvested at the mature green stage, due to high
43
44 99 respiration rate, moisture loss and microbial attack (Aina 1990; Joseph and Aworh 1991; Joseph and
45
46 100 Aworh 1992; Etebu 2013). Etebu (2013) isolated four genera of fungi (*Aspergillus*, *Penicillium*,
47
48 101 *Rhizopus* and *Mucor*) from postharvest fruits of *I. gabonensis* and *I. wombolu*, concluding that
49
50 102 *Rhizopus* and *Mucor* species were the most predominant genera of fungi associated with postharvest
51
52 103 *Irvingia* fruits.

1
2 104 Aina (1990) described the physicochemical changes in *I. gabonensis* fruits during normal storage
3
4 105 ripening and revealed that, with the ripening process, the fruit peel gets yellow and the sweetness of
5
6 106 the pulp increases due to starch degradation. The sourness and the acidity decreases, the fruit turns
7
8
9 107 softer, mainly due to pectin degradation, and, finally, the vitamin C content decreases as ascorbic acid
10
11 108 is very susceptible to oxidative degradation. In order to extend the shelf-life of *I. gabonensis* fruits
12
13 109 during storage, Joseph and Aworh (1991; 1992) studied the influence of some post-harvest treatments.
14
15
16 110 Firstly, while comparing ripening at room temperature and refrigerated storage of the fruits, it was
17
18 111 noticed that low temperatures induced cold injuries in *I. gabonensis* and that room-ripened fruits had
19
20 112 better flesh colour and texture, although, they also had a higher moisture loss (Joseph and Aworh
21
22
23 113 1991). After these primary results, the authors conducted other experiments in order to determine the
24
25 114 effects of dipping fruits in hot water and in different concentrations of benomyl, DHA-S, and $\text{Na}_2\text{S}_2\text{O}_5$
26
27 115 at different temperatures, on the shelf life and quality. While untreated fruits had become brownish
28
29
30 116 black and unmarketable by day 12, the fruits treated with hot 0.1% benomyl or 0.5% $\text{Na}_2\text{S}_2\text{O}_5$ followed
31
32 117 by waxing had an attractive appearance and good quality until day 14. Dipping fruits in hot water (55
33
34 118 °C) or chemical solutions (0.1% benomyl, 0.5% DHA-S or 0.5% $\text{Na}_2\text{S}_2\text{O}_5$) followed by waxing or
35
36 119 packaging in boxes overwrapped with stretch PVC film, delayed ripening, controlled decay,
37
38
39 120 minimised weight loss and extended the shelf life of the fruits under tropical ambient conditions,
40
41 121 without adverse effects on visual and chemical qualities (Joseph and Aworh 1992).
42
43 122 *I. gabonensis* pulp is consumed to a considerable extent, normally eaten raw as a dessert or snack;
44
45
46 123 however, large quantities are usually wasted (Akubor 1996). Juice, beverage, and jam manufacturing
47
48 124 requires little processing and addresses the need to use the raw pulp, injured or not. Various authors
49
50 125 cited bush mango as being more suitable for juice, wine, and jam production, compared to other
51
52
53 126 known tropical fruits (Ejiofor 1994; Okolo 1994; Agbor 1994; Okafor, Okolo and Ejiofor 1996;
54
55 127 Akubor 1996; Ainge and Brown 2001; Aworh 2015).
56
57 128 Laboratory trials have shown that jam can be produced from lesser known Nigerian fruits including
58
59
60 129 *I. gabonensis* (Aina and Adesina 1991; Ainge and Brown 2001; Aworh 2014; Aworh 2015). Aworh

1
2 130 (2014) produced jams from three indigenous fruits containing 50% of pulp. For the *I. gabonensis* jam
3
4 131 recipe, 500 g of pulp was mashed and boiled with 638 g of sugar, 100 g of water, 6 g of citric acid
5
6 132 and 5 g of calcium chloride in a steam-jacketed kettle. In a sensory evaluation of the wild fruit jams,
7
8
9 133 *I. gabonensis* jam was the less preferred, especially in terms of flavour and consistency. The author
10
11 134 concluded that although *I. gabonensis* jam is manufacturable, it may not be marketable for its low
12
13 135 acceptance.

15
16 136 Akubor (1996) studied the suitability of *I. gabonensis* fruits for juice and wine production. The pulp
17
18 137 was blended with water in a 1:5 proportion, then filtered in cheesecloth and cane sugar added in order
19
20 138 to obtain 23 °Brix. A yield of 75% was achieved and the obtained juice was compared to other tropical
21
22 139 fruit juices obtained from banana, orange and cashew. No differences were observed among these
23
24
25 140 juices and the *I. gabonensis* juice showed only a lower protein content and a higher ascorbic acid
26
27 141 content compared to the other tropical fruit juices.

29
30 142 For wine production, the *I. gabonensis* juice was fermented with *Saccharomyces cerevisiae* at 30 °C
31
32 143 for 28 days. The wine produced had 8.12% (v/v) alcohol, 0.78% protein, 6.5 °Brix SS, and a pH 3.10.
33
34 144 Consumer test showed that the obtained product was generally accepted and had no significant
35
36 145 differences in colour, sweetness, mouthfeel, and general acceptability as compared to a German
37
38
39 146 reference wine.

41 147 Besides beverage production, osmotic dehydration has also been cited as an excellent application of
42
43 148 *I. gabonensis* fruits (Falade and Aworh 2004; Falade and Aworh 2005; Aworh 2015). With this
44
45
46 149 process, a variety of new shelf-stable food products can be developed with few modifications in the
47
48 150 fruits' colour, flavour, and texture characteristics. Osmose-dried products could reduce perishable
49
50 151 fruit losses postharvest and ensure that seasonal fruit products are available throughout the year. The
51
52 152 osmotic process is very suitable as a pre-treatment prior to air-drying of fruits, resulting in a fruit
53
54
55 153 product with an intermediate moisture content (Falade and Aworh 2004; Falade and Aworh 2005;
56
57 154 Aworh 2015).

1
2 155 Falade and Aworh (2004) studied the influence of osmotic pre-treatment on the adsorption isotherms
3
4 156 of osmo-air dried *I. gabonensis* fruits. The treatments were performed at 27 °C and 40 °C, with sugar
5
6 157 concentrations of 52 °Brix, 60 °Brix and 68 °Brix, maintaining a fruit:syrup ratio of 1:4 w/w for 10 h.
7
8
9 158 Afterwards the fruit slices were oven air-dried at 60 °C for 72 h. The authors concluded that the
10
11 159 adsorption isotherms of osmo-oven dried fruits followed a type III isotherm, which characterizes high
12
13 160 sugar products like many other fruits. In the experiments, *I. gabonensis* isotherm was affected by fruit
14
15 161 ripeness degree. In fact, the equilibrium moisture content of the fruit increased with higher degree of
16
17 162 ripeness at the same water activity (a_w), concentration of the sucrose solution used for pre-treatment
18
19 163 (the higher the sugar concentration, less water was absorbed at low and intermediate a_w ranges), and
20
21 164 equilibrium temperature (equilibrium moisture content decreased with increasing temperature, when
22
23 165 $a_w < 0.8$).
24
25 166 Dried fruits of *I. gabonensis* can also be used as a flavouring agent in other food products in order to
26
27 167 diversify its usage. Mbaeyi and Anyanwu (2010) evaluated the use of these products as a yogurt
28
29 168 flavourant. The dried and pliable fruits were milled, sieved through a 0.59 mm sieve, and added at
30
31 169 0.8%, 1.6%, 2.4%, 3.2%, 4.0%, and 4.8% in commercial full-fat cow yogurt. The best sensory results
32
33 170 were obtained in the yogurt containing 0.8% of dried fruit with an overall acceptability statistically
34
35 171 not different from commercial yogurt.
36
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43

44 173 3. Seeds

45
46 174
47
48 175 The kernels are the main products of *I. gabonensis* and constitute an important part of West and
49
50 176 Central Africa diet, mainly in rural communities, providing carbohydrate and protein. The seed
51
52 177 consists of a hard shell, an outer brown testa (hull) and inside, the kernel, composed of two white
53
54 178 cotyledons. The seeds of the fruits of *I. gabonensis*, can be eaten raw or roasted and are used in food
55
56 179 preparations (National Research Council, 2006).
57
58
59
60

1
2 180 The summary of the proximate composition of *I. gabonensis* kernels is provided in Table 3.
3
4 181 According to literature, *I. gabonensis* seed has a high energetic value (595 – 729 kcal), due to high
5
6 182 percentages of fat (10 – 72%), carbohydrates (3 - 52%) and protein (7-22%). With crude protein
7
8
9 183 content ranging from 7 to 22%, *I. gabonensis* seeds have comparable or higher protein levels than the
10
11 184 majority of the cereals comprising our daily diet (corn, sorghum, rice, etc), which generally does not
12
13 185 exceed 13%. Fibre content was generally low in the studies reported, except by Onimawo et al.
14
15
16 186 (2003), who observed an outlying value of 10.23%. This may be due to sample preparation and/or
17
18 187 plant origin.

19
20 188 The analysis revealed that *I. gabonensis* is essentially a rich source of edible fat, with a mean
21
22
23 189 percentage of 61.56%. Some oil-bearing products with such high percentage of oil are coconut,
24
25 190 almond, pistachio, sunflower, walnut, and watermelon seeds which contain 62.3, 58.9, 53.5, 52.1,
26
27 191 64.5 and 52.6% of oil, respectively (Gopalan, Rama Sari and Balasubramanian 2014).

