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Research Article
Sensory Evaluation of Tropical Bush Mango (*Irvingia gabonensis*) Fruits

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Abstract

Background: *Irvingia gabonensis* is a profitable forest fruit tree found in West and Central Africa, which kernels are widely traded regionally and internationally for ethnic markets. The expanding and growing market for the seed kernels requires that the product has quality characteristics to enhance the marketability. Also the increased cultivation and consumption of the fruit pulp requires the pulp to be characterized for appropriate description and market attention. Sensory tasting is an important tool for description of food products and the development of their quality standards. **Objective:** This study aimed to investigate the desirable and undesirable sensory characteristics of *I. gabonensis* fresh pulp and partially processed kernels. **Materials and Methods:** Eight fruit color cultivars and four kernel types of *Irvingia gabonensis*, commonly grown and consumed in West and Central Africa were evaluated for the intensity of their sensory attributes using a trained and consumer panels respectively. *Irvingia* fruits were subjected to morphological measurements and then tasted along with a reference popular mango (*Mangifera indica*). Desirable attributes evaluated were flavor, juiciness, sweetness, taste, texture and overall acceptability. Undesirable attributes evaluated were astringency, bitterness and fibrousness. A common 7-point scale was used for evaluation. Additionally, a consumer panel evaluated partially processed kernel types of Irvingia for color, texture, flavor, overall acceptability and purchase intent using a 7-point hedonic scale. **Results:** There were significant differences ($p< 0.05$) in both the desirable and undesirable fruit flesh attributes as well as kernel attributes evaluated. Fruit type 4A8 scored higher in pulp sensory attributes while oven-dried kernels were highly preferred. Popular mango pulp scored the highest intensities for desirable and the lowest intensities for undesirable attributes measured. **Conclusion:** It is concluded that sensory analysis is an important tool for describing products in breeding and marketing programmes.

Key words: *Irvingia gabonensis*, fruits and vegetables, sensory analysis, product development, forest foods, fruit color, kernel types

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Irvingia gabonensis is an economic food tree of West and Central Africa (WCA) with on-farm food production potential. This food tree is a source of financial revenue for rural farmers, wholesale traders and can help achieving longterm food security[1,2]. It can produce good quality wine comparable to German reference wine[3], is a good source of micro and macronutrients including vitamin C[4]. The fruit oilseed has potential for industrial applications such as cooking oil, margarine, perfume, soap[5], gum[6], obesity and diabetes management[7] as well as pest management[8] and binding agent in tablet formulation[9]. The fruit pulp of *I. gabonensis* is sweet and edible while that of *I. wombolu*, a closely related species is bitter and inedible[10]. Farmers eat the ripe sweet flesh of *I. gabonensis* while collecting the fruits away from home and later when they return to their homes. The kernel from the seed of both species is alike and cannot be visually distinguished from its counterpart. The kernel is favoured as soup thickener when pounded into a paste[11]. For the last three decades, interest in the domestication of *Irvingia* species (*Irvingia gabonensis* and *Irvingia wombolu*) has produced important literature about the physiology of the plants, breeding techniques and marketing of the extracted nuts[12,13]. But what is still lacking behind all the available literature is the quality of the sweet edible pulp of *I. gabonensis*, even though there are numerous reports that mention fresh fruits being eaten as dessert fruits and snack[14].

Irvingia gabonensis and *I. wombolu* fruits are produced and traded locally in WCA and are also traded to non-producing areas, where prices are much more higher. Detail estimates of the production of *Irvingia* species in countries of the sub-region are still missing especially those related to the trade of fresh fruits. Nonetheless, Agbor[15] and Ladipo[16] concluded that farmers, in good years in southwestern Nigeria, collect up to 750,000 t of fresh fruits, from which 120,000 t are extracted as kernels. These figures imply that a seizable part of the remaining 630,000 t of fruits, excluding the nut shells, are eaten as sweet flesh. From the latter figures it is estimated that a total of 1,2,000,000 t of Irvingia kernels are traded annually in Nigeria[16]. In Southern Cameroon, 70.79 t of kernels were traded in a 29 weeks study period between 1995 and 1996. The same study surveys 28 markets for 29 weeks and concluded that the value of sales was about US $70,000 (34,633,000 CFA francs)[17]. All the latter reports focus primarily on the collection and trade of kernels while the volume of fresh fruits eaten by farmers has so far not been reported. This missing figures include volumes of fruits eaten during harvest, at home and how much they take to the market for sell. Ladipo[18] concluded that the quality characteristics of marketed *I. gabonensis* and *I. wombolu* products is still an area to explore.

