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Possibilities of valorization of *Gnetum* spp leaves in modern gastronomy: Production and characterization of new vegetable tarts and salads

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ABSTRACT

Gnetum spp is a green creeper plant abundantly found in the Central African forests. Their leaves are eaten as vegetable by inhabitants. In order to valorize this vegetable in modern gastronomy, a survey was carried out in three towns of Cameroon to evaluate its importance in the feeding habits. The leaves were also sliced in two different forms, precooked, spin-dried and used for *Gnetum* tarts and salads production. 50, 100 and 150 g of thin sliced precooked leaves were used to prepare three salads and three tarts, keeping the other ingredients constant. Three additional tarts were prepared similarly using thinnest sliced precooked leaves. The final products were analyzed in terms of physiochemical, nutritional and sensorial properties. More than 96.9% of people investigated eat *Gnetum* leafy vegetables at least once per month. The survey study indicates that the transformation of *Gnetum* is mostly done by people within the age of 20 to 40 years old. Results of the physicochemical analyses showed that the total protein, lipid and carbohydrate contents increased in general with the increasing of the *Gnetum* leaf quantities used for preparation. The crude fiber contents of salads and tarts ranged from 52.00 ± 0.68 to 62.66 ± 1.26 and 29.33 ± 0.67 to 33.66 ± 0.47 g/100 g DW respectively. They were positively correlated with the quantity of *Gnetum* leaves used. The total phenolic contents, also increased significantly ($p < 0.05$) with the quantity of *Gnetum* leaves, from 182.45 ± 1.69 to 493.52 ± 2.10 mg/100 g DW for the salad and from 86.69 ± 4.08 to 283.21 ± 6.79 mg/100 g DW for the tart. The calculated energy density of tarts and salads permitted to classify these food products as low and high energy density foods respectively. The nutritional densities of produced tarts oscillated from 0.27 to 0.3 and that of salads from 0.58 to 0.71. With their nutritional values and the significant amount of fibers, *Gnetum* tarts and salads could be good new recipes to valorize the *Gnetum* leafy vegetables.

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1. Introduction

Modern gastronomy in the last decade occupied an important position in the socio-economical aspect of many countries [1]. Its exponential development is so important that it has been used to valorize certain foods left out by lack of knowledge or technology. Low level of nutritional education alongside with poor socioeconomic status led to malnutrition [2]. In this regard, many researches have been carried out with the aim of seeking information about unknown food and provided other forms of food products different from those already part of the feeding habit [3]. This has been one of the main goals of the modern gastronomy which has played an important role in human nutrition. Ten years ago, one of the proposed solution was the application of gastronomy technology to design and improve culinary recipe of a new tart [4]. Tarts and salads are foods made with the combination of vegetable and other ingredients. They are foods naturally made with lot of fatty ingredients such as butter, milk, almond meal, eggs and lower fiber content for most of them [5]. Given the high interest of children and some adults for tarts and salads and knowing the positive correlation between obesity, overweight and some forms of cardiovascular diseases with foods rich in saturated fat [6], it becomes necessary to substitute some or part of their ingredients in order to reduce the energy density. Therefore, producing a new tarts and salads with local vegetable may have not only an economical added value but also help for the reduction of the risk of some metabolic diseases. In fact, vegetables are rich in dietary fibers which help to protect the organism against cardiovascular diseases, cancers (colon, breast), diabetes and obesity [7,8].

Gnetum spp. is a creeping plant of the family of *Gnetaceae* which grows abundantly in Central Africa, South America, tropical and subtropical Asia [9,10]. In Cameroon, *Gnetum* spp. leaves, eaten as vegetable and locally known as "*eru*", "*okok*" are naturally found in the forests of South West, Littoral, South and Centre regions [11]. These leaves are sliced, cooked and consumed as vegetable due to their nutritional and therapeutic properties [10]. Classified as Non Timber Forest Products (NTFP), *Gnetum* spp. leaves are good source of minerals (2–9%), fibres (28–37%), carbohydrates (38–44%), proteins (13–18%), essential amino acids, phenolic compounds [10, 12]. These leaves have very low fat content (3.6%) and the little that they contain are known for their antibacterial and antioxidant properties [9]. Despite its nutritional importance, these leafy vegetable is still less valorised by inhabitants and not yet used in the modern gastronomy as far as our research is concerned. One of the possibilities to valorize *Gnetum* leafy vegetables and to increase its consumption out of the production zones may be to find out new food formulations with modern gastronomic techniques. Therefore, it is important to think about new food recipes based on *Gnetum* leafy vegetables with low calories which can commonly be accepted in Cameroon and throughout the world by inhabitants irrespective of their food cultures. These formulations may help not only to increase the knowledge and consumption of this rich vegetable but also to reduce overweight and obesity. With this, the main goal of this study was to produce, characterize and evaluate the overall acceptability of *Gnetum* spp salads and tarts.

2. Materials and methods

2.1. Materials

Mature leaves of *Gnetum* spp. (Fig. 1(A - B), used as the main biological material in this study were harvested in the month of June 2021 from a farm at Pouma, (Littoral Region, Cameroon, geographical coordinate: 3° 51′ 0″ North, 10° 31′ 0″ East). The freshly harvested leaves were kept in a vented bag from farm to the laboratory. The botanic authentication of the leaves was done by the National Herbarium of Yaounde (Cameroon). The wheat flour, butter, egg, cheese, fresh milk, skimmed milk, salt, white pepper, nutmeg used for tart production as well as tomato, carrot, sweet pepper, onion, vinegar, sunflower oil in case of salad formulation as other ingredients, a part of *Gnetum* leafy vegetables were purchased from a supermarket in Ngaoundere (Cameroon).

All chemicals used for analyses were of analytical grade.

Fig. 1. Mature leaves with stem (A) and fresh young leaves (B) of *Gnetum* spp.