28
29
30 192 This oilseed is a good source of minerals, especially phosphate and chloride, and is therefore
31
32 193 recommended for use in the diets of individuals with low levels of these cations and anions.

33
34 194 Acid value is used as an indicator for edibility of oil and suitability for use in the paint industry (Etong
35
36 195 et al., 2014). The acid value for samples of *I. gabonensis* oil found in literature (3.18 - 24.7 mg
37
38
39 196 KOH/g) were considerably diverse, and most of them did not fall within the allowable limits for
40
41 197 edible oils, 4.0 mg KOH/g fat for oil (Codex Alimentarius 2015). The free fatty acid values ranged
42
43 198 from 0.30 to 4.70%, which can be considered low if compared with other vegetable oils (Omoniyi et
44
45
46 199 al. 2017). Etong, Mustapha and Taleat (2014) reported that a low acid value with a correspondingly
47
48 200 low level of free fatty acid, suggests the low level of hydrolytic and lipolytic activities in the oil, thus
49
50 201 the seed oil studied could be a good source of raw materials for industries. The peroxide value (0.04
51
52
53 202 – 3.33 meq O₂/kg fat) was incredibly low, characterizing *I. gabonensis* fat as a fresh oil as it has a
54
55 203 peroxide value lower than 10 meq/kg (Codex Alimentarius 2015). Low peroxide values indicate a
56
57 204 low level of oxidative rancidity and also suggests a high antioxidant level in the oil (Etong, Mustapha
58
59
60 205 and Taleat 2014). Etong, Mustapha and Taleat (2014) also stated that the relative low iodine number

1
2 206 of the seed oil may be indicative of the presence of few unsaturated bonds and low susceptibility to
3
4 207 oxidative rancidity. High saponification value (187.90 – 701.00 mg KOH/g) also indicates it has
5
6 208 potential for industrial use (Omoniyi et al. 2017). Low unsaponifiable matter (0.12 – 1.70%) indicates
7
8
9 209 that the oil is pure (Etong, Mustapha and Taleat 2014).
10
11 210 *I. gabonensis* seed kernel oil (Table 6) is mostly cited as a mystiric-lauric oil, with mystiric acid being
12
13 211 the most abundant followed by lauric acid (Matos et al. 2009; Silou et al. 2011; Yamoneka et al. 2015;
14
15
16 212 Lieb et al. 2018). Nine free fatty acids were described in literature, only three of which are
17
18 213 unsaturated.
19
20 214 Amongst triacylglycerols the most abundant are LaMM (31.1%), CMM/LaLaM (25.6%) and
21
22
23 215 MMM/LaMP (12.9%) (Lieb et al. 2018). Similar results were reported by Silou et al. (2011) and
24
25 216 Yamoneka et al. (2015).
26
27 217 According to Matos et al. (2009), *I. gabonensis* kernel oil is a technical fat because it resists thermo
28
29
30 218 oxidative, hydrolytic, and enzymatic activities due to its fatty acid profile.
31
32 219 *In-vivo* and *in-vitro* assays have already been developed to functionally characterize the seed. Data
33
34 220 comprising of the antioxidant activity, total phenol (TPC), total flavonoid (TFC), total anthocyanin
35
36 221 (TAC) and total tannin (TTC) contents, as well as total carotenoid (TCC) and ascorbic acid contents,
37
38
39 222 are described in Table 7.
40
41 223 The presence of steroids, flavonoids, alkaloids, cardiac glycosides, volatile oils, terpenoids, tannins
42
43 224 and saponins in *I. gabonensis* kernel extract has been revealed on phytochemical screening by
44
45
46 225 Obianime and Uche (2010).
47
48 226 Giami, Okonkwo and Akusu (1994) studied the influence of heat treatment in the composition of *I.*
49
50 227 *gabonensis* seed flour and stated that increase in temperature occasioned an undesired loss in ascorbic
51
52
53 228 acid, total carotenoid and total polyphenol contents.
54
55 229 *I. gabonensis* seed phytochemical constituents were also compared with mango (*Mangifera indica*)
56
57 230 kernels and with a mix of both species (Arogba and Omede 2012; Arogba 2014). According to DPPH,
58
59
60 231 lipid peroxidation and FRAP assays, mango kernels had a higher antioxidant activity than *I.*

1
2 232 *gabonensis* kernels, contrary to nitric oxide assay results. However, *I. gabonensis* kernel results were
3
4 233 similar or higher than mango kernel for ascorbic acid content. Total phenol, flavonoid and tannin
5
6 234 contents were also higher in *Mangifera indica* samples, whereas, *I. gabonensis* kernels presented a
7
8
9 235 much higher anthocyanin content. The mix of kernels presented higher total phenol and tannin
10
11 236 contents than individual samples of mango and *I. gabonensis*. The author showed in these studies that
12
13 237 processed kernels of mango (*Mangifera indica*) and *I. gabonensis* contain significant amounts of
14
15
16 238 gallotannins with high antioxidant capacity even with statistically ($p < 0.05$) higher activity than some
17
18 239 other known naturally-occurring phenolic antioxidants (Arogba and Omede 2012; Arogba 2014).
19
20 240 *I. gabonensis* kernel was also compared to 13 Cameroonian herbs/spices. It presented the highest
21
22
23 241 FRAP-free antioxidant capacity followed by *Thymus vulgaris* and ranked third in FRAP total
24
25 242 antioxidant but had one of the lowest results in Folin total antioxidant assay (Agbor et al. 2005).
26
27 243 Obianime and Uche (2010) studied the effects of *I. gabonensis* seed phytoconstituents in an *in vivo*
28
29
30 244 study, which described the influence of aqueous extract of *I. gabonensis* kernels on biochemical
31
32 245 parameters of adult male guinea pigs. The animals were divided into groups in order to perform time-
33
34 246 dependent and dose-dependent studies. Groups 1-5 were administered a fixed dose of *I. gabonensis*
35
36 247 extract (400 mg/kg/day) over a period of 7, 14, 21, 28 days, respectively. Groups 6-10 were
37
38
39 248 administered different doses of the extract (50-400 mg/kg/day) for 96 hours. Results showed that the
40
41 249 aqueous extract of *I. gabonensis* kernels caused a dose and time-dependent decrease in urea, uric acid,
42
43 250 creatine, total cholesterol, protein, alkaline acid, and prostatic phosphatases. Pre-treatment with *I.*
44
45
46 251 *gabonensis* was also able to inhibit the increase in most biochemical parameter levels caused by
47
48 252 cadmium administration. The highest reduction effect was obtained with uric acid at 400 mg/kg of *I.*
49
50 253 *gabonensis* extract while the least effect was observed in total cholesterol (Obianime and Uche,
51
52
53 254 2010).
54
55 255 *I. gabonensis* seed extracts were also evaluated for obesity management (Ngondi, Oben and Minka
56
57 256 2005). The subjects ingested three capsules, three times daily, each containing 350 mg of *I.*
58
59
60 257 *gabonensis* seed extract (active formulation) or oat bran (placebo), for one month. After 4 weeks, the

1
2 258 mean body weight of the *I. gabonensis* group had decreased by 5.26% and that of the placebo group
3
4 259 by 1.32%. By the second week, the systolic blood pressure was significantly reduced by the active
5
6 260 extract. Obese patients under *I. gabonensis* treatment also had a reduction of 39.21% in total
7
8
9 261 cholesterol, 44.9% in triglycerides, 45.58% in LDL and 32.36% in blood glucose level, as well as an
10
11 262 increase of 46.85% in HDL-cholesterol.

13
14 263 Dosumu et al. (2012) studied more specifically the antimicrobial effect of three Nigerian condiments,
15
16 264 including *I. gabonensis* dried seed extracts. Clinical isolates of bacteria strains (*Staphylococcus*
17
18 265 *aureus*, *Escherichia coli*, *Bacillus subtilis*, *Pseudomonas aeruginosa*, *Klebsiella pneumoniae*,
19
20 266 *Salmonella typhi*) and fungi (*Candida albicans*, *Aspergillus niger*, *Rhizopus stolon*, *Penicillium*
21
22 267 *notatum*, *Tricophyton rubrum*, *Epidermophyton floccosum*) were used in the study. All extracts had
23
24
25 268 higher anti-fungal but lower antibacterial activities. *I. gabonensis* seed extracts obtained with ethyl
26
27 269 acetate (200 mg/ml) and methanol (200 mg/ml) presented considerable fungal inhibition when
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29
30 270 compared to the positive control (Tioconazole, 10 µg/ml).

31
32 271 The first step in processing *I. gabonensis* kernels is separating the seeds from the mesocarp, using
33
34 272 three principal methods for this operation: "Fresh Cracking"; "Wet Cracking" and "Dry Cracking".