The economic benefits drawn from the trade of the dry seeds have culminated to an increased cultivation of the *Irvingia* tree leading to a shift from it being uniquely a wild tree species to on-farm tree. The benefits of Irvingia to farmers are cultural, nutritional, financial and environmental[19-21]. Farmers own *Irvingia*, *Dacryodes edulis* and other fruit trees in their farmland and can make financial plans on the trade of products because of the benefit-induced cultivation of the tree[22]. However, because the cultivation of the tree is being encouraged by the research and development community, the hope to see more studies focus on the quality of the product for higher prices in the market has not follow the same pace. Product quality is an incentive for sustained production and farmer financial status improvement[23]. So far, it is believed that the lack of quality of Irvingia products as well as other food tree products (safou for instance), may be partly due to lack of available desirable and undesirable descriptive attributes for both fresh fruits and dried seeds. Because *Irvingia* products have emerged above their main role of achieving food security and as a source of income for rural communities, there is a need to fill this gap in knowledge in the quality characterization. Currently, production is not meeting the demand either locally or internationally for ethnic markets[24]. Consequently, most of the products are still being sold in local markets where users purchase them for direct consumption. Regional and ethnic international trade is just a small part of the trade of processed *Irvingia* kernels and numerous other value-added products have been reported[9]. As the demand for *Irvingia gabonensis* kernels increases, so needs to be the quality of the pulp both nutritionally and financially.

Farmers in WCA know how to grow quality tree products such as Citrus fruits (*Citrus* spp.), avocado (*Persea americana*), papaya (*Carica papaya*), guava (*Psidium guajava*), some of which are destined to exports in Europe[25]. Moreover, farmers have been growing cash crops such as coffee and cocoa for exports for many decades and for which the needs of the overseas consumers are more stringent. So, research should provide them with the quality standards related to the production of *Irvingia* products, they would have little obstacles to adjust for improved products. The objective of this study was to investigate the desirable and undesirable sensory characteristics of *I. gabonensis* fresh pulp and partially processed kernels.

MATERIALS AND METHODS

Sampling and morphological measurements: Fresh fruits of *I. gabonensis* were collected from individual trees in two locations in Southern Cameroon: Elig-Nkouma in the Centre Province and Nko'ovos in the South province. These areas are considered high in genetic diversity. Once labeled and transported at the World Agroforestry Centre's African Humid Tropic laboratory in Yaounde, Cameroon, they were washed with clean tap water, dried at ambient temperature and submitted to morphological measurements. The skin and flesh colors of fruits were determined using the Methuen Code of Color[26]. Then a triplicate of 8 good fruits, one each from a single tree, were stored at 4-5°C in the refrigerator for sensory analysis. All fruits with skin blemishes were avoided because skin scratch may affect visual appearance, the taste and other characteristics of the fruit during sensory testing[27]. Popular mango (*Mangifera indica*) fruits were purchased from the Mokolo marketplace in Yaounde, Cameroon. Both fruits types were treated alike.

Sample preparation: When fruits were removed from the refrigerator, they were rewashed with clean tap water and re-dried at ambient temperature on a sieve. Then for each fruit a Kenwood kitchen knife was used to cut out 15 longitudinally skinned-fruit pulp slices of about 1 cm thick and 3 cm long each. Fruit pulp slices were labeled with 3-digit codes, put on clean petri dishes (pyrex) and anonymously served to judges at ambient temperature for skin color tasting. For kernels, sun drying was conducted on racks for 15 days and smoke drying over a fireplace for 8 days. Oven drying was conducted in a ventilated oven (GALLEN KAMP, UK) at 60°C for 13 h. Fresh kernels were extracted the day before the experiment and kept at room temperature. Kernels were also labeled with 3-digit codes, put on clean petri dishes (pyrex) and anonymously served to judges at ambient temperature for evaluation.

