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### RESEARCH ARTICLE

#### SURVEY ON THE CONSUMPTION AND STUDY OF PHYSICOCHEMICAL CHARACTERISTICS OF *IRVINGIA WOMBOLU* VERMOESEN SEEDS IN IVORY COAST.

Akuailou Eléonore-Nausica<sup>1</sup>, Assanvo Bomo Justine<sup>1</sup>, Chatigre Kouamé Olivier<sup>1</sup>, Monsan Vincent<sup>2</sup>, Coxam  
Véronique<sup>3</sup> and Kati-Coulibaly Séraphin<sup>4</sup>.

1. Laboratoire de Biochimie et Sciences des Aliments-UFR Biosciences-Université Félix Houphouët-Boigny, 22 BP 582 Abidjan 22, Côte d'Ivoire.
2. UFR Mathématiques et Informatique, Université Félix Houphouët Boigny, Abidjan, Côte d'Ivoire, 22 BP 582 Abidjan 22, Côte d'Ivoire.
3. Institution National de Recherche Agronomique/Unité de Nutrition Humaine/Université d'Auvergne/France, 63122 Saint Genès-Champanelle – France.
4. Laboratoire de Nutrition et Pharmacologie-UFR Biosciences-Université Félix Houphouët-Boigny, 22 BP 582 Abidjan 22, Côte d'Ivoire.

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#### Abstract

In Ivory Coast, the seeds of *Irvingia wombolu* are widely consumed. For valorizing their important potential, a survey and a physicochemical study of the mature seeds were performed. The survey targeting the consumption of these seeds by the populations revealed that they hold a staple place in their food habits, as 96.6% of participants eat them. The reasons that justify such a level of consumption were cultural attachment and adoption of eating habit. Seeds are used as an additive for thickening of sauces and are very appreciated because of the pleasant flavor and slimy consistency. A small proportion (15.2%) of participants used them also for medical and cosmetic purposes. The main selection criteria for their purchase were the good sanitary quality and good smell (not fermented). Their price at the urban market was 110 CFA francs (15 seeds) during the harvest time and 145 CFA francs (12 seeds) off season, despite the lower quality. However, the percentage of participants eating the seeds off season remains high (80.1%). The physicochemical analysis of the seeds of *I. wombolu* collected from the region of «Lagunes» revealed that they contained 69.44%, 19.05%, 12.37%, 4.10%, and 2.65% of crude fat, total carbohydrates, protein, ash, and moisture respectively, while those from the region of «Fromager» consist of 70.56% (crude fat), 17.06% (total carbohydrates), 13.7% (protein), 4.23% (ash) and 2.66% (moisture). In-depth studies of the exact nature of fatty acids, protein and ash in seeds would better guide its use for the benefit of consumers.

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**Corresponding Author:-Assanvo Bomo Justine.**

Address:-Laboratoire de Biochimie et Sciences des Aliments-UFR Biosciences-Université Félix Houphouët-Boigny, 22 BP 582 Abidjan 22, Côte d'Ivoire.

## Introduction:-

The species *Irvingia wombolu* Vermeesen, commonly called «wild mango» belongs to the family *Irvingiaceae*. It is a tall tree found in the dense forests of Central and West Africa (Harris, 1996). The fruit is a green drupe that turns yellow when ripe. It looks like the mango (*Mangifera indica*), but its bitter mesocarp is inedible. The seed is used in cooking as a thickening condiment and is appreciated because it has mucilaginous and flavoring properties (Ejiofor *et al.*, 1987; Harris, 1996; Lapido, 2000; Lapido *et al.*, 1996). Therefore, it is popular and its sale is an important source of income for local people (Ainge and Brown, 2001; Leakey, 1999; N'Doye *et al.*, 1997; Kengni *et al.*, 2011). The weekly gain of traders can vary from 3,700 CFA francs to 13,700 CFA francs (N'Doye *et al.*, 1997; Awono and Manirakiza, 2007). Ainge and Brown (2001) reported that in Cameroon a peasant can hope to get US \$ 300 annually from the sale of *I. wombolu* seeds, from a mature tree. Therefore, because of their nutritious, cooking and economical interest for local populations, studies on species domestication were performed in some countries of Central Africa for increasing the productivity and facilitating the access to trees during the gathering of the fruits (Dolor, 2011).

In Ivory Coast, the seeds of *I. wombolu* are also widely consumed. However, the species is still growing in the wild. For developing this potential important resource, a socio-economic survey was conducted to estimate how important the consumption of this food is for the populations living in Ivory Coast. Then after a physicochemical study of the mature seeds was performed to evaluate their nutritional properties.

## Methodology:-

### Survey on the consumption of *Irvingia wombolu* seeds

#### Survey design

The sampling method described by Dunod (2001) was adopted for our study. The general census of population and household (GRPH) of 1998, which is the most recent census in Ivory Coast, was used as a basis for the investigation (Anonymous, 1998). As all major cultural groups of Ivory Coast and people from neighboring countries (Mali, Burkina Faso, Ghana, Nigeria, Niger, etc.) are represented in Abidjan, the survey was restricted to the city. The 5 most populated municipalities composed of 75% of the population in Abidjan were visited and were Adjamé, Cocody, Abobo, Koumassi and Yopougon.

The sampling method used was the stratified random sampling with two levels, coupled to the routes method. In the first level, a number of settings were chosen within each of the 5 municipalities. The choice of the areas was based on a simple random sampling, without replacement. When a district was chosen to be investigated, a route was imposed on the investigating officer who randomly chose the households to investigate throughout this route. That is the second level. The overall sample size is estimated at 696 households (*table 1*). The household is the basic survey sampling unit, obtained from a random drawing.