36
37 273 The "Fresh Cracking" method was reported by Ayuk et al. (1999) and Nkwatoh et al. (2010), in which
38
39 274 the whole ripe fruit (pulp and seed) is split in half, through its natural longitudinal line of weakness,
40
41 275 with a cutlass or sharp knife. On the other hand, for the other methods, *I. gabonensis* fruits are piled
42
43 276 up in heaps and left to fermentate before seed extraction, which facilitates this operation. After
44
45
46 277 fermentation, the seeds can be sun-dried ("Dry Cracking") or directly split ("Wet Cracking"), using
47
48 278 truncheons or hard stones as helping tools (Ejiofor, Onwubuke and Okafor 1987; Ladipo, Fondoun
49
50 279 and Ganga 1996; Ladipo 1999; Ogunsina, Koya and Adeosun 2008^a). As soon as the seeds are
51
52
53 280 cracked, the kernels wrapped in a dark brown testa are exposed and extracted with a knife (Ladipo
54
55 281 1999). The nut cracking process is, therefore, complicated and the dried kernel-in-shell is brittle,
56
57 282 resulting in a large percentage of cotyledons being crushed during the process, thereby reducing the
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60

1
2 283 market value of the kernels (Ogunsina, Koya and Adeosun 2008^a; Ogunsina, Koya and Adeosun
3
4 284 2008^b).
5
6 285 Ogunsina, Koya and Adeosun (2008^a and 2008^b) investigated fracture behaviour of *I. gabonensis* seed
7
8
9 286 in order to provide baseline data for designing an appropriate nutcracker. The physical analysis
10
11 287 revealed that minimum toughness was required for nutshell fracture with the small size nuts loaded
12
13 288 along the transverse axis. Furthermore, a machine, whose fracture mechanism was based on the
14
15 289 deformation characteristics of dried *I. gabonensis* seeds under uni-axial compression, was fabricated.
16
17
18 290 The experimental machine gave 100% cracking efficiency but with 24% kernel breakage in cracking
19
20 291 sun-dried *I. gabonensis* seeds with 6.6% moisture content (w.b.). The machine provides a viable and
21
22
23 292 effective technique for safe *I. gabonensis* kernel extraction. Orhevba et al. (2013) also studied
24
25 293 physical and mechanical parameters of *I. gabonensis* seed cracking and the influence of moisture
26
27 294 content (13.75% and 8.74%). The two moisture content levels were observed to be the range between
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29
30 295 which *I. gabonensis* kernels can be extracted with least percentage of crushing. Further decrease in
31
32 296 the moisture content will make the kernel brittle, while a higher moisture level will make the kernel
33
34 297 to stick to the shell, therefore, resulting in crushing during cracking. A motorized machine that is
35
36 298 capable of multiple cracking of dika nuts was designed, fabricated and tested by Ogundahunsi,
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38
39 299 Ogunsina and Ibrahim (2016). The device utilizes the impact of a sliding hammer block falling from
40
41 300 a height to crack a tray of 20 nuts; cracking and splitting them, liberating the embedded kernels as
42
43 301 split cotyledons. The highest cracking efficiency and throughput values (72% and 12.86 kg/h,
44
45
46 302 respectively) were obtained for big roasted nuts. The method of pre-treatment and dika nut sizes were
47
48 303 found to affect the cracking efficiency and throughput of the motorized dika nut cracking machine.
49
50 304 After being removed, the kernels are dried for 2 to 7 days, in the sun or on bamboo drying racks over
51
52 305 the fireplace (Tchoundjeu, Atangana and Degrande 2005), in order to remove all moisture (Onimawo
53
54
55 306 et al. 2003; Nkwatoh et al. 2010). This procedure guarantees the quality of the product during storage,
56
57 307 by preventing it from discolouring and from fungal degradation (Ladipo 1999; Ainge and Brown
58
59 308 2001).
60

1
2 309 Fermentation helps to increase the protein and nitrogen-free extractives of the seeds, as well as to
3
4 310 reduce the fat content, which is an advantage if the kernels are consumed integrally (Ekpe, Umoh and
5
6 311 Eka 2007; Ekundayo, Oladipupo and Ekundayo 2013). Otherwise, if seeds proceed to further
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8
9 312 processing, the fat loss may be undesired.

10
11 313 At this point, the kernels can be marketed or subjected to further processing. The cotyledons, without
12
13 314 the hull, are pounded with a mortar and pestle (Ekpe, Umoh and Eka 2007). The kernels can also be
14
15
16 315 milled with a grinding machine (Onimawo et al. 2003), which is a more industrial option (Festus and
17
18 316 Ibor 2014). The mash, called 'cake', is then moulded manually into convenient sizes and shapes,
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20 317 placed in bags or leaves and smoke dried for a few days over a fireplace (Ekpe, Umoh and Eka 2007;
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22
23 318 Caspa et al. 2015).

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25 319 *I. gabonensis* cake can become too slimy over time because of its high fat content; therefore, for an
26
27 320 extended shelf-life, deffating is needed (Ainge and Brown 2001; Festus and Ibor 2014). This
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29
30 321 operation yields, besides crude fat, defatted cake as a product, which, according to Ejiofor, Onwubuke
31
32 322 and Okafor (1987), is still acceptable in terms of its colour, taste, texture, and drawability after 9
33
34 323 months of storage under ambient conditions, and is more viscous, with greater emulsifying properties
35
36 324 than regular flour. The normal flour and defatted flour from *I. gabonensis* kernels are used as
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38
39 325 ingredients for the popular Ogbono or draw soup which imparts unique flavour, drawability, and
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41 326 thickening properties to the stew (Agbor 1994; Leakey and Newton 1994, Vivien and Faure 1996),
42
43 327 and also as 'dika bread' after being baked (Leakey et al. 2005). Ogbono soup is one of the cheapest,
44
45
46 328 easiest, and fastest Nigerian soups to prepare (Oktay and Sadıkoğlu 2018). Onabanjo and Oguntona
47
48 329 (2003) described the following recipe as the most representative of this dish: *I. gabonensis* nuts, bitter
49
50 330 (*Vernonia amygdalina*) leaves and okro (*Hibiscus esculentus*) cooked with dried fish, crayfish,
51
52
53 331 ground pepper, pepper, palm oil, bouillon cubes, salt, and water. The influence of *I. gabonensis* seed
54
55 332 flour fat content and time of storage on the sensory characteristics of the Ogbono soup was evaluated.
56
57 333 Sensory parameters of sliminess (viscosity), taste, aroma, colour, and overall acceptability showed
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59
60 334 that soups prepared from partially defatted *I. gabonensis* seed flour samples (especially the samples

1
2 335 with 9% and 12% fat) were more acceptable to the panellists than soups prepared from full-fat *I.*
3
4 336 *gabonensis* seed flour (Idowu et al. 2013). The preference test carried out by Idowu et al. (2013)
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6 337 during the 12-week period of storage also showed that sliminess, colour, taste, aroma, and overall
7
8
9 338 acceptability of Ogbono soups prepared from defatted *I. gabonensis* seed flour (12% and 9% fat)
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11 339 samples packaged in low- and high-density polyethylene films were all acceptable to the panellists.
12
13 340 However, the full-fat flour had its sensory parameters significantly decreased in a period of 4 weeks
14
15
16 341 (Akusu and Kiin-Kabari 2013; Idowu et al. 2013).
17
18 342 The defatted cake can also be extruded and moulded into Ogbono cubes, which are sold as a
19
20 343 convenient cooking ingredient, used as thickeners in Ogbono soup (Okafor, Okolo and Ejiofor 1996;
21
22
23 344 Ejiofor and Okafor 1997). Bamidele, Ojedokun and Fasogbon (2015) and Kiin-Kabari and Akusu
24
25 345 (2017) developed and analysed a "ready-to-cook" powder mix (*I. gabonensis* seed powder, crayfish,
26
27 346 stock fish, Ugwu, mixture of locust bean, onion mix, seasoning, and Cameroon powder) for Ogbono
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29
30 347 soup. Five formulations of instant Ogbono premix were evaluated by Bamidele, Ojedokun and
31
32 348 Fasogbon (2015) (proximate composition, functional properties, micronutrients and sensory
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34 349 analysis). Moisture, protein and carbohydrate contents increased as *I. gabonensis* seed powder
35
36 350 percentage decreased in formulations, inversely to fat content. Sensory evaluation showed that the
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39 351 samples with higher percentage of *I. gabonensis* seed powder rated the highest on overall
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41 352 acceptability based on the fact that they showed the real attribute of Ogbono soup that people like
42
43 353 which is attributed to the quantity of *I. gabonensis* kernel powder added to the sample (Bamidele,
44
45
46 354 Ojedokun and Fasogbon 2015). These results are similar to that obtained by Kiin-Kabari and Akusu
47
48 355 (2017), which tested formulations of *I. gabonensis* seed (Ogbono) and melon (Egusi) seeds soup
49
50 356 premix. They concluded that consumers who do not like very thick soups and low drawability would
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52
53 357 prefer the formulation with 40:60 Ogbono/Egusi ratio, while consumers who prefer thick soups but
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55 358 low drawability will go for the formulation of 100% "Egusi".
56
57 359 Although oil is the major constituent of the seed, according to Nwokocha and Williams (2014), the
58
59 360 defatted seed flour essentially consists of polysaccharides with lower than 5% of non-polysaccharide
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1
2 361 constituents. Nwokocha and Williams (2014) extracted *I. gabonensis* seed gum from its defatted flour
3
4 362 by removing soluble sugars and organic pigments with 95% ethanol, followed by dispersion in
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6 363 distilled water (2% w/w), stirring (6 h), and double centrifugation (2500 rpm for 2h) at 25 °C. On the
7
8
9 364 other hand, Ndjouenkelu et al. (1996) heated the diluted flour (10 g/250 mL) under reflux and then
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11 365 centrifuged the mixture (2000×g for 30 min), repeating the process with the supernatant (2 times),
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13 366 then precipitated the crude polysaccharide with 85% ethanol and purified the extract by protein
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15
16 367 removal. Both studies concluded that *I. gabonensis* seed gum has polyelectrolyte properties, as it is
17
18 368 an arabinogalactan but also contains a small proportion of neutral sugars and uronic acids
19
20 369 (Ndjouenkelu et al. 1996; Nwokocha and Williams 2014). It showed non-Newtonian behaviour at
21
22
23 370 concentrations from 0.2 to 3.0%, having mostly viscous response at concentrations less than 1.0%
24
25 371 and elastic response at higher concentrations (Nwokocha and Williams, 2014).
26
27 372 Ogaji, Nan and Hoag (2012) developed a largely physical method for simultaneous extraction of the
28
29
30 373 lipid and polymeric portions of *I. gabonensis*, which was simple, safer, and less expensive than the
31
32 374 traditional use of *n*-hexane to extract the lipids. This method was also able to efficiently remove
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34 375 impurities from the gum fraction. The physicochemical properties of the extractives were evaluated,
35
36 376 and the results showed similarities in the extractives obtained by this method and those obtained by
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38
39 377 conventional methods.
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41 378 Uzomah and Ahiligwo (1999) studied the rheological properties of achi (*Brachystegea eurycoma*)
42
43 379 and Ogbono (*I. gabonensis*) seed gums and their potential use as stabilizers in ice cream production.
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45
46 380 Ogbono seed gum (OSG) cream obtained similar results for quality parameters (maximum overrun,
47
48 381 viscosity, shape factor, and meltdown) as the control sample. However, OSG imparted some viscosity
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50 382 to the mixture which resulted in a poor ability to trap and hold air and a poor tendency to resist
51
52
53 383 melting, all of which are characteristics of a satisfactory ice cream. That being said, *I. gabonensis*
54
55 384 seed gum was found to be unsuitable as an ice cream stabilizer (Uzomah and Ahiligwo 1999).
56
57 385 It was found that the fat extracted from the kernels can be used for food applications, such as food
58
59 386 additive, flavour ingredient, coating fresh citrus fruits and in the manufacture of margarine, oil