Descriptive sensory analysis: A panel of fifteen trained judges consisting of 2 researchers and 2 technical staff of the Institute of Agricultural Research for Development (IRAD) and 11 postgraduate students of the Faculty of Science of the University of Yaounde 1, Cameroon, was deputed. The panel evaluated the relative intensity of organoleptic characteristics based on the tastes, flavors, texture and visual appearance of the skin of the fruit. For this study, intensity rating training covered 2 days a week for a total of 14 days and was conducted as described by O'Mahony[28] and Dijksterhuis *et al.*[29]. Samples were presented on Petri dishes together with a napkin and in clean individual booths for each panelist. A list of agreed main sensory characteristics (taste, flavor, texture, juiciness, sweetness and overall acceptability) and undesirable characteristics (astringency, bitterness and fibrousness) was supplied to judges. Judges evaluated the relative intensity of perception of each variable using a continuous scale 0-7[30] (0-1: Absent, 1-2: Almost absent, 2-3: Barely, 3-4: Perceptible, 4-5: Delicate, 5-6: Moderate and 6-7: Strong). The scale for the texture was as follows: 0-1: Not fibrous, 1-2: Almost fibrous, 2-3: Barely fibrous, 3-4: Perceptible, 4-5: Fairly fibrous, 5-6: Moderately fibrous and 6-7: Strongly fibrous. Between two individual evaluations, judges neutralized the previous smell or perception in their mouth by rinsing it with a locally marketed natural mineral water. For the overall acceptability, panelists gave an overall score of 0-7 depending on their liking of the presented sample versus fresh fruits they usually eat[31].

Consumer sensory analysis of the kernels: Participants in an untrained consumer taste panel were recruited among undergraduate students and staff of the University of Yaounde 1. Consumers retained were those who indicated that they are consumers of *Irvingia* fruits and processed kernels. A total of 82 consumers (49 women and 33 men), aged 21-47 years old, participated in the sensory consumer tasting. An evaluation form, previously developed by the investigator, called for the judges to rate the four samples of *Irvingia* kernel types for color, texture, flavor, acceptability and purchase intent using 7-point hedonic scale (from dislike extremely to like extremely). The wording of the questionnaire in the form and the selection of the seven-point hedonic scale were adapted from previous research involving consumer product evaluation[32]. Labeled and randomly coded samples of fresh (F), sun-dried (SUD), oven-dried (OVD) and smoke-dried (SMD) kernels were presented to panelists in a white clean plate. Each panelist seated in a small booth equipped with a table and woody chair in an illuminated room with white lighting. Consumers received samples in randomized order to eliminate any bias in the order of presentation[33]. Sample codes had three digits.

Statistical analysis: Multiple variable analysis of variance was performed on sensory data using a statistical package Genstat 5.0 Release 7.22DE (GENSTAT, Rothamsted, UK)[34]. Least Significant Difference (LSD) test was used to determine the statistical difference between fruit skin color types as well as kernel types. Statistical significance was set at $p<0.05$.