2.2. Methods

2.2.1. Survey on Gnetum leafy vegetables

In order to evaluate the importance of *Gnetum* leafy vegetables in the food behaviors of the population, a survey was carried out in three different regions of Cameroon named Center (Bafia), Littoral (Pouma) and South (Ebolowa). These regions were chosen based on the production and the abundant activities related to *Gnetum* vegetables. The main goal of this survey was to seek information associated with socio-professional categories of people involved in *Gnetum* spp., the reason of its consumption as well as the eating frequencies.

A questionnaire was designed and 250 printed copies helped to collect relevant corresponding information from individuals according to each question.

2.2.2. Leaves preparation

Gnetum leaves were sliced in two different forms (thin slice with thickness >1 mm and thinnest diameter with thickness <1 mm). They were all precooked into boiling water for an hour using a pressure cooker (leaves/water ratio was 100 g/L), spin-dried and used for *Gnetum* tarts and salads preparation.

2.2.3. Tarts and salads preparation

2.2.3.1. Tarts preparation. The precooked and spin-dried leaves were used with various ingredients for *Gnetum* tarts preparation (Table 1). The masses of vegetable used were 50, 100 and 150 g and the final produced tarts were coded as tart T50, tart T100, tart T150 and tart P50, tart P100, tart P150 respectively for tarts made with thin sliced (T) and thinnest sliced (P) leaves. The first kneading step was done with a Kitchen Aid® mixer for 8 min whereas the second and the third step were carried out respectively for 3 min (Fig. 2).

2.2.3.2. Salads production. Three salad were made with different masses of thin sliced precooked *Gnetum* leaves 50, 100, 150 g and coded as salad S50, salad S100 and salad S150 (Fig. 3). The additional ingredients as well as their quantities used are presented in Table 2.

2.2.4. Proximate composition

The proximate composition of the formulated salads and tarts was evaluated using different analytical methods.

2.2.4.1. Moisture and ash contents. The moisture contents of formulated salads and tarts were determined using the AFNOR method as described by Ref. [13], while the AOAC method [14] was applied for the ash content after complete incineration of the sample at 550 °C.

2.2.4.2. Lipid contents. 20 g of sample were used to determine the lipid contents through Soxhlet extractor with hexane as solvent as described by Ossoko [15], with slight modifications. After 10 h of extraction, oil was separated from the solvent by evaporation using a Rotary evaporator (Rotavapor® R-210/VWR). The extracted oil was dried in an oven at 80 °C for 15 min and its total amount was calculated from the difference in the flask weight before and after the process.

2.2.4.3. Total nitrogen and total crude protein contents. The total nitrogen contents of salads and tarts were evaluated using the method of Kjeldahl [16]. The percentage of nitrogen obtained after mineralization and distillation of defatted samples (2 g) were multiplied by a factor of 6.25 to estimate the total crude protein contents.

Table 1
Ingredients used for the preparation of tarts with *Gnetum* leaves.

Ingredients	Units	Formulations		
		Tart 50 (T50/P50)	Tart 100 (T100/P100)	Tart 150 (T150/P150)
Wheat Flour	Gram	250	250	250
Butter	Gram	125	125	125
Eggs	Piece	5	5	5
Water	mL	50	50	50
Cooked *Gnetum* leaves	Gram	50	100	150
Fresh cream	mL	200	200	200
Skim-Milk	mL	200	200	200
Cheese	Gram	150	100	50
Salt	Gram	5	5	5
White pepper (*Piper nigrum*)	Gram	5	5	5
Nutmeg	Piece	1	1	1

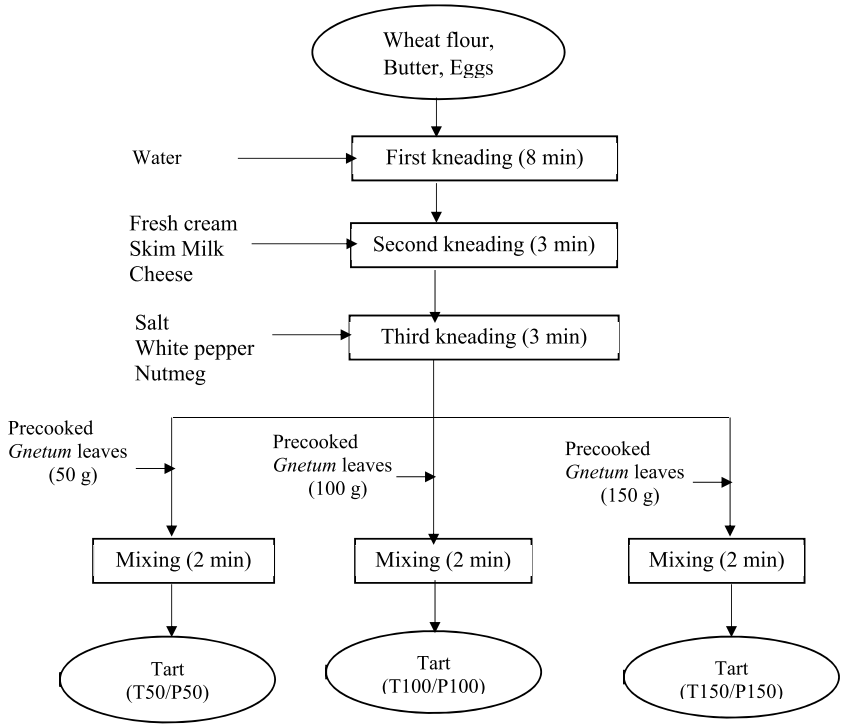


Fig. 2. Flow diagram of various tarts preparation.