1
2 387 creams, cooking oil, and defoaming agent. It is also suitable for soap, cosmetics, pharmaceutical
3
4 388 products and lather shaving cream (Ejiofor, Onwubuke and Okafor 1987; Ogunsina et al. 2012; Zouè
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6 389 et al. 2013; Okoronkwo et al. 2014; Etong, Mustapha and Taleat 2014; Omoniyi et al. 2017).
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8
9 390 Matos et al. (2009) characterized margarine made from *I. gabonensis* kernels from two different
10
11 391 origins, with and without lecithin. The major fatty acids found in these margarines were oleic acid
12
13 392 (35.5%-37%), palmitic acid (18.5%-19.5%) and lauric acid (13.1%-15.1%). The margarines were
14
15
16 393 more unsaturated than the original oil and could be regarded as an oleic acid source. The ratio between
17
18 394 linoleic acid (7.07%) and linolenic acid (0.63%) was lower than 2%, showing it can be used for frying
19
20 395 food.
21
22
23 396 *I. gabonensis* seed oil has also been studied as a possible biodiesel source (Bello et al. 2011; Adekunle
24
25 397 et al. 2016). It was observed that the kernel fat has similar properties to diesel fuel and superior cold
26
27 398 flow properties and flash point, which makes it a suitable alternative fuel for diesel engines (Bello et
28
29
30 399 al. 2011). Adekunle et al. (2016) also concluded that the degumming process improves the
31
32 400 physicochemical and biodiesel properties of *I. gabonensis* seed fat, as well as other vegetable oils.
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34 401

36 402 **4. Other parts**

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39 404
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41 404 Bark and leaves from *I. gabonensis* have already been traditionally used in Nigeria, Cameroon, and
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43
44 405 other countries where the fruit is available. Proximate composition of stem bark, leaf, and root bark
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46 406 from *I. gabonensis* reveals them to be nutritionally rich (Table 8).
47
48 407 *I. gabonensis* leaves have been reported to be used as a self-care plant for icterus treatment, by Benin
49
50
51 408 inhabitants (Allabi et al. 2011). The appropriation of *I. gabonensis* leaves may be associated with high
52
53 409 levels of phytochemicals. Ezeabara and Ezeani (2016) reported that *I. gabonensis* leaves contained
54
55 410 2.44% alkaloids, 1.07% flavonoids, and 2.37% anthraquinone, which can be considered high
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57
58 411 compared to other parts from the same plant. Awah et al. (2012) compared the free radical scavenging
59
60 412 activity and phenolic contents from Nigerian medicinal plants and revealed that *I. gabonensis* had

1
2 413 high results when compared to the other samples. However, *I. gabonensis* extract presented relative
3
4 414 toxicity to humans in the WST-1-based cytotoxicity and cell viability assays (Awah et al. 2012). This
5
6 415 toxicity might be related to the high hydrogen cyanide content of 3.45% (Ezeabara and Ezeani 2016).
7
8
9 416 *I. gabonensis* stem and root barks, instead, do not present relevant levels of hydrogen cyanide, 1.87%
10
11 417 and 1.66%, respectively (Ezeabara and Ezeani 2016). Two research studies involving farmers and
12
13 418 collectors in Cameroon revealed that *I. gabonensis* stem bark is popular as a traditional medicine. It
14
15
16 419 is reported to treat hernia, yellow fever, dysentery, diarrhoea, malaria, to relieve abdominal pain in
17
18 420 women, and as antidote for poisons (Ayuk et al. 1999; Zihiri et al. 2005; Caspa et al. 2015).
19
20 421 These effects must be associated with the phytochemicals present in the stem bark. Ezeabara and
21
22
23 422 Ezeani (2016) noted that *I. gabonensis* bark was the most valuable part of the plant, in terms of
24
25 423 functional constituents. It consists of the highest percentages of alkaloids (2.78%), flavonoids
26
27 424 (1.17%), tannins (1.05%), saponins (0.91%), sterols (0.25%), phenols (0.18%) and anthraquinones
28
29
30 425 (3.17%), compared to the leaf, root bark and raw seed from the same species (Ezeabara and Ezeani
31
32 426 2016).
33
34 427 Zihiri et al. (2005) tested the antiplasmodial activity of ethanol extracts of West African plants,
35
36 428 including *I. gabonensis*, and concluded that stem bark extract (10 mg/ml) had a weak antiplasmodial
37
38
39 429 activity against *Plasmodium falciparum* with IC₅₀ value of 21.6 µg/ml. However, in a study
40
41 430 investigating the analgesic effect, the water extract of the stem bark of *I. gabonensis*, when
42
43 431 administered to male mice, was found to protect the mice from pain stimuli (Okolo et al. 1995).
44
45
46 432 Another *in vivo* assay evaluated long-term effects of *I. gabonensis* and other two plants, also known
47
48 433 to be hypoglycaemic, on the oxidative status of normal rabbits (Omonkhua and Onoagbe 2012).
49
50 434 Oxidative status was determined by measuring activities of superoxide dismutase (SOD) and catalase
51
52
53 435 (CAT), and the concentration of malondialdehyde (MDA). *I. gabonensis* extract had positive effects
54
55 436 on increasing serum and tissue antioxidant enzymes, particularly in the pancreas, and on decreasing
56
57 437 liver MDA levels (Omonkhua and Onoagbe 2012).
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59 438
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5. Conclusion

As shown in this work, *I. gabonensis* is a good source of nutrients and phytochemicals and its seeds are already widely consumed and processed traditionally. This review enhances our knowledge about the use of other parts of the fruit, especially the pulp, and about improving the existing methods for a safer and more efficient production of value-added products.

I. gabonensis pulp is suitable for juice and wine production, can be also consumed osmose-dried or raw and used as flavourant in the development of other products. It is a vitamin C rich fruit (51-76 mg/100g) having higher ascorbic acid content than mango or orange. Carotenoids, phenolic compounds, and other phytochemical constituents have also been determined, as well as the hypolipidemic effect of *I. gabonensis* juice administration *in vivo*.

I. gabonensis kernel proximate composition revealed its high fat content, as well as a relevant carbohydrate content. *I. gabonensis* kernel oil is considered a “technical” fat because it resists thermo oxidative, hydrolytic, and enzymatic activities due to its fatty acid profile. The presence of steroids, flavonoids, alkaloids, cardiac glycosides, volatile oils, terpenoids, tannins and saponins in *I. gabonensis* kernel extract has been revealed on phytochemical screening and its hepatoprotective, nephroprotective, hypolipidemic effects and its influence on body weight have been confirmed. Potential anti-carcinogenic, anti-lipidemic, analgesic and anti-inflammatory effects of the kernel have been highlighted.