RESULTS

Fruit characteristics: Considerable significant variations were observed between fruit types. The average overall fruit and flesh weights per fruit skin color type ranged from 46.60±2.15 to 137.00±3.40 g and 40.40±21.10 to 117.60±3.40 g for fruit skin colors 29A7 and 28C6, respectively (Table 1). The average flesh thickness ranged from 13.10±0.23 and 13.22±0.20 mm in fruit skin colors 29A7 and 3A6, respectively to 16.70±0.16 and 17.00±0.22 mm in fruit skin colors 4A8 and 28C6, respectively. The mean pulp fruit ratio was significantly ($p<0.05$) greater in fruit skin colors 28D7 (0.89±0.00) and 4A8 (0.88±0.01) than the observed values of many other fruit color cultivars. The kernel weight was significantly ($p<0.05$) higher for cultivar 4A8 while it was lowest for cultivar 29A7. In general, fruit type 29A7 showed the lowest values for fruit and kernel morphological characteristics whereas fruit types 28C6 and 4A8 had the greatest values. The greatest values for kernel mass, fruit flesh thickness and fruit mass were recorded for fruit types 4A8 and 28C6 while fruit type 3A6 was greater in nutshell mass (11.31±0.60 g).

Descriptive sensory attributes: Significant differences ($p<0.05$) were observed between whole fruit skin color types for the desirable characteristics taste, flavor, texture, juiciness, sweetness and overall acceptability. As expected, the reference mango fruit (*M. indica*) received the greatest values of perception of desirable organoleptic attributes (Table 2). Overall, the perception of desirable organoleptic characteristics of bush mango types ranged from 'perceptible' for the sweetness of fruit type 28D7 to 'Strong' for that of fruit type 4A8. In the meantime, juiciness and flavor/aroma were only found as 'barely' and 'perceptible' in fruit type 28D7 respectively. Panelists marginally had no significant ($p>0.05$) difference in the perception of texture of fruit type 28C6 with a value of 5.67 versus 6.23 for reference mango. Likewise, the taste (rated 6.32) for fruit type 4A8 was found to be marginally, but not significantly, lower than that of reference mango fruit (rated 6.78). Most of the fruit types scored significantly lower in desirable quality attributes compared to popular mango. The rating of the overall acceptability (5.23) for fruit type 4A8, was marginally, but significantly ($p<0.05$) lower than that of reference mango (6.78). Fruit type 4A8 was greater in flavor, juiciness, sweetness, taste and the overall acceptability followed by fruit types 28C6 and 3A4. In general, fruit types 28D7, 27D7, 3A6 and 29A7 were less sweet and juicy. The perception of these differences in sensory attributes is related to fruit desirability.

Table 1: Morphological characteristics of *Irvingia* fruits types/cultivars

Morphological characteristics	Fruit types								LSD (5%)
	4A8	4A4	3A4	3A6	29A7	27D7	28D7	28C6	
Fruit length (mm)	59.23±0.63^{c}	58.45±0.92^{c}	52.91±1.48^{d}	55.07±0.83^{d}	46.53±0.60^{e}	58.15±0.58^{c}	70.14±0.68^{a}	66.30±0.50^{b}	2.317
Fruit width (mm)	61.14±0.65^{b}	58.00±0.93^{c}	56.29±1.70^{c}	51.40±0.72^{d}	47.27±0.70^{e}	57.21±0.62^{c}	58.25±0.50^{c}	64.73±0.50^{a}	2.421
Fruit flesh thickness (mm)	17.00±0.22^{a}	14.90±0.24^{c}	15.70±0.48^{b}	13.22±0.20^{d}	13.10±0.23^{d}	14.90±0.21^{c}	15.00±0.16^{c}	16.70±0.16^{a}	0.7149
Fruit weight (g)	113.30±3.18^{b}	88.50±3.50^{c}	91.90±4.25^{c}	68.20±2.45^{d}	46.60±2.15^{e}	89.30±2.43^{c}	110.10±2.04^{b}	137.00±3.40^{a}	10.20
Kernel weight (g)	13.51±0.41^{a}	4.20±0.14^{e}	4.80±0.27^{d}	5.50±0.28^{c}	0.78±0.14^{f}	4.08±0.13^{e}	4.65±0.17^{de}	7.06±0.23^{b}	0.6640
Nut weight (g)	4.22±0.15^{f}	14.24±0.54^{c}	14.93±0.47^{c}	16.80±0.80^{b}	6.14±0.36^{e}	13.58±0.40^{cd}	12.25±0.40^{d}	19.40±0.64^{a}	1.401
Nut shell weight (g)	9.30±0.31^{b}	10.06±0.47^{b}	10.14±0.40^{b}	11.31±0.60^{a}	5.35±0.35^{d}	9.50±0.30^{b}	7.60±0.37^{c}	12.35±0.41^{a}	1.133
Fruit flesh weight (g)	99.10±2.70^{b}	74.30±3.37^{c}	77.00±7.11^{c}	51.40±2.70^{d}	40.40±2.10^{e}	75.70±2.34^{c}	97.90±2.15^{b}	117.60±3.40^{a}	9.97
Pulp/fruit ratio	0.88±0.01^{ab}	0.83±0.01^{d}	0.80±0.02^{e}	0.74±0.02^{f}	0.86±0.01^{bc}	0.85±0.01^{c}	0.89±0.00^{a}	0.86±0.01^{bc}	0.02866
Shell/fruit ratio	0.08±0.00^{d}	0.12±0.01^{b}	0.13±0.02^{b}	0.17±0.0^{2a}	0.12±0.01^{b}	0.11±0.01^{bc}	0.07±0.01^{d}	0.09±0.01^{cd}	0.02063