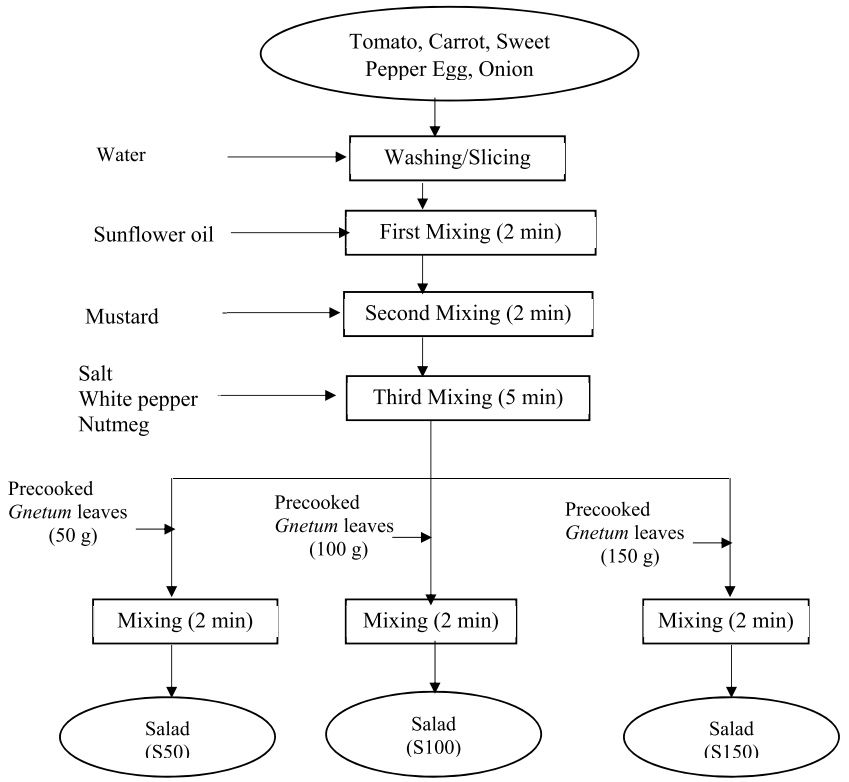


Fig. 3. Flow diagram of various salads preparation.

Table 2
Ingredients and quantities used for the preparation of salads with *Gnetum* leaves.

Ingredients	Units	Formulations		
		Salad 50 (S50)	Salad 100 (S100)	Salad 150 (S150)
Cooked *Gnetum* leaves sliced	Gram	50	100	150
Tomato	Gram	315	300	285
Carrot	Gram	415	400	385
Sweet Pepper	Gram	315	300	285
Onion (*Allium cepa*)	Gram	105	100	95
Vinegar	mL	100	100	100
Sunflower oil	mL	200	200	200
Mustard	Gram	20	20	20
Salt	Gram	10	10	10
White pepper (*Piper nigrum*)	Gram	5	5	5

2.2.4.4. Crude fiber contents. Crude fiber contents were estimated by the method described by Ref. [17]. Briefly, 5 g of the defatted sample (M_1) were mixed with 100 mL of sulfuric acid 0.255 N and the mixture was boiled at 100 °C for 30 min and later centrifuged for 20 min at 4500 g. The deposited particles were washed 3 times with distilled water before heating with 100 mL of sodium hydroxide solution 0.313 N and then centrifuged under the same conditions. The settled particles were washed three times with distilled water and once with acetone. The final residue was dried in an oven at 105 °C for 8 h and then weighed (M_2) before incinerated in a furnace at 550 °C for 3 h (M_3). The crude fiber content (%) was calculated with equation (1):

$$\text{Fibers } (\%) = \frac{M_2 - M_3}{M_{1\ \text{x DM}}}\ x\ 100 \tag{1}$$

Where, DW stands for the Dry Weight

2.2.4.5. Carbohydrate contents. The carbohydrate contents were computed by difference according to the method described by Ref. [18]. From 100, the sum of the percentage of proteins, lipids and fibers was subtracted.

2.2.4.6. Total phenolic contents. 5 g of salads and tarts were respectively triturated in a mortar, mixed with 50 mL of distilled water and homogenized as reported by Ref. [19]. The mixture was submitted to continuous agitation for an hour and subsequently centrifuged at 3000 g for 15 min at 20 °C. The supernatant was collected and kept at 4 °C till further analyses.

The total phenolic contents (TPC) of salads and tarts were estimated with the colorimetric Folin-Ciocalteu method, as described by Ref. [20]. 20 μL of the sample extract were mixed in the test tube with 0.5 mL Folin-Ciocalteu reagent and 2 mL of distilled water. The mixture was incubated at room temperature in darkness for 5min then 1 mL of Na_2CO_3 (20% w/v) solution was added and the mixture was kept in darkness at room temperature for 1 h. After an hour of reaction, the absorbance of the final solution was read against the blank at 765 nm using *Beckman Du 64 UV–Visible* spectrophotometer. The standard curve was made using gallic acid as reference and the result of TPC was expressed as equivalents milligrams of gallic acid per 100 g of salad or tart.

2.2.5. Vitamin C contents

2 g of the *Gnetum* salads were triturated in the presence of a pinch of sand and 5 mL of 90% acetic acid then 5 mL of distilled water were added and the mixture was centrifuged 10 min at 4000 g/min to obtain *Gnetum* leaves extract. The 2,6 – dichlorophenol indophenol (DCPIP) reagent has a red color in acid solution, blue in basic and neutral solution. The intensity of the complex formed in the overall equation was used as described by Ref. [21] to evaluate the vitamin C content in the produced *Gnetum* salads. A 0.01 mg/mL of ascorbic acid solution was prepared in 20% metaphosphoric acid at the same time 0.1 g/L DCPIP solution was made using distilled water. The latter solution was used to titrate *Gnetum* salad extract as well as the standard solution of vitamin C. The vitamin C content (Q in mg/100 g of DW) of the *Gnetum* salad was estimated using equation (2):

$$Q = \frac{C_{DCPIP} \times V_{DCPIP} \times 100}{m \times V_{ascorbic\ acid} \times DW} \tag{2}$$

Where C is the concentration, V the volume, m the mass used for extraction and DW the dry weight of the salad sample.