Various methods are employed to process the seed however, all of them have safety issues, when it comes to cracking operation. Various researchers indicated that fermented seeds with specific moisture content, with the appropriate equipment, are easier to crack and kernel loss is reduced. Main products from traditional processing are the sun-dried kernels and the ‘cake’ which is used as a thickener in ‘ogbono soup’, a conventional African food. It was described, that with a more sophisticated process, the fat could be extracted from the kernel powder generating a defated *I. gabonensis* cake. This product can be used as a thickener, stabilizer and as a kind of gum. It is also

1
2 464 possible to obtain a crude oil, that can be used not only as edible oil, but in other industries like soup,
3
4 465 cosmetic and the pharmaceutical industries.
5
6 466 Furthermore, the production of *I. gabonensis* value-added products could reduce food loss, as this
7
8
9 467 would allow the whole fruit to be used. This will also encourage the consumption of wild fruits and
10
11 468 support plant biodiversity. This new approach could ameliorate the diet of rural communities as the
12
13 469 *I. gabonensis* fruits are a good source of nutrients and phytochemicals. Commercialization of *I.*
14
15
16 470 *gabonensis* derived products can also increase the income of the rural communities.
17

20 472 6. References

- 23 473 Achinewhu, S. (1983). Ascorbic acid content of some Nigerian local fruits and vegetables. *Plant*
24
25 474 *Foods for Human Nutrition*, 33(4):261-266.
- 27
28 475 Adekunle, A.S., Oyekunle, J.A.O., Obisesan, O.R., Ojo, O.S. and Ojo O.S. (2016). Effects of
29
30 476 degumming on biodiesel properties of some non-conventional seedoils. *Energy Reports*, 2:188-
31
32 477 193.
- 34
35 478 Agbor, G., Oben, J., Ngogang, J., Xinxing, C. and Vinson, J. (2005). Antioxidant capacity of some
36
37 479 herbs/spices from Cameroon: a comparative study of two methods. *Journal of Agricultural and*
38
39 480 *Food Chemistry*, 53:6819-6824.
- 41
42 481 Agbor, L.O.N. (1994). Marketing trends and potentials for *Irvingia gabonensis* products in Nigeria.
43
44 482 Paper presented at the ICRAF-IITA Conference on *Irvingia gabonensis*, Ibadan, Nigeria, May.
- 45
46 483 Aina, J. (1990). Physico-chemical changes in African mango (*Irvingia gabonensis*) during normal
47
48 484 storage ripening. *Food Chemistry*, 36:205-212.
- 50
51 485 Aina, J. and Adesina, A. (1991). Quality attributes of jams from low-usage tropical fruits. *Food*
52
53 486 *Chemistry*, 40:345-351.
- 54
55 487 Ainge, L and Brown, N. (2001). *Irvingia gabonensis* and *Irvingia wombolu*. A state of knowledge.
56
57 488 Report undertaken for the Central African Regional Program for the Environment, Oxford
58
59
60 489 Forestry Institute Department of Plant Sciences University of Oxford, UK.

- 1
2 490 Akubor, P. (1996). The suitability of African bush mango juice for wine production. *Plant Foods for*
3
4 491 *Human Nutrition, 49(3):213-219.*
5
- 6 492 Akusu, O.M., and Kiin-Kabari, D.B. (2013). Effect of storage period on selected functional, chemical
7
8 stability and sensory properties of bush mango (*Irvingia gabonensis*) seed flour. *African*
9 493 *Journal of Food Science and Technology, 4(6):136-140.*
10
11 494
- 12
13 495 Allabi, A., Busia, K., Ekanmian, V. and Bakiono, F. (2011). The use of medicinal plants in self-care
14
15 in the Agonlin region of Benin. *Journal of Ethnopharmacology, 133(1):234-243.*
16 496
17
- 18 497 Amujoyegbe, O., Idu, M., Agbedahunsi, J. and Erhabor, J. (2016). Ethnomedicinal survey of
19
20 498 medicinal plants used in the management of sickle cell disorder in Southern Nigeria. *Journal*
21
22 *of Ethnopharmacology, 185, pp.347-360.*
23 499
24
- 25 500 Arogba, S. (2014). Phenolics, antiradical assay and cytotoxicity of processed mango (*Mangifera*
26
27 501 *indica*) and bush mango (*Irvingia gabonensis*) kernels. *Nigerian Food Journal, 32(1):62-72.*
28
29
- 30 502 Arogba, S. and Omede, A. (2012). Comparative antioxidant activity of processed mango (*Mangifera*
31
32 503 *indica*) and bush mango (*Irvingia gabonensis*) kernels. *Nigerian Food Journal, 30(2):17-21.*
33
34 504
- 35 Atangana, A.R., Tchoundjeu, Z., Fondoun, J.M., Asaah, E., Ndoumbe, M. and Leakey, R.R.B. (2001)
36
37 505 Domestication of *Irvingia gabonensis*: 1. Phenotypic variation in fruits and kernels in two
38
39 506 populations from Cameroon. *Agroforestry Systems, 53(1):55-64.*
40
- 41 507 Awah, F., Uzoegwu, P., Ifeonu, P., Oyugi, J., Rutherford, J., Yao, X., Fehrmann, F., Fowke, K. and
42
43 508 Eze, M. (2012). Free radical scavenging activity, phenolic contents and cytotoxicity of selected
44
45 Nigerian medicinal plants. *Food Chemistry, 131:1279-1286.*
46 509
47
- 48 510 Aworh, O.C. (2014). *Lesser-known Nigerian fruits and vegetables: Post-harvest handling, utilization*
49
50 511 *and nutritional value.* Ibadan, Nigeria: Ibadan University Press.
51
- 52 512 Aworh, O.C. (2015). Promoting food security and enhancing Nigeria's small farmers' income through
53
54 value-added processing of lesser-known and under-utilized indigenous fruits and vegetables.
55 513
56
57 514 *Food Research International, 76:986-991.*
58
59
60

- 1
2 515 Ayivor, J.E., Debrah, S., Nuviadenu, C.K. and Forson, A. (2011). Evaluation of elemental contents
3
4 516 of wild mango (*Irvingia gabonensis*) fruit in Ghana. *Advance Journal of Food Science and*
5
6 517 *Technology*, 3(5):381-384.
- 8
9 518 Ayuk, E., Duguma, B., Franzel, S., Kengue, J., Mollet, M., Tiki-Manga, T. and Zenkeng, P. (1999).
10
11 519 Uses, management and economic potential of *Irvingia gabonensis* in the humid lowlands of
12
13 520 Cameroon. *Forest Ecology and Management*, 113(1):1-9.
- 15
16 521 Bamidele, O., Ojedokun, O. and Fasogbon, B. (2015). Physico-chemical properties of instant ogbono
17
18 522 (*Irvingia gabonensis*) mix powder. *Food Science & Nutrition*, 3(4):313-318.
- 19
20 523 Bello, E.I., Fade-Aluko, A.O., Anjorin, S.A., and Mogaji, T.S. (2011). Characterization and
21
22 524 evaluation of African bush mango Nut (Dika nut) (*Irvingia gabonensis*) oil biodiesel as
23
24 525 alternative fuel for diesel engines. *Journal of Petroleum Technology and Alternative Fuels*,
25
26 526 2(9):176-180.
- 28
29 527 Bvenura, C. and Sivakumar, D. (2017). The role of wild fruits and vegetables in delivering a balanced
30
31 528 and healthy diet. *Food Research International*, 99(1):15-30.
- 33
34 529 Caspa, R.G., Tchouamo, I.R., Mate Mweru, J.P., Mbang Amang, J. and Ngang Ngwa, M. (2015). The
35
36 530 place of *Irvingia Gabonensis* in village communities around the Lobeke National Park in
37
38 531 Cameroon. *Bois & Forets des Tropiques*, 324(2):5-17.
- 40
41 532 Codex Alimentarius (2015). Standard for edible fats and oils not covered by individual standards.
42
43 533 CODEX STAN 19-1981. Revision: 1987 and 1999. Amendment: 2009, 2013 and 2015.
- 45
46 534 Dosumu, O., Oluwaniyi, O., Awolola, G. and Oyedeji, O. (2012). Nutritional composition and
47
48 535 antimicrobial properties of three Nigerian condiments. *Nigerian Food Journal*, 30(1):43-52.
- 49
50 536 Ejiofor, M.A.N. and Okafor, J. (1997). Prospects for commercial exploitation of Nigerian indigenous
51
52 537 trees, vegetables, fruits and seeds through food and industrial products formulation.
53
54 538 *International Tree Crops Journal*, 9(2):119-129.
- 56
57
58
59
60

- 1
2 539 Ejiofor, M.A.N., Onwubuke, S. and Okafor, J. (1987). Developing improved methods of processing
3
4 540 and utilization of kernels of *Irvingia gabonensis* (var. *Gabonensis* and var. *Excelsa*).
5
6 541 *International Tree Crops Journal*, 4(4):283-290.
- 8
9 542 Ejiofor, M.A.N. (1994). Nutritional values of Ogbono (*Irvingia gabonensis* var. *excelsa*). Paper
10
11 543 presented at the ICRAF-IITA Conference on *Irvingia gabonensis*, Ibadan, Nigeria, May.
- 13
14 544 Eka, O.U. 1980. Proximate Composition of seeds of bush mango tree and some properties of dika fat.
15
16 545 *Nigerian Journal of Nutrition Science*, 1:33 – 36.
- 18 546 Ekpe, O.O., Umoh, I.B. and Eka, O.U. (2007). Effect of a typical rural processing method on the
19
20 547 proximate composition and amino acid profile of bush mango seeds (*Irvingia gabonensis*).
21
22 548 *African Journal of Food, Agriculture, Nutrition and Development*, 7(1):1–12.
- 24
25 549 Ekundayo, F.O., Oladipupo, O.A., and Ekundayo, E.A. (2013). Studies on the effects of microbial
26
27 550 fermentation on bush mango (*Irvingia gabonensis*) seed cotyledons. *African Journal of*
28
29 551 *Microbiological Research*, 7(34):4363-4367.
- 31
32 552 Elah, E. (2010). Markets and market chain analysis for bush mango (*Irvingia* sp.) in the South West
33
34 553 and East regions of Cameroon. PhD diss., University of Buea.
- 36
37 554 Emejulu, A.A., Alisi, C.S., Asiwe, E.S., Iheanacho, K.M. and Onwuliri, V.A. (2014). Hypolipidemic
38
39 555 effect of *Irvingia gabonensis* fruits juice on sodium fluoride induced dyslipidemia in rats.
40
41 556 *African Journal of Biochemistry Research*, 8(8):151-157.
- 43
44 557 Etebu, E. (2013). Differences in Fruit Size, Postharvest Pathology and Phytochemicals between
45
46 558 *Irvingia gabonensis* and *Irvingia wombolu*. *Sustainable Agriculture Research*, 2(1):52-61.
- 47
48 559 Etong, D.I., Mustapha, A.O., and Taleat, A.A. (2014). Physicochemical properties and fatty acid
49
50 560 composition of dikanut (*Irvingia gabonensis*) seed oil. *Research Journal of Chemical Sciences*,
51
52 561 4(12):70-74.
- 54
55 562 Ezeabara, C.A. and Ezeani, D.S. (2016). Comparative study of phytochemical and nutrient contents
56
57 563 of various parts of *Irvingia gabonensis* (Aubry-Lecomte ex O' Rorke) Baill. and *Irvingia*
58
59 564 *wombolu* Vermoesen. *Scientia Agriculturae*, 14(3):284-288.