Fruit color codes are from Kornerup and Wanscher[26]. Values are Means±SE for 30 determinations. Values with the same letter superscript in the same row are not statistically significant ($p>.05$)

Table 2: Relative intensity of desirable sensory attributes of *Irvingia* skin color types

	Attributes					
Cultivars	Taste	Flavor	Texture	Juiciness	Sweetness	Acceptability
4A8	6.32±0.10^{b}	5.37±0.16^{b}	5.03±0.23^{b}	5.22±0.14^{b}	5.53±0.16^{b}	5.23±0.18^{b}
4A4	5.52±0.10^{d}	4.08±0.20^{e}	4.30±0.15^{c}	4.75±0.14^{cb}	4.28±0.10^{d}	4.25±0.20^{cde}
3A4	5.77±0.10^{cd}	4.62±0.25^{cd}	4.07±0.29^{cdf}	4.35±0.10^{cd}	4.63±0.14^{cd}	4.30±0.10^{cde}
3A6	4.47±0.11^{f}	3.78±0.17^{f}	3.67±0.33^{df}	3.07±0.27^{fg}	3.87±0.14^{e}	4.12±0.18^{cde}
29A7	4.82±0.12^{e}	4.30±0.27^{def}	4.62±0.16^{bc}	3.50±0.17^{ef}	3.52±0.18^{ef}	4.21±0.19^{cde}
27D7	5.03±0.10^{e}	4.40±0.23^{de}	3.53±0.29^{f}	3.25±0.20^{gf}	3.30±0.15^{f}	4.53±0.22^{cd}
28D7	4.25±0.20^{f}	3.95±0.13^{ef}	4.21±0.22^{cd}	2.85±0.27^{g}	3.33±0.16^{f}	3.95±0.13^{e}
28C6	6.05±0.10^{bc}	5.08±0.19^{cb}	5.67±0.10^{a}	3.93±0.17^{de}	4.92±0.12^{c}	4.65±0.14^{c}
M. indica	6.78±0.06^{a}	6.45±0.13^{a}	6.23±0.15^{a}	6.52±0.11^{a}	6.67±0.10^{a}	6.78±0.10^{a}
LSD (5%)	0.3042	0.5330	0.6276	0.5114	0.3930	0.4556

Values are Means±SE for 4 determinations. Cultivar codes were determined using a scientific book of color[26]. Values with the same letter superscript in the same column are not statistically significant (p>0.05). *Mangifera indica* is the popular reference mango fruit with very sweet pulp highly priced in the marketplace. Scale: continuous scale 0-7 (0-1: Absent, 1-2: Almost absent, 2-3: Barely, 3-4: Perceptible, 4-5: Delicate, 5-6: Moderate and 6-7: Strong). The scale for the texture was as follows: 0-1: Not fibrous, 1-2: Almost fibrous, 2-3: Barely fibrous, 3-4: Perceptible, 4-5: Fairly fibrous, 5-6: Moderately fibrous and 6-7: Strongly fibrous