2.2.6. Some nutritional parameter values

2.2.6.1. Energy value. The Energy Value (EV) expressed in kilocalorie (Kcal) represents the quantity of energy that a consumer may gain after total digestion of the food. The EV of produced tarts and salads were evaluated using the method described by Ref. [22], with slight modifications. The total EV was performed by multiplying the energy value by 0.85 taking into consideration that 15% of energy is lost during digestion [23]:

$$EV\left(\frac{kCal}{100g}\right) = ((\%\ Carbohydrates \times 4) + (\%\ Lipids \times 9) + (\%\ Proteins \times 4)) \times 0.85 \tag{3}$$

2.2.6.2. Energy density and nutritional density values. The Energy Density (ED) is the amount of energy stored in a particular mass of food whereas the Nutritional Density (ND) indicates the ratio of the nutrient content to the total energy content of the food. The ED and ND values were calculated with equations (4) and (5) respectively, developed by Ref. [24].

$$ED(kCal\,/\,100g) = \frac{EV}{Food\ weight(g)} \tag{4}$$

$$\mathrm{ND}(g\,/\,100kCal) = \frac{1}{EV} \tag{5}$$

2.2.7. Sensorial analyses

Sensorial analyses were done with a panel of 50 naive individuals as outlined by Ref. [25]. The panel was composed of 23 males and 27 females with age ranged from 16 to 40 years old and plus. Different salad and tart samples were prepared and respectively served to trained panelists. A slice of sugarless bread was given to the latter between two samples in order to avoid taste interference. A 9-points hedonic scale ranging from (9)-like extremely to (1) disliked extremely was used to rate the odor, color, taste, and overall acceptability of the produced salads and tarts. The general view of each sensorial characteristic tested by the panelists was represented using radar plot.

2.2.8. Statistical analyses

Experimentations were done at least in triplicate and results were presented as means ± SD. Stagraphic Centurion version XVI.I software package was used to perform one-way ANOVA in order to evaluate the statistical difference of obtained means. The difference was considered to be statistically significant when the probability is less than 0.05 ($p < 0.05$). Data obtained from the survey were analyzed using Sphinx plus^2- Edition Lexica software.

3. Results and discussion

3.1. Survey on the importance of Gnetum in the food habit

A survey was carried out in the Centre, Littoral and South regions of Cameroon with the main goals being to evaluate the importance of the *Gnetum* in the feeding habit of the society. The socio-professional categories of people involved in *Gnetum* leafy vegetable activities and their ages were identified on one hand. On the other hands, the form of leaves used as well as the frequency of consumption were estimated. The main investigated points were Bafia, Pouma and Ebolowa respectively for Centre, Littoral and South regions. These towns were the intense points due to the high population density and the *Gnetum* activities. The results in Table 3 showed that in each locality people with aged between 20 and 40 years old constituted more than half of the total population (Bafia 53.3%; Pouma 55.2% and Ebolowa 54.8%) followed by the range from 41 to 60 years old (Bafia 36.7%; Pouma 27.6% and Ebolowa 32.3%). Individuals inquired with ages less than 20 and above 60 represented the lowest percentages. This can be justified by the fact that many activities related to *Gnetum* spp vegetable need physical effort and therefore attributed to active adults.

As far as the socio-professional categories of people involved in *Gnetum* spp. leaf activities are concerned, housekeepers are the most represented (Ebolowa, 35.5%; Bafia, 26.7%; Pouma, 24.1%) followed by traders (Bafia, 30%; Ebolowa, 29%; Pouma, 17.2%). These differences can be attributed to the availability of an individual in relation with his/her function. In fact, civil servants in general do not have enough time to take *Gnetum* leaf activities as extra work. Various activities done on these leaves from the farm (harvesting) to the dish (eating form) fall directly in the housekeepers and traders work description.

Talking about the motive why inhabitants consume *Gnetum* leaves, three main reasons were identified and they are shown on the chart (Table 4). 69% of the population eat *Gnetum* leaves as vegetable because they do appreciate it, 28% like it as traditional food, whereas 3.1% eat it for their medicinal properties. The cooking or consumption manners differ from one locality to another. Fig. 4 (a–c), gives a clear examples of different dishes made with *Gnetum* vegetable and the variation can be due to inhabitant culture.

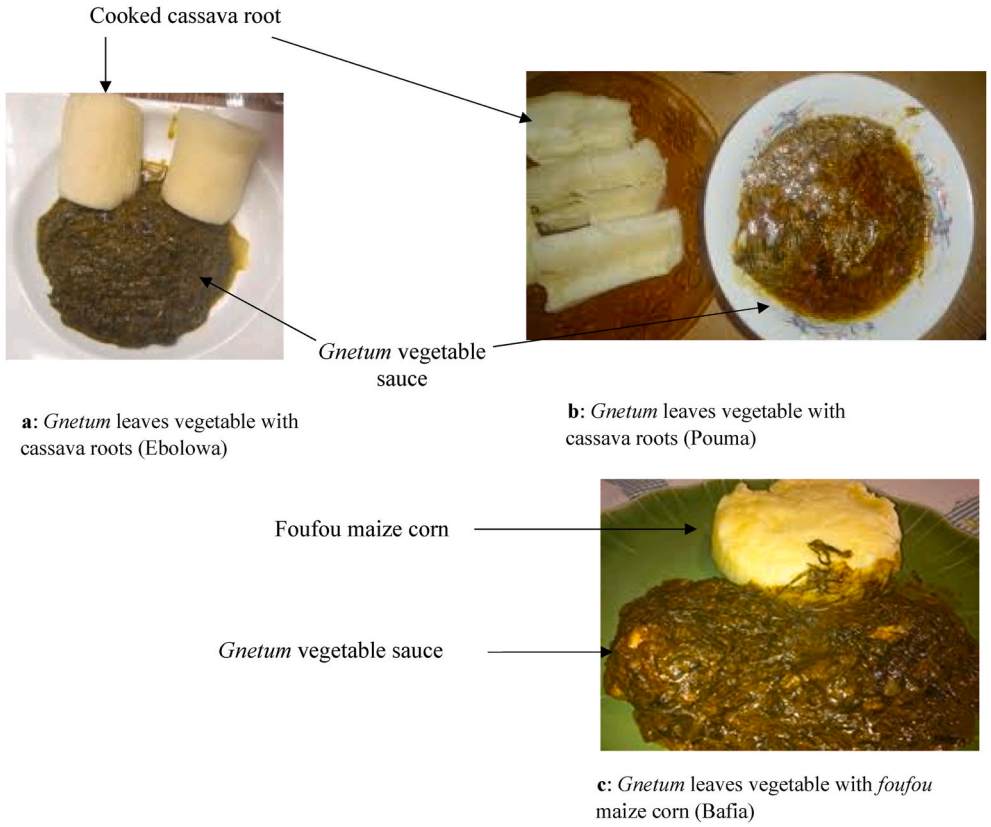
The consumption frequencies of *Gnetum* leaves in the different localities were evaluated in order to suggest the number of people who may like or appreciate a new food products (Tarts and Salads) made with this leafy vegetable. From the result presented in Table 5, all inquired individuals consume *Gnetum* leaves at different proportions. Most of them (96.9%), eat the leaves prepared almost in the same way from one locality to another, at least once per month. This was a great motivation to propose new formulations or recipes base on *Gnetum* leafy vegetables.