- 1
2 565 Ezekwe, C.I. and Obidoa, O. (2001). Biochemical effects of *Vernonia amygdalina* on rat liver
3
4 566 microsome. *Nigerian Journal of Biochemistry and Molecular Biology*, 16:1745-1798.
5
- 6 567 Falade, K. and Aworh, O. (2004). Adsorption isotherms of osmo-oven dried african star apple (
7
8 *Chrysophyllum albidum*) and african mango (*Irvingia gabonensis*) slices. *European Food*
9 568 *Research and Technology*, 218(3):278-283.
10
11 569
12
- 13 570 Falade, K. and Aworh, O. (2005). Sensory evaluation and consumer acceptance of osmosed and oven-
14
15 dried African star apple and African mango. *Journal of Food, Agriculture and Environment*.
16 571
17 3:91-96.
18 572
19
- 20 573 FAO (1968). Food composition table for use in Africa. Accessed December 29, 2018.
21
22 <http://www.fao.org/docrep/003/X6877E/X6877E00.htm#TOC>
23 574
24
- 25 575 Festus, C. and Ibor, M. (2014). The effect of defatting on the sliminess and shelf-life of Ugiri
26
27 576 cotyledons. *Archives of Applied Science Research*, 6(6):1-6.
28
- 29 577 Franzel, S., Jaenicke H. and Janssen W. (1996). *Choosing the right trees: setting priorities for*
30
31 *multipurpose tree improvement*. ISNAR Research Report 8. The Hague: International Service
32 578
33 for National Agricultural Research.
34 579
35
- 36 580 Fungo, R., Muyonga, J., Kabahenda, M., Okia, C. and Snook, L. (2016). Factors influencing
37
38 consumption of nutrient rich forest foods in rural Cameroon. *Appetite*, 97:176-184.
39 581
40
- 41 582 Giami, S., Okonkwo, V. and Akusu, M. (1994). Chemical composition and functional properties of
42
43 583 raw, heat-treated and partially proteolysed wild mango (*Irvingia gabonensis*) seed flour. *Food*
44
45 *Chemistry*, 49:237-243.
46 584
47
- 48 585 Gopalan, C., Rama Sari, B.V. and Balasubramanian, S.C. (2014). *Nutritive Value of Indian Foods*.
49
50 586 Hydebarad, India: National Institute of Nutrition, Indian Council of Medical Research.
51
- 52 587 Harris, D.J. (1996). A revision of the *Irvingiaceae* in Africa. *Bulletin du Jardin Botanique National*
53
54 *de Belgique*, 65:143-196.
55 588
56
- 57 589 Ibezim, G.N.U. (2015). Chemical constituents of dikanut and soyabean seeds. *Time Journals of*
58
59 590 *Medicinal Plant Sciences and Pharmacology*, 3(2):17-22.
60

- 1
2 591 Idowu, M., Omoniyi, S., Henshaw, F. and Olayiwola, I. (2013). Sensory acceptability of partially
3
4 592 defatted dikanut (*Irvingia gabonensis*) flour in ogbono soup. *Journal of Culinary Science &*
5
6 593 *Technology*, 11(4):346-355.
- 8
9 594 Joseph, J. (1995). Physico-chemical attributes of wild mango (*Irvingia gabonensis*) seeds.
10
11 595 *Bioresource Technology*, 53(2):179-181.
- 13
14 596 Joseph, K. and Aworh, O. (1991). Composition, sensory quality and respiration during ripening and
15
16 597 storage of edible wild mango (*Irvingia gabonensis*). *International Journal of Food Science &*
17
18 598 *Technology*, 26(3):337-342.
- 20
21 599 Joseph, K. and Aworh, O. (1992). Post-harvest treatment of wild mango (*Irvingia gabonensis*) for
22
23 600 improved shelf life. *Food Chemistry*, 44:45-48.
- 25
26 601 Kiin-Kabari, D. B., and Akusu, O. M. (2017). Production, proximate, functional and organoleptic
27
28 602 assessment of Ready-To-Cook “Ogbono”/“Egusi” seeds premix (Dry mix powder).
29
30 603 *International Journal of Food Science and Nutrition*, 2(1):82-85.
- 31
32 604 Kuete, V. and Efferth, T. (2011). Pharmacogenomics of Cameroonian traditional herbal medicine for
33
34 605 cancer therapy. *Journal of Ethnopharmacology*, 137(1):752-766.
- 36
37 606 Ladipo, D.O. (1999) The development of quality control standard for Ogbono (*Irvingia gabonensis*
38
39 607 and *Irvingia wombolu*) kernels: efforts toward encouraging organized and further international
40
41 608 trade in NWFP in West and central Africa. In *Non wood forest products of central Africa -*
42
43 609 *Current research issues and prospects for conservation and development*, ed. T.C.H
44
45 610 Sundarland, L.E. Clark and P. Vantomme, 245-250, Rome: FAO.
- 47
48 611 Ladipo, D.O., Fondoun, J.M. and Ganga, N. (1996). Domestication of the bush mango (*Irvingia* spp):
49
50 612 Some exploitable intra-specific variation in West and Central Africa. In *Domestication and*
51
52 613 *commercialization of non-timber forest products in agroforestry systems*, ed. R.R.B. Leakey,
53
54 614 A.B. Temu, M. Melnyk and P. Vantomme, 193-205, Rome:FAO.
- 56
57
58
59
60

- 1
2 615 Leakey, R. and Page, T. (2006). The 'Ideotype Concept' and its application to the selection of
3
4 616 cultivars of trees providing agroforestry tree products. *Forests, Trees and Livelihoods*, 16(1):5-
5
6 617 16.
7
8
9 618 Leakey, R., Fondoun, J., Atangana, A. and Tchoundjeu, Z. (2000). Quantitative descriptors of
10
11 619 variation in the fruits and seeds of *Irvingia gabonensis*. *Agroforestry Systems*, 50(1):47-58.
12
13 620 Leakey, R., Greenwell, P., Hall, M., Atangana, A., Usoro, C., Anegbeh, P., Fondoun, J. and
14
15 621 Tchoundjeu, Z. (2005). Domestication of *Irvingia gabonensis*: 4. Tree-to-tree variation in food-
16
17 622 thickening properties and in fat and protein contents of dika nut. *Food Chemistry*, 90(3):365-
18
19 623 378.
20
21
22 624 Leakey, R.R.B. and Newton, A.C. (1994). Domestication of 'Cinderella' species as the start of a
23
24 625 woody-plant revolution, In *Tropical Trees: The Potential for Domestication and the Rebuilding*
25
26 626 *of Forest Resources*, ed. R.R.B. Leakey and A.C. Newton, 3-6, London:HMSO.
27
28
29 627 Lieb, V.M., Schuster, L.K., Schmarr, H.G., Carle, R. and Steingass C.B. (2018). Lipophilic
30
31 628 compounds and thermal behaviour of African mango (*Irvingia gabonensis* (Aubry-Lecomte ex.
32
33 629 O'Rorke) Baill.) kernel fat. *International Journal of Food Science & Technology*.
34
35 630 <https://doi.org/10.1111/ijfs.13940>.
36
37
38 631 Matos, L., Nzikou, J., Matouba, E., Pandzou-Yembe, V., Guembot Mapepoulou, T., Linder, M. and
39
40 632 Desobry, S. (2009). Studies of *Irvingia gabonensis* seed kernels: oil technological applications.
41
42 633 *Pakistan Journal of Nutrition*, 8(2):151-157.
43
44
45 634 Mbaeyi, I.E. and Anyanwu, L.N. (2010). Production and evaluation of yoghurt flavoured with solar-
46
47 635 dried bush mango (*Irvingia gabonensis*) pulp. *Agro-Science*, 9(2):137-146.
48
49
50 636 Nangue, T.J., Womeni, H.M., Mbiapo, F.T., Fanni, J. and Michel, L. (2011). *Irvingia gabonensis* fat:
51
52 637 nutritional properties and effect of increasing amounts on the growth and lipid metabolism of
53
54 638 young rats wistar sp. *Lipids in Health and Disease*, 10:43.
55
56
57 639 National Research Council (2006). *Lost crops of Africa. Volume II: vegetables*. Washington, D.C.:
58
59 640 The National Academies Press.
60