Table 3: Relative intensity of undesirable sensory attributes of *Irvingia* skin color types

	Attributes			
Cultivars	Astringency	Bitterness	Fibrousness	Acceptability
4A8	1.50±0.06^{e}	1.28±0.06^{cb}	1.60±0.14^{e}	5.23±0.18^{b}
4A4	1.30±0.07^{f}	1.10±0.05^{cb}	1.87±0.13^{cde}	4.25±0.20^{cde}
3A4	1.57±0.07^{de}	1.60±0.06^{b}	2.27±0.18^{ab}	4.30±0.10^{cde}
3A6	2.20±0.07^{a}	1.78±0.05^{b}	1.92±0.08^{cd}	4.12±0.18^{cde}
29A7	1.97±0.05^{cb}	1.95±0.12^{b}	1.63±0.07^{de}	4.21±0.19^{cde}
27D7	2.12±0.06^{ab}	3.23±1.31^{a}	2.42±0.12^{a}	4.53±0.22^{cd}
28D7	1.83±0.05^{cd}	2.25±0.41^{ab}	2.02±0.06^{bc}	3.95±0.13^{e}
28C6	1.72±0.06^{d}	1.63±0.05^{b}	1.80±0.07^{cde}	4.65±0.14^{c}
M. indica	0.68±0.10^{g}	0.39±0.12^{c}	0.72±0.10^{f}	6.78±0.10^{a}
LSD (5%)	0.1843	1.237	0.3086	0.4556

Values are Means±SE for 4 determinations. Cultivar codes were determined using a scientific book of color[26]. Values with the same letter superscript in the same column are not statistically significant (p>0.05). *Mangifera indica* is the popular reference mango fruit with very sweet pulp highly priced in the marketplace. Scale: continuous scale 0-7 (0-1: Absent, 1-2: Almost absent, 2-3: Barely, 3-4: Perceptible, 4-5: Delicate, 5-6: Moderate and 6-7: Strong). The scale for the texture was as follows: 0-1: Not fibrous, 1-2: Almost fibrous, 2-3: Barely fibrous, 3-4: Perceptible, 4-5: Fairly fibrous, 5-6: Moderately fibrous and 6-7: Strongly fibrous

The perception and sensation of undesirable flavor/aroma also known as off-flavors -and other defects of the unpeeled bush mango were low. Astringency, bitterness and fibrousness were the principal undesirable attributes perceived (Table 3). This perception of undesirable organoleptic attributes differed significantly ($p<0.001$) between fruit types. The relative intensities of perception of the attribute astringency, bitterness and fibrousness were at least 'Almost absent' when extremely low and 'Perceptible' when relatively greater. Bitterness and fibrousness scored greater ratings in fruit type 27D7 and 28D7. Likewise, the perception of the astringency in fruit type 3A6 and 27D7 was rated greater. Fruit with the greater perception of undesirable organoleptic attributes (for instance, 27D7) also showed the lowest ratings for the overall acceptability. Interestingly, the reference mango scored the lowest ratings for all three undesirable organoleptic attributes, found as 'Absent'.

Consumer sensory testing of partially processed kernels: The perception of the degree of liking of sensory organoleptic attributes of bush mango showed significant ($p<0.001$) variation between kernel types. The consumer rating scores ranged from 3.62 for the flavor of fresh unprocessed kernels (F) to 6.42 for the color of oven-dried (OVD) kernels (Table 4). Overall, the perception of the intensities of color, texture and flavor of oven-dried samples was greater followed by sun-dried (SUD) samples while the perception of the intensities of the same characteristics in fresh unprocessed samples scored the lowest ratings. Smoked-dried (SMD) samples marginally scored lower ratings for the intensity of color, texture and flavor than sun-dried samples. However, the consumer panel rated the 'acceptability' and the 'purchase intent' greater for OVD samples followed by SUD samples while fresh unprocessed samples received the lowest ratings for these two market sensory attributes. The mean score for the acceptability varied from 3.94 for fresh samples to 6.22 for OVD samples while the mean scores for the ratings of the 'Purchase intent' varied from 3.76 in fresh samples to 6.17 in oven-dried samples. Oven-dried samples were generally well liked and fresh unprocessed samples were the least liked.