Table 3
Percentage of the socio-professional categories of people involved in *Gnetum* leaves activities in different localities.

Towns	Functions					
	Public Servant	Servant	Trader	Farmer	Housekeeper	Retired
Bafia	10	3.3	30	10	26.7	20
Pouma	20.7	0	17.2	17.2	24.1	20.7
Ebolowa	3.2	3.5	29	3.2	35.5	22.6

Table 4
Frequency of the reason of *Gnetum* leaves consumption.

	Reasons of *Gnetum* leaves consumption		
	Like of *Gnetum* vegetable	Traditional Food	Health Reason
Frequency (%)	68.8	28.1	3.1



a: *Gnetum* leaves vegetable with cassava roots (Ebolowa)

b: *Gnetum* leaves vegetable with cassava roots (Pouma)

c: *Gnetum* leaves vegetable with *foufou* maize corn (Bafia)

Fig. 4. Some local meals based on Gnetum leafy vegetables.

Table 5
Frequencies (%) of *Gnetum* leaves consumption.

	Consumption Frequencies			
	At least once per week	Once in two week time	Once per month	Once in three month
Number of individual investigated (%)	31.3	34.4	31.2	3.1

3.2. Preparation salads and tarts, proximate composition and nutritional value

In order to reduce the percentage of fat and develop new food recipe with precooked *Gnetum* leafy vegetables, new tarts and salads were prepared with precooked *Gnetum* leaves sliced in two forms. Based on the different sliced forms (thin and thinnest) and the quantities of *Gnetum* leaves used (50, 100 and 150 g), six tarts were produced (Fig. 5(a–f)). They were named and coded as tart T50 (T50), tart T100 (T100), tart T150 (T150) for tarts made with thin sliced leaves and tart t50 (t50), tart t100 (t100), tart t150 (t150) for tarts formulated with thinnest sliced leaves. At the same time, three salad samples: salad 50 (S50), salad 100 (S100) and salad 150 (S150) were formulated (Fig. 6(a–c)).

The proximate composition of *Gnetum* tarts and salads were determined using various methods and the results are presented in Table 6 and Table 7 respectively. The moisture content of tart samples ranged from 40.12 to 47.16 g/100 g Fresh Weight (FW) which is significantly low compared to that of the precooked leaves 61.33 g/100 g FW. Salads samples however had higher moisture contents values from 89.72 to 91.69 g/100 g FW compared to the single leaves (61.33 g/100 g FW). This difference can be explained by the

a: Tart with 50 g of *Gnetum* thinly sliced (T50)

b: Tart with 50 g of *Gnetum* thinnest sliced (t50)

c: Tart with 100 g of *Gnetum* thinly sliced (T100)

d: Tart with 100 g of *Gnetum* thinnest sliced (t100)

e: Tart with 150 g of *Gnetum* thinly sliced (T150)

f: Tart with 150 g of *Gnetum* thinnest sliced (t150)

Fig. 5. Vegetable tarts made with sliced *Gnetum* leaves.

composition of the new salad. In fact, salad is made with great quantity of high water content ingredients such as onion, carrot compared to the precooked leaves taken individually. The considerable value of moisture found both in salad and tart can facilitate the digestion process as this will increase the activity of enzymes [26]. However, the high water content also increases the susceptibility of microbial attack which could affect considerably the shelf life of the product [12].

The ash contents of tarts varied from 2.23 to 2.40 g/100 g DW and that of salad samples from 0.21 to 0.41 g/100 g DW. All these values were lower than that of the *Gnetum* leaves (6.96/100 g DW) used for preparations. The difference can be attributed to the quantities of the *Gnetum* leaves in these different food products since the other ingredients were kept constant. The high values of ash in tart samples indicate the presence of significant amount of minerals [26–28].

a: Vegetable salad with 50 g of *Gnetum* (S50)

b: Vegetable salad with 50 g of *Gnetum* (S100)

c: Vegetable salad with 150 g of *Gnetum* (S150)

Fig. 6. Vegetable salads made with sliced *Gnetum* leaves.

Table 6
Proximate Composition of tarts made with different quantities of precooked *Gnetum* leaves thinly (T) and thinnest (t) sliced.