- 1
2 641 Ndjouenkeu, R., Goycoolea, F., Morrissa, E. and Akingbala, J. (1996). Rheology of okra (*Hibiscus*
3
4 642 *esculentus* L.) and dika nut (*Irvingia gabonensis*) polysaccharides. *Carbohydrate Polymers*,
5
6 643 *29(3):263-269*.
7
8
9 644 Ngondi, J.L., Oben, J.E., and Minka, S.R. (2005). The effect of *Irvingia gabonensis* seeds on body
10
11 645 weight and blood lipids of obese subjects in Cameroon. *Lipids in Health and Disease*, *4:12*.
12
13 646 Nkwatoh, A., Labode, P., Iyassa, S. and Nkwatoh, F. (2010). Evaluation of *Irvingia* (*I. gabonensis*
14
15 647 and *I. wombulu*) trade; a major non-timber forest product in the Ejagham Forest Reserve of
16
17 648 South West Cameroon. *Ethiopian Journal of Environmental Studies and Management*, *3(1):70-*
18
19 649 *77*.
20
21
22 650 Nwokocho, L. and Williams, P. (2014). Hydrodynamic and rheological properties of *Irvingia*
23
24 651 *gabonensis* gum. *Carbohydrate Polymers*, *114:352-356*.
25
26
27 652 Obianime, A. and Uche, F. (2010). The phytoconstituents and the comparative effects of aqueous
28
29 653 extract of *Irvingia gabonensis* seeds and proviron on the biochemical parameters of male guinea
30
31 654 pigs. *Asian Pacific Journal of Tropical Medicine*, *3(2):101-104*.
32
33
34 655 Ofundem, T., Ndip, N.R., Abdon, A. and Patrice, L. (2017). Bush mango (*Irvingia* spp.): forest and
35
36 656 on-farm resource availability and market chains in the Southwest region of Cameroon. *Forests*,
37
38 657 *Trees and Livelihoods*, *26:170-182*.
39
40
41 658 Ogaji, I., Nan, A. and Hoag, S. (2012). A novel extraction method and some physicochemical
42
43 659 properties of extractives of *Irvingia gabonensis* seeds. *Journal of Young Pharmacists*, *4(2):66-*
44
45 660 *72*.
46
47
48 661 Ogundahunsi O.E., Ogunsina B.S. and Ibrahim R.O. (2016). A motorized device for cracking pre-
49
50 662 treated dika nuts. *Agricultural Engineering International: CIGR Journal*, *18(2):309-322*.
51
52 663 Ogunsina, B.S., Bhatnagar, A.S., Indira, T.N. and Radha, C. (2012). The proximate composition of
53
54 664 African bush mango kernels (*Irvingia gabonensis*) and characteristics of its oil. *Ife Journal of*
55
56 665 *Science*, *14(1):177-183*.
57
58
59
60

- 1
2 666 Ogunsina, B.S., Koya, O.A. and Adeosun, O.O. (2008a). Deformation and fracture of Dika nut
3
4 667 (*Irvingia gabonensis*) under uniaxial compressive load. *International Agrophysics*. 22:249-253.
5
6 668 Ogunsina, B.S., Koya, O.A. and Adeosun, O.O. (2008b). A table mounted device for cracking dika
7
8 nut (*Irvingia gabonensis*). *Agricultural Engineering International: CIGR Journal*. Manuscript
9 669 PM 08 011, Vol. X.
10
11 670
12
13 671 Ogunsina, B., Olatunde, G. and Adeleye, O. (2014). Effect of pre-treatments on mechanical oil
14
15 expression from dika kernels. *Nigerian Food Journal*, 32(1):1-9.
16 672
17
18 673 Okafor, J.C. Okolo, H.C. Ejiofor, M.A.N. (1996) Strategies for enhancement of utilization potential
19
20 674 of edible woody forest species of south-eastern Nigeria. In *The Biodiversity of African Plants*,
21
22 ed. van der Maesen L.J.G., van der Burgt X.M., van Medenbach de Rooy J.M., 684-695,
23 675
24 Dordrecht: Springer.
25 676
26
27 677 Okolo, C., Johnson, P., Abdurahman, E., Abdu-Aguye, I. and Hussaini, I. (1995). Analgesic effect of
28
29 *Irvingia gabonensis* stem bark extract. *Journal of Ethnopharmacology*, 45(2):125-129.
30 678
31
32 679 Okolo, H.C. (1994). Industrial potential of various *Irvingia gabonensis* products such as oil, Ogbono
33
34 680 and juice. Paper presented at the ICRAF-IITA Conference on *Irvingia gabonensis*, Ibadan,
35
36 681 Nigeria, May.
37
38
39 682 Okoronkwo, C.U., Agoha, E.E.C., Alloysius, O., Ogodo, A.C. and Nwachukwu, N.O. (2014).
40
41 683 Physical and chemical characteristics of the african bush mango (*Irvingia gabonensis* var.
42
43 684 *garbonensis*) seed oil. *International Journal of Advances in Engineering and Management*,
44
45 685 1(6):28-31.
46
47
48 686 Oktay, S. and Sadıkoğlu, S. (2018). The gastronomic cultures' impact on the African cuisine. *Journal*
49
50 687 *of Ethnic Foods*, 5:140-146.
51
52
53 688 Olayiwola, I., Akinfenwa, V., Oguntona, C., Sanni, S., Onabanjo, O. and Afolabi, W. (2013).
54
55 689 Phytonutrient, antioxidant and mineral composition of some wild fruits in South West Nigeria.
56
57 690 *Nigerian Food Journal*, 31(2):33-40.
58
59
60

- 1
2 691 Omoniyi, S., Idowu, M., Adeola, A. and Folorunso, A. (2017). Chemical composition and industrial
3
4 692 benefits of dikanut (*Irvingia gabonensis*) kernel oil. *Nutrition & Food Science*, 47(5):741-751.
5
6 693 Omonkhua, A.A. and Onoagbe, I.O. (2012). Long-term effects of three hypoglycaemic plants
7
8 694 (*Irvingia gabonensis*, *Urena lobata* and *Carica papaya*) on the oxidative status of normal
9
10 695 rabbits. *Biokemistri*, 24(2):82-89.
11
12
13 696 Onabanjo, O.O. and Oguntona, C.R.B. (2003). Iron, zinc, copper and phytate content of standardized
14
15 697 Nigerian dishes. *Journal of Food Composition and Analysis*, 16(6):669-676.
16
17
18 698 Onimawo, I., Oteno, F., Orokpo, G. and Akubor, P. (2003). Physicochemical and nutrient evaluation
19
20 699 of African bush mango (*Irvingia gabonensis*) seeds and pulp. *Plant Foods for Human Nutrition*,
21
22 700 58(3):1-6.
23
24
25 701 Onyeike, E. and Acheru, G. (2002). Chemical composition of selected Nigerian oil seeds and
26
27 702 physicochemical properties of the oil extracts. *Food Chemistry*, 77(4):431-437.
28
29
30 703 Orhevba, B.A., Idah, P.A, Adebayo S. E. and Nwankwo C.C. (2013). Determination of some
31
32 704 engineering properties of dika nut (*Irvingia gabonensis*) at two moisture content levels as
33
34 705 relevant to its processing. *International Journal of Engineering Research and Applications*,
35
36 706 3(2):182-188.
37
38
39 707 Ruth Charrondière, U., Stadlmayr, B., Rittenschober, D., Mouille, B., Nilsson, E., Medhammar, E.,
40
41 708 Olango, T., Eisenwagen, S., Persijn, D., Ebanks, K., Nowak, V., Du, J. and Burlingame, B.
42
43 709 (2013). FAO/INFOODS food composition database for biodiversity. *Food Chemistry*,
44
45 710 140(3):408-412.
46
47
48 711 Shaheen, S., Ahmad, M. and Haroon, N. (2017). Edible Wild Plants: A Solution to Overcome Food
49
50 712 Insecurity. In *Edible Wild Plants: An alternative approach to food security*, ed. S. Shaheen, M.
51
52 713 Ahmad and N. Haroon, 41-57. 1st ed. Heidelberg:Springer
53
54
55 714 Silou, T., Loumouamou, B.W., Nsikabaka, S., Kinkela, T., Nzikou, M., Chalard P. and G. Figueredo
56
57 715 G. (2011). Contribution to the varietal delimitation of *Irvingia gabonensis* and *Irvingia*
58
59
60