DISCUSSION

This is the first quantitative study that combines the variation of morphological, descriptive sensory and consumer sensory characteristics of bush mango (*I. gabonensis*) fruits and kernels in Cameroon. Locals reported differences in fruit

Table 4: Relative intensities of consumer liking of desirable sensory attributes of *Irvingia* kernel types (data from a 82-consumer panelist)

	Kernel types				
Attributes	Fresh	OVD	SUD	SMD	LSD (5%)
Color	4.22±0.08[b]	6.42±0.84[a]	4.90±0.10[b]	3.97±0.27[b]	1.180
Texture	5.71±0.10[a]	5.23±0.08[b]	4.13±0.08[d]	4.82±0.08[c]	0.2292
Flavor	3.62±0.29[d]	6.03±0.57[a]	5.47±0.07[b]	5.12±0.48[c]	0.2143
Acceptability	3.94±0.10[d]	6.22±0.08[a]	5.60±0.08[b]	5.32±0.10[c]	0.2364
Purchase Intent	3.76±0.10[c]	6.17±0.07[a]	5.76±0.10[b]	5.58±0.08[b]	0.2339

Values are Means±SE for 4 determinations. Values with the same letter superscript in the same row are not statistically significant (p>0.05). OVD: Oven-dried, SUD: Sun-dried, SMD: Smoked-dried. Scale: 7-point hedonic scale (from dislike extremely to like extremely)

color, taste, sweetness and fibrousness in previous survey studies[35]. In the present study, both morphological, descriptive sensory and consumer sensory characteristics continuously and significantly ($p<0.05$) varied between fruit types studied. This variation suggests that, more studies with wide range of sample populations are needed to capture the extent of variation in desirable traits that includes all populations of Irvingia fruits. Results from this study indicate that bigger fruits had greater pulp and nutshell masses. Although high nutshell mass is not preferred by farmers because of its tedious and time consuming[36] kernel extraction, bigger fruits are most wanted because of their greater pulp mass and their tendency to have bigger kernels in terms of mass (e.g., 4A8 and 28C6). The observed considerable variation in morphological measurements implies that it will be very difficult to accurately predict fruit attributes from most fruit color appearance, fruit size and fruit weight only. However, some of the fruit parameters evaluated tend to show a consistent pattern namely the fruit weight, pulp depth, flesh weight and kernel weight in fruit types 4A8 and 28C6. Interestingly, these two fruit types were also bigger in appearance. The continuous variation in the ranges of morphological measurements reported in this study (Table 1), is consistent with previous studies in the sub-region[37].

The variation in sweetness and juiciness may be attributed to differences in the quantity and quality of fruit sugar content formed as the result of fruit ripeness[38]. Sweetness and juiciness play an important role in the acceptability and purchase intent of conventional marketed fruits such as oranges, pineapple, grapes, papaya and mangoes[39]. It is interesting to observe that the perception of sweetness and juiciness in the present study allowed to clearly discriminate fruit types 4A8 and 28C6 compared to reference mango. Sweetness and juiciness were also used in the screening of breeding selections of apple (*Malus domestica*)[40]. This observation calls for more breeding work to improve the flesh desirable characteristics for Irvingia fruits.

Differences observed in the perception of the texture may be partly due to the quantity and nature of pectic polysaccharides composing the cell walls, environmental factors and location of growth. Seymour *et al.*[41] have reported that in edible fruits, juiciness is one of the attributes that influence cell wall strength and cell-to-cell adhesion. Juiciness is therefore a major factor of fruit texture, which influences its desirability and consequently consumer's choice.