Parameters	*Gnetum* leaves	Tart T50	Tart T100	Tart T150	Tart t50	Tart t100	Tart t150
Moisture (g/100 g FW)	61.33 ± 0.74^{c}	40.69 ± 1.24^{a}	41.60 ± 4.60^{a}	47.16 ± 3.60^{b}	40.12 ± 1.41^{a}	43.42 ± 3.90^{ab}	47.09 ± 2.20^{b}
Ash (g/100 g DW)	6.96 ± 0.31^{c}	2.23 ± 0.14^{a}	2.27 ± 0.23^{a}	2.33 ± 0.03^{a}	2.26 ± 0.18^{a}	2.31 ± 0.27^{a}	2.40 ± 0.12^{b}
Lipids (g/100 g DW)	6.25 ± 0.39^{c}	21.07 ± 3.43^{a}	24.11 ± 0.97^{ab}	24.92 ± 2.12^{b}	21.82 ± 3.37^{a}	24.91 ± 2.50^{b}	23.77 ± 2.40^{ab}
Proteins (N x 6.25) (g/100 g DW)	12.78 ± 1.49^{c}	24.71 ± 1.50^{a}	25.21 ± 0.99^{ab}	26.09 ± 0.99^{ab}	25.04 ± 0.74^{a}	25.48 ± 1.11^{ab}	26.00 ± 0.86^{b}
Carbohydrates (g/100 g DW)	36.14	24.89	19.02	13.92	24.15	18.59	17.42
Crude Fibers (g/100 g DW)	44.83 ± 1.64^{d}	29.33 ± 0.67^{a}	31.66 ± 1.88^{b}	33.66 ± 0.47^{c}	28.99 ± 0.10^{a}	31.02 ± 1.56^{b}	32.81 ± 0.56^{b}
Vitamin C (mg/100 g DW)	15.62 ± 0.02^{f}	86.69 ± 4.08^{a}	205.33 ± 5.39^{b}	281.8 ± 7.02^{c}	92.03 ± 3.11^{d}	199.87 ± 4.98^{e}	283.21 ± 6.79^{c}
Total Phenolic Compounds (mg GAE/ 100 g DW)	242.73 ± 4.12^{e}	86.69 ± 4.08^{a}	205.33 ± 5.39^{d}	281.80 ± 7.02^{f}	92.03 ± 3.11^{b}	199.87 ± 4.98^{c}	283.21 ± 6.79^{f}
Energetic Value (Kcal)	214.14 ± 3.02^{e}	373.28 ± 4.12^{a}	362.02 ± 4.08^{b}	360.57 ± 10.21^{c}	334.17 ± 9.05^{b}	340.39 ± 5.01^{d}	329.47 ± 8.01^{a}
Energetic Density (Kcal/g)	2.14 ± 0.01^{d}	3.73 ± 0.02^{a}	3.62 ± 0.01^{b}	3.61 ± 0.02^{a}	3.34 ± 0.03^{b}	3.40 ± 0.00^{c}	3.29 ± 0.01^{a}
Nutritional Density (g/Kcal)	0.46 ± 0.01^{e}	0.27 ± 0.00^{ab}	0.28 ± 0.01^{b}	0.28 ± 0.00^{b}	0.30 ± 0.00^{d}	0.29 ± 0.00^{bc}	0.30 ± 0.00^{d}

Tart T50: Tart made with 50 g of Gnetum leaves thinly sliced Tart t50: Tart made with 50 g of Gnetum leaves thinnest sliced.
Tart T100: Tart made with 100 g Gnetum leaves thinly sliced Tart t100: Tart made with 100 g Gnetum leaves thinnest sliced.
Tart T150: Tart made with 150 g Gnetum leaves thinly sliced Tart t150: Tart made with 150 g Gnetum leaves thinnest sliced.
Experimentations were done in triplicate and values are presented in the form of mean ± standard deviation, except carbohydrate values. Different superscript letters in the same line denote significant differences according to ANOVA test ($P < 0.05$).

Table 7
Proximate composition of salads made with different quantities of precooked *Gnetum* leaves thinly (T) sliced.

Parameters	*Gnetum* leaves	Salad S50	Salad S100	Salad S150
Moisture (g/100 g FW)	61.33 ± 0.74^{c}	91.69 ± 0.50^{a}	91.17 ± 0.96^{a}	89.72 ± 1.03^{b}
Ash (g/100 g DW)	6.96 ± 0.31^{d}	0.21 ± 0.03^{a}	0.28 ± 0.02^{b}	0.41 ± 0.14^{c}
Lipids (g/100 g DW)	6.25 ± 0.39^{b}	2.01 ± 0.99^{a}	2.76 ± 1.21^{a}	2.97 ± 1.03^{a}
Proteins (N x 6.25) (g/100 g DW)	12.78 ± 1.49^{d}	8.32 ± 0.02^{a}	9.19 ± 0.80^{b}	10.48 ± 1.21^{c}
Carbohydrates (g/100 g DW)	36.14	37.67	27.02	23.89
Crude Fibers (g/100 g DW)	44.83 ± 1.64^{c}	52.00 ± 0.68^{a}	60.83 ± 1.28^{b}	62.66 ± 1.26^{b}
Vitamin C (g/100 g DW)	1.56 ± 0.02^{b}	3.39 ± 1.36^{a}	4.32 ± 1.84^{a}	4.50 ± 0.91^{a}
Total Phenolic Compounds (mg GAE/100 g DW)	242.73 ± 4.12^{b}	182.45 ± 1.69^{a}	240.30 ± 1.44^{b}	493.52 ± 2.10^{c}
Energetic Value (Kcal)	214.14 ± 1.67^{d}	171.74 ± 2.53^{a}	144.23 ± 2.84^{b}	139.58 ± 0.65^{c}
Energetic Density (Kcal/g)	2.14 ± 0.00^{d}	1.71 ± 0.06^{a}	1.44 ± 0.02^{b}	1.40 ± 0.02^{c}
Nutritional Density (g/Kcal)	0.46 ± 0.00^{d}	0.58 ± 0.01^{a}	0.69 ± 0.00^{b}	0.71 ± 0.00^{c}

Salad S50: Salad made with 50 g of Gnetum leaves.
Salad S100: Salad made with 100 g Gnetum leaves.
Salad S150: Salad made with 150 g Gnetum leaves.
Experimentations were done in triplicate and values are presented in the form of mean ± standard deviation, except carbohydrate values. Different superscript letters in the same line denote significant differences according to ANOVA test ($P < 0.05$).

Lipids are the most important sources of energy in the human system, however, it should be consumed with a lot of care to avoid obesity and other related diseases. The lipid contents of tarts were significantly superior to that of the precooked *Gentum* leaves (6.25 g/100 g DW). In general, the lipid contents of salad samples ((2.01 to 2.97 g/100 g DW) were smaller compared to that of the precooked *Gentum* leaves. The value of lipids in tart varied from 21.07 (Tart T50) to 24.91 (Tart t100) g/100 g DW which are slightly above the 20% daily norm recommended by the World Health Organization and the Food and Nutrition Board, Institute of Medicine [29]. Therefore, *Gnetum* tart should be consumed with caution. In revenge, the lipid contents of *Gnetum* salad ranges from 2.01 (Salad S50) to 2.97 (Salad S150) g/100 g DW which indicate that these foods could be consumed in high quantity without risk of increasing corona and cardiovascular diseases.