- 1
2 716 *wombulu*. Chemical composition variability of fats extracted from kernels. *Journal of Food*
3
4 717 *Technology*, 9(1):36–42
5
- 6 718 Singh, A.K. (2007). Bush mango (*Irvingia gabonensis*): new potential multipurpose fruit tree for
7
8 India. *Indian Journal of Plant Genetic Resources*, 20(1):32-37.
9 719
10
- 11 720 Stadlmayr, B., Charrondière, U., Eisenwagen, S., Jamnadass, R. and Kehlenbeck, K. (2013). Nutrient
12
13 721 composition of selected indigenous fruits from sub-Saharan Africa. *Journal of the Science of*
14
15 *Food and Agriculture*, 93(11):2627-2636.
16 722
17
- 18 723 Tchoundjeu, Z., Atangana, A. and Degrande, A. (2005). Indigenous methods in preserving bush
19
20 724 mango kernels in Cameroon. *American Journal of Applied Sciences*, 2(9):1337-1342.
21
- 22 725 USDA (2018). Food Composition Databases. Accessed December 29, 2018.
23
24 <https://ndb.nal.usda.gov/ndb/>
25 726
26
- 27 727 Uzomah, A. and Ahiligwo, R. (1999). Studies on the rheological properties and functional potentials
28
29 728 of achi (*Brachystegia eurycoma*) and ogbono (*Irvingia gabonensis*) seed gums. *Food Chemistry*,
30
31 67(3):217-222.
32 729
33
- 34 730 Vihotogbé, R., van den Berg, R.G. and Sosef, M.S.M. (2013). Morphological characterization of
35
36 731 African bush mango trees (*Irvingia* species) in West Africa. *Genetic Resources and Crop*
37
38 *Evolution*, 60(4):1597-1614.
39 732
40
- 41 733 Vivien, J. and Faure, J.J. (1996). *Fruitiers sauvages d'Afrique. Espèces du Cameroun*. Clohars
42
43 734 Carnoetn, F: Nguila-Kerou Editions.
44
- 45 735 Yamoneka, J., Malumba, P., Blecker, C., Gindo, M., Richard, G., Fauconnier, M.L., Lognay, G. and
46
47 Danthine, S. (2015). Physicochemical properties and thermal behaviour of African wild mango
48 736 (*Irvingia gabonensis*) seed fat. *LWT-Food Science and Technology*, 64:989–996.
49
50 737
51
- 52 738 Zirihi, G., Mambu, L., Guédé-Guina, F., Bodo, B. and Grellier, P. (2005). In vitro antiplasmodial
53
54 activity and cytotoxicity of 33 West African plants used for treatment of malaria. *Journal of*
55 739
56 *Ethnopharmacology*, 98(3):281-285.
57 740
58
59
60

1

2 741 Zoué, L., Bédikou, M., Faulet, B., Gonnety, J. and Niamké, S. (2013). Characterisation of a highly

3

4 742 saturated *Irvingia gabonensis* seed kernel oil with unusual linolenic acid content. *Food Science*

5

6 743 *and Technology International*, 19(1):79-87.

8

9 744

10

11 745

12

13 746

14

15 747

16

17 748

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Table 1: Proximate composition of *Irvingia gabonensis* ripe raw pulp

	FAO, 1968	Onimawo et al., 2003	Stadlmayr et al., 2013	Aina, 1990	Joseph and Aworh, 1991	Mbaeyi and Anyanwu, 2010
Moisture (%)	81.4	80.0	78.8	80.5	80.0	90.47
Ash (%)	1.8	0.8	0.8	-	-	1.41
Fibre (%)	0.4	0.4	0.4	-	-	4.91
Fat (%)	0.2	1.06	1.1	-	-	2.20
Protein (%)	0.9	1.09	1.1	-	-	4.37
Carbohydrate (%)	15.7	16.7	17.8	-	-	4.65
Total Acidity (%)	-	0.112	-	0.31	0.11	-
pH	-	5.84	-	4.7	5.0	6.18
Soluble solids (%)	-	10.0	-	10.5	14.0	9.51

Table 2: Phytochemical content (mg/100 g fresh fruit) of *I. gabonensis* ripe raw pulp

Reference		
Ascorbic Acids	51.00-76.07	FAO, 1968; Onimawo et al., 2003; Stadlmayr et al., 2013; Aina, 1990; Joseph and Aworh, 1991; Olayiwola et al., 2013; Achinewhu, 1983
Carotenoids	1.26 – 2.21	Olayiwola et al., 2013; Aina, 1990
Tannin	54.9	Aina, 1990
Phenolics	382.20	Olayiwola et al., 2013
Vitamin A	280.18*	Mbaeyi and Anyanwu, 2010

* Retinol equivalent

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2 1 Table 3: Proximate composition of *Irvingia gabonensis* kernel
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	Reference														
	Idowu et al., 2013	Onyeike and Acheru, 2002	Elah, 2010	Okoronkwo et al, 2014	Ibezim, 2015	Matos et al., 2009	Ekpe et al., 2007	Ogunsina et al., 2012	Joseph, 1995	Onimawo et al., 2003	Dosumu et al., 2012	Ezeabara and Ezeani, 2016	Giami et al., 1994	Eka, 1980	Ejiofor et al., 1987
Energy (kcal)	684.5	688.00	-	-	-	729.36	-	-	-	-	595.05	-	682	-	-
Moisture Content (%)	4.26	5.93	2.55	3.21	8.28	0.02	5.20	2.55	-	3.36	3.75	11.54	4.1	2.10	11.90
Protein (%)	8.10	8.71	8.90	7.47	8.81	8.52	7.60	8.90	8.70	7.76	21.52	17.43	10.9	8.60	9.24
Fat (%)	67.69	62.80	68.37	68.81	69.34	68.24	66.60	68.37	66.50	65.46	55.09	9.81	64.2	70.80	51.32
Fiber (%)	5.88	-	-	4.38	1.25	-	1.90	-	-	10.23	-	4.18	3.4	1.40	0.86
Ash (%)	3.35	0.63	2.32	8.71	4.52	2.93	9.50	2.32	-	2.26	16.35	4.66	2.2	6.80	2.46
Carbohydrate (%)	10.72	21.93	18.67	-	11.39	20.28	-	18.67	-	10.93	3.29	52.40	15.2	14.10	26.02

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For Peer Review Only

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2 1 Table 4: Micronutrient content (mg/100 g) of *I. gabonensis* kernel
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	Reference		
	Onyeike and Acheru, 2002	Ayivor et al., 2011	Dosumu et al., 2012
Lead	0.054	-	-
Iron	0.315	19.374	10.101
Copper	0.139	5.722	2.346
Zinc	0.285	5.786	4.386
Potassium	15.600	0.723	612.55
Sodium	2.020	4.383	59.99
Phosphate	16.800	-	-
Sulphate	0.008	-	-
Chloride	259.000	42.639	-
Aluminium	-	3.567	-

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Table 5: Physicochemical parameters of *I. gabonensis* kernel oil

	Reference						
	Onyeike and Acheru, 2002	Joseph, 1995	Ogunsina et al., 2012	Okoronkwo et al., 2014	Matos et al., 2009	Zoué et al., 2013	Etong et al., 2014
Chemical Parameters							
Oil yield (%)	62.80	66.5	68.37	68.81	62.67	69.76	22.50
Acid value (mg KOH/g)	24.7	-	-	3.18	12.94	4.67	9.40
Saponification value (mg KOH/g)	701	219.2	256.5	230.95	199.50	233.75	187.90
Peroxide value (meq O₂/kg fat)	0.04	1.98	0.5	2.67	1.9	3.33	1.80
Iodine value (g I₂/ 100g fat)	21.5	4.2	8.2	13.40	4.3	32.43	4.50
Free fatty acids (%)	1.19	0.30	2.72	1.59	4.61	2.33	4.70
Unsaponifiable matter (%)	1.70	0.12	-	-	-	1.50	1.50

Physical Parameters							
State at room temperature	Semi liquid	-	Solid	-	-	-	Solid
Specific gravity	0.89	0.85	-	-	-	-	0.88
Smoke point (°C)	-	213.0	-	147.57	-	-	78
Cloud point (°C)	-	35.0	-	41.83	-	-	-
Flash point (°C)	-	-	-	335.33	-	-	-
Fire point (°C)	-	-	-	340.67	-	-	-
Setting point (°C)	26.3	-	-	-	-	-	25.30
Melting/freezing point (°C)	56.0	39.5	-	32.47	-	-	13
Colour	Golden yellow	-	White	-	-	-	Grey yellow

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2 1 Table 7: Phytochemical constituents of *I. gabonensis* kernel
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	Value	Reference
DPPH antiradical assay	177.22% (IC ₅₀)	Arogba and Omede, 2012
FRAP* assay	431.58 mg of catechin equiv/g	Agbor et al., 2005
	65.43 mM Fe ⁺² (IC ₅₀)	Arogba, 2014
Lipid peroxidation assay	375.38% (IC ₅₀)	Arogba, 2014
Nitric oxide assay	106.12% (IC ₅₀)	Arogba, 2014
TPC*	2.6 mg/100g	Giami et al., 1994
	10.74 mg/g	Agbor et al., 2005
	1.15 mg/g dw	Arogba, 2014
TFC*	077 mg QUE/g dw	Arogba, 2014
TAC*	0.67 ng cyanidin chloride/g dw	Arogba, 2014
TTC*	1.25 mg catechin/g dw	Arogba, 2014
TCC*	3.6 mg/100g	Giami et al., 1994
Ascorbic acid	6.2 mg/100g	Giami et al., 1994

31 3 *(FRAP - Ferric reducing antioxidant power; TPC – Total Phenolic Compounds; TFC – Total Flavonoid Compounds; TAC – Total Anthocyanin Compounds; TTC – Total Tannin Compounds; TCC – Total Carotenoid content)
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2 1 Table 8: Proximate composition (%) of *I. gabonensis* stem bark, leaf and root bark (Ezeabara and Ezeani 2016)
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	Stem bark	Leaf	Root bark
6 3 Moisture	9.43	10.83	8.91
7			
8 4 Dry matter	90.58	89.17	91.09
9			
10			
11 Ash	7.72	9.61	6.58
12			
13 Fibre	11.38	15.34	8.69
14			
15 Fat	2.78	1.86	1.45
16			
17 Protein	5.28	14.78	5.92
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19 Carbohydrates	63.43	47.58	68.44
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