The higher perception of undesirable characteristics such as astringency, bitterness and fibrousness is mostly unwanted by consumers. The taste of bitterness and the sensation of the astringency in bush mango and other fruits such as *Citrus* spp. and peach (*Prunus persica*) is partly attributed to the presence of alkaloids, flavanol polymers like proanthocyanidins and condensed tannins[42]. The present study shows that bitterness varied widely among fruit types (from "Almost absent" to 'Perceptible'). The variation in bitterness may be related to the balance between the levels of alkaloids and flavanol and levels of tannins and glucosides in the pulp after harvest. In fact, Etebu[43] observed that the levels of bitter alkaloids and flavonoids compounds in *Irvingia* fruit mesocarp diminished after one week of storage after harvest, while tannins and glucoside levels increased. An important finding of this study is that all fruit types were at least fibrous. Currently, fibrousness is a major undesirable sensory attribute for Irvingia pulp compared to reference mango. It appears almost all fruit types studied were at least fibrous. In a parallel study, Kengni *et al.*[44] found that fibrousness was also perceived as a major undesirable sensory characteristic in the pulp of another local fruit, *D. edulis*, commonly known as safou. Perception of greater levels of undesirable organoleptic characteristics may constitute a rejection factor for consumers.

The kernel of bush mango seed is the most consumed and traded part of the fruit. Fresh kernels scored poor ratings for flavor, acceptability and the purchase intent. This finding suggests that although fresh kernels retained their natural characteristics like texture and color, consumers preferred kernels with desirable flavor when they were dried (e.g., oven and sun-dried kernels). In fact, apart from reducing the water content and the resulting weight loss, drying generates desirable odors due to aromatic compounds formed during

the process of drying, thereby contributing to added convenience to the consumer[45]. This study concluded that oven-dried kernels received the greatest ratings for consumer sensory attributes indicating that controlled processing may preserve the sensory quality that meets the needs of locals. Under uncontrolled traditional methods of drying (e.g., sun-drying and smoke-drying), off flavors may form due to longer periods of drying and other conditions (pH, temperature, insect attacks), as also observed in the sun drying of cocoa beans[46]. Additionally, the smoke changes the color, making it darker, which then influences the overall acceptability of the product. Customarily, local people use both sun-drying and smoke drying from over the fire place in their kitchen as preferred methods of preservation. However, no report is available on which of the two methods is preferred or yields high-quality products.

CONCLUSION AND FUTURE RECOMMENDATIONS

An important part of the financial revenues generated by the trade of kernels benefits the traders but not the farmers, who are mainly collectors. This suggests that what benefits local farmers directly is the flesh that they eat at home or in the forest while collecting the fruits. These fruits are therefore a major part of collectors' daily nutrient and energy needs. Quality standards are also important to regulators as the trade for Irvingia products grows. The current informal collection and trade of fruits and other non-wood forest products in West and Central Africa is partly due to the lack of quality standards available to government agencies and market controllers to help them identify different brand products of the same species. Sensory description as shown in the present work, can help provide the vocabulary to discriminately describe fruits and kernels for different cultivars and markets if carefully designed and carried out appropriately.

This study did not evaluate to final product, which is the ogbono paste used to thicken soups. Also fruit types are based on the color of the fruit exocarp and not the mesocarp. There is a need of a similar study on the color of the pulp and the ultimate processed paste of the kernels in order to provide a basis for interrelated quality attributes for consumer-oriented cultivation and handling of *Irvingia* fruits and processing of the seeds. These future quantitative assessments of the sensory quality of tropical bush mango, will form the basis for standards for grading.

SIGNIFICANCE STATEMENTS

This study discovers the appropriate sensory terms for describing the pulp and the partially processed seed of *Irvingia gabonensis*. The sensory terms relevant to the description of the pulp and seed reported in this study can be beneficial in product description and grading for farmers and traders in product as well as market development initiatives. On one hand this study will help government agencies and market controllers to better identify different *Irvingia* brand products in the market. On the other hand this study will help researchers to uncover the critical multiple aspects of quality characteristics required for a strong cultivar selection program. Thus a new theory in the selection, cultivation and trade of bush mango may be arrived at.

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