As presented in Tables 6 and 7, the total protein contents of tarts are relatively high compared to that of the normal *Gnetum* leaves. *Gnetum* leafy vegetable contains all essential amino acids in different proportions as reported by Ref. [9]. These various amino acids in tart and salad can permit these foods to contribute as a source of high quality proteins. Also they may help in the formation of different proteins which are essential for human health [30,31]. Given that part of this protein is from *Gnetum* leaves and that plant protein is known as a non-expensive protein, compared to protein from animal sources, *Gnetum* tarts and salads could be good sources of proteins for the less privileged population in developing countries [12].

3.2.1. Total phenolic compounds

Secondary metabolites found in almost all plants like phenolic compounds are bioactive molecules that play different rules in plants as well as in the human system when ingested. The Folin-Ciocateu method was used to determine the total phenolic compounds (TPC) present in salads and tarts made with *Gnetum* leaves and the results are presented in Table 6 and Table 7 respectively. The values of TPC in salad samples varied from 182.45 ± 1.69 to 493.52 ± 2.10 mg GAE/100 g DW with respect to the increase of *Gnetum* leaves in the formulation. The results showed that the TPC increase with the increasing of the proportion of *Gnetum* leaves. This can be explained by the fact that these leaves are the main source of phenolic compounds of the different salad formulations. Phenolic compounds can play an important role in the taste salads. In fact [32], reported that phenolic compounds in general and tannins in particular affect the sensorial properties of the food.

As far as the tart samples were concerned, TPC ranged from 326.67 ± 6.56 to 359.30 ± 6.15 mg GAE/100 g DW. In general the TPC values of the tarts made with *Gnetum* leaves thinly sliced are lower compared to that of the samples made with leaves thinnest sliced. This can be justified by the important surface contact (vegetal matrix and solvent) that thinnest sliced leaves possess compared to that of the thinly sliced leaves which facilitated the TPC extraction process. The extraction of TPC as well as other biomolecules is mainly affected by the particle size of the sample [33]. Taking in consideration their TPC value, tarts and salads produced with *Gnetum* leaves may have health benefit properties. TPC in most cases are related with the antioxidant activity which scavenges free radicals and therefore purifies the human system [34]. These same authors reported many physiological activities of phenolic compounds including antihypertensive, antioxidant, antibacterial activities, analgesic agents, anti-ulcer and anti-inflammatory [35]. Irrespective of the sliced form, the TPC of tart samples increased with the quantity of the *Gnetum* vegetable used. The same trend was observed in salad samples. This high TPC is of great importance for human health, mostly in the management of obesity. It is known that the amount consumed alongside with the bioavailability of the polyphenols govern the health effects. Also, polyphenol compounds have the ability to stimulate beta-oxidation of fatty acids and inhibit the growth of adipocyte differentiation [36,37]. All these constitute some advantages that salads and tarts prepared using *Gnetum* leaves can provide to the consumers.

3.2.2. Vitamin C contents

Vitamin C is an important water soluble vitamin found abundantly in fruits and vegetable [38]. Vitamin C contents of tarts and salads were evaluated using 2,6- dichlorophenol indophenol method. From the results presented in Table 6, vitamin C contents of tarts ranged from 86.69 ± 4.08 to 283.21 ± 6.79 mg/100 g DW. The highest value is that of the tart made with 150 g of *Gnetum* leaves

thinnest sliced (tart t150) while the sample prepared with 50 g of *Gnetum* leaves thinly sliced (tart T50) had the lowest value. For salad samples, the vitamin C content ranged from 3.39 ± 1.36 to 4.50 ± 0.91 g/100 g DW, with the highest value belonging to the salad made with 150 g of *Gnetum* leaves (Salad S150) (Table 4). In both cases, *Gnetum* leaves were the main ingredient that varied significantly (form and mass) during the preparations. The difference observed therefore, could be due to the quantity of *Gnetum* leaves and the method used to extract vitamin C from *Gnetum* leaves which is positively correlated with the mass increase and size reduction.

According to Refs. [39,40], the recommended dietary allowance of vitamin C varies from 40 to 220 mg/day. They also reported that the human body demand of vitamin C changes with the biological statute. For example, smokers, pregnant and lactating women need more ascorbic acids than normal individual. Therefore, a daily consumption of 100 g of *Gnetum* leaf salads or tarts could cover the vitamin C demand of a normal individual for a day. The consumption of salads or tarts produced with *Gnetum* leaves may have positive impact on the consumer's health through its vitamin C content. In fact, apart from its normal prevention property against scurvy, researches have showed that vitamin C when taken above the recommended dietary can impact on the prevention of some cancers and cardiovascular diseases [39].

In addition, with its antioxidant activity, vitamin C protect from oxidative stress, reduces the lipid peroxidation and lessens inflammation [41].

In general, for both produced tarts and salads, the vitamin C contents were found to be positively proportional to the mass increases of *Gnetum* leaves.

3.3. Energy values, energy density and nutritional density

There are several parameters which can affect the choice of food by a human being. They include concerns with nutrition and body weight, religion, taste, convenience, cost, energy density and nutritional density. Stelmach-Mardas and collaborators found that energy density of food is an important parameter which may significantly influence energy consumption of an individual [42]. The energy value as well as the energy density of tarts and salads were evaluated based on the macronutrient contents: lipids, proteins and carbohydrates and the results are shown in Table 6 and Table 7, respectively. The energy value of *Gnetum* tarts ranged from 329.47 (Tart t150) – 373.28 (Tart T50) kCal which is significantly high compared to that of *Gnetum* leaves (214.14 kCal), while that of *Gnetum* salads fluctuated from 139.57 (Salad S150) to 171.74 (Salad S50) kCal) and was lower compared to that of the *Gnetum* leaves.

The evaluation of *Gnetum* leaves contribution as far as energy value is concerned indicates that 57–65% of energy provided by tart samples are from the *Gnetum* leaves. The energy value from proteins for the produced tarts and salads varied from 22.58 to 31.56% and 19.38–30.03% respectively, which makes these new food products to be considered as good source of proteins. In fact, a food product is considered as good source of proteins, when at least 12% of its cumulative energy value is from the metabolism of its protein content [43].

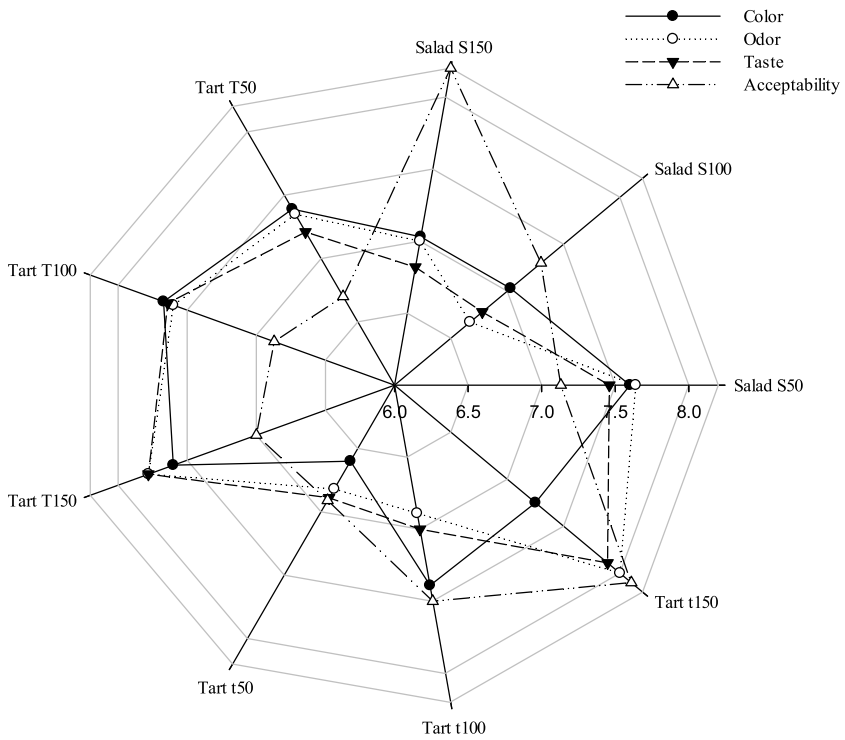


Fig. 7. Radar plot showing the total sum of the results obtained by all the panelists for each tart and salad evaluated parameters (n = 50).

The nutritional density of the produced tarts is between 0.27 and 0.30 g/kCal which was significantly lower compared to that of the precooked *Gnetum* leaves (0.46 kCal). This could be one of the reasons of using *Gnetum* vegetable in the formulation of new tart products which may be helpful in weight management and obesity. Nutrient dense food is one of the healthiest food, it provides many nutrients for fewest calories. Previous researches have reported a strong and positive relationship between chronic overeating and energy accumulation which lead to the development of overweight and obesity [44]. In this line, limiting the energy intake by feeding with nutrient dense foods is a common solution to fight against overweight and obesity [44].

For the salad samples, the nutritional density ranged from 0.58 to 0.71 g/kCal. These values increased proportionately with the incorporated quantity of precooked *Gnetum* leafy vegetable.

3.4. Sensory evaluation and overall acceptability

The 9 scale hedonic test was used to evaluate the color, odor, taste and overall acceptability of the tarts and salads. A panel of fifty trained individuals examined three salads and six tarts made with different quantities of precooked *Gnetum* leaves (50, 100 and 150 g) and different forms (thin sliced: T and thinnest sliced: t) of *Gnetum* leaves. Responses from the panelists were recorded and the calculated mean scores are represented on Fig. 7.

All the three salads presented almost the same color with a mean score approximately equal to 7. Sample S50 (salad made with 50 g of *Gnetum* leaves thinly sliced) had the highest score as far as the odor and taste were concerned. However, there was no significant difference concerning the color of the salads.

For the texture, the score recorded with tart samples varied significantly from one to another, with the highest value noted with thinnest sample. This may be due to the fact that the thinnest of the *Gnetum* leaves permitted them to be well tied to other ingredients than the thin sliced samples. With the mean scores greater than 6.5. All the samples evaluated felt in the acceptable rang. However, the salad S150 and tart t150 were the most appreciated samples by the panelists. These sensorial variations among samples can be partly due to the different concentrations of TPC. In fact, as earlier reported, phenolic compounds influenced the determination of flavor, color and taste of foods [33].

4. Conclusion

Looking at the results of these investigations, it is possible to valorize *Gnetum* leafy vegetables in modern gastronomy and give them added value. The newly formulated *Gnetum* tarts and salads are some examples which through their energy values, their nutritional densities are interesting recipes for the management of some metabolic diseases such as weight management and obesity. Tarts and salads produced with *Gnetum* leaves have good nutritional values. With their total phenolic compounds, associated with antioxidant activities these new food recipes are potential functional food. However, additional research should be done to evaluate their digestibility, safety and microbiological properties. Also further research on chemical composition by high technical instruments such as FTIR and HPLC or LCMS can provide more detailed information.

5. Ethical statement

Appropriate protocols for protecting the rights and privacy of all participants were used during the performance of the research. There was no compulsion to participate, no announcement of participant data without their knowledge and full disclosure of study requirements and risks was respected. Authors received a verbal informed consent from all participants for the questionnaire and sensory evaluation before the activities. There was an ability for a participant to withdraw from the study at any time.

Author contribution statement

Laurette Blandine Kenfack Mezajoug: Conceived and designed the experiments; Analyzed and interpreted the data.

Eric Serge Ngangoum: Conceived and designed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Horliane Ghomdim Nzali, Stève Djiazet, Joseph Pascal Mekongo Otabela, Clergé Tchiégang: Performed the experiments; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Data availability statement

Data included in article/supplementary material/referenced in article.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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