**Table 1:-**Sample size for the survey on the consumption of *Irvingia wombolu* seeds in Ivory Coast

| Town    | Municipality | Number of households interviewed |
|---------|--------------|----------------------------------|
| Abidjan | Adjamé       | 130                              |
|         | Cocody       | 130                              |
|         | Abobo        | 150                              |
|         | Koumassi     | 135                              |
|         | Yopougon     | 151                              |
| Total   | 5            | 696                              |

### Collection support (questionnaire)

A pre-survey, conducted in Gagnoa (a town located in the region of Fromager, in Western Ivory Coast) was used to collect information to establish the survey questionnaire. This city was chosen because it is a great area of production, consumption and supply of *I. wombolu* seeds. The survey questionnaire was composed of 4 sections.

#### Section 1:

Identification of the participants. This section collected demographic information about men and women surveyed.

#### Section 2:

Knowledge and uses of *I. wombolu* seeds. This section assesses the level of knowledge of the seeds and their different uses.

**Section 3:**

Supply, methods of conservation and selection criteria of *I. wombolu* seeds. This section examines the sources of supply, methods of conservation and characteristics used as selection criteria of the seeds.

**Section 4:**

Availability and consumption of *I. wombolu* seeds during the non-harvest period. This section examines the availability and rate of consumption of *I. wombolu* seeds off season.

**Survey**

The frame set up for the fieldwork contained two levels: the investigating officers (three persons) and one supervisor. The investigating officer, under the authority of the supervisor was responsible for selecting the households to be interviewed on the basis of the sampling and for directly collecting information from participants on the questionnaire. The supervisor was responsible for monitoring, control and correction of the work of the investigating officers under his authority.

**Statistical Analysis Technique**

The double entry technique, with the CSPRO software version 4.0, was used for entering data. The descriptive statistics, with the STATA 10 software, was used to analyze the survey data. The number of times a modality in a question is chosen shows its importance in the use of *I. wombolu* seeds.

**Physicochemical study of *Irvingia wombolu* seeds**

The mature fruits of *I. wombolu* were gathered from two areas of Ivory Coast: the forest of Banco in the South and Mama, Grebo-Drahio, Mahiboua and Gnagbodougnoa, localities located in the department of Gagnoa. In Ivory Coast, *I. wombolu* is distributed in the West, the Center, the South and the East. The region of «Fromager» was chosen for the gathering of the fruits because the cultural group «Krou» is one of the main consumers of *I. wombolu* seeds for cultural reasons. The region of «Lagunes» was randomly chosen to compare the seeds from two different production areas. To extract the seed, the fruit (*figure 1*) was split, with a machete according to a visible longitudinal line on the epidermis, to reveal the pulp bearing in its center a hard core that contains the seed (*figure 2*). *Figure 3* shows the seeds extracted and dried in an oven at 70 °C for 24 hours according to AOAC (1984). They were then crushed (mill Magimix Cuisine System 4100 G Ch.) for subsequent physicochemical analyzes (*figure 4*). The contents of crude fat, protein, ash (a mineral rich indicator) and moisture in the seeds were obtained respectively by the soxhlet method (AOAC, 1975), the Kjeldahl method (% total N x 6.25), the mineralization of the organic material by the dry method in a muffle furnace at 550 °C for 24 hours and the drying in an oven at 80 °C until a constant weight (AOAC, 1984). The total carbohydrates concentration of the seeds was obtained by calculation of difference (FAO, 1998).

Results were analyzed by ANOVA, at the 5% significance level, using SPSS software version 19. The results shown are the average of three replicates.



**Figure 1:-**Green and yellow fruits of *Irvingia wombolu*



**Figure 2:-**Longitudinal section of a fruit of *Irvingia wombolu*



**Figure 3:-**Dried seeds of *Irvingia wombolu*



**Figure 4:-**Ground seeds of *Irvingia wombolu*

## **Results and Discussion:-**

### **Survey on the consumption of *Irvingia wombolu* seeds**

#### **Socio-demographic characteristics of participants**

##### **Age and gender**

The surveyed population was mostly 15 to 45 years old (78.5% of participants) and predominantly female (78%). As *I. wombolu* seed is essentially used to cook sauces, the large number of women in the sample allowed us to have sufficient information on its supply, price in the market, methods of conservation, and the desired quality when buying.

### Cultural groups

Table 2 shows that the big five cultural groups in Ivory Coast were represented in the sample. These were the groups «Krou» (from the South-West), «Mandé du Sud» (from the West), «Mandé du Nord» (from the North-West), «Gur» (from the North-East) and «Akan» (from the East, the Center and the South-East). Non-Ivorian people interviewed are from the ECOWAS (Economic Community of West African States).

The survey on the living standards of the populations, conducted in 2008 by the National Statistics Institute (NSI) revealed that the average household size in Ivory Coast is 6 people. Our survey showed that 46.4% of the surveyed households had fewer than 5 members and 40.7% were of 5 to 10 members.

### Income level

The monthly income of 48.3% of participants was less than or equal to 100,000 CFA francs, while 51.7% of participants have a monthly income of 200,000 CFA francs. This finding supports the conclusion that social class has no influence on the consumption of *I. wombolu* seeds in Ivory Coast.

### Knowledge, use and appreciation of *Irvingia wombolu* seeds

#### Knowledge of *I. wombolu* seeds

Generally, the reputation of *I. wombolu* seeds is widespread. Indeed, 98.9% of participants know them, including those from non-production areas. The name of *I. wombolu* seeds is different from one language to another, except for those culturally very close. For example, the languages Yacouba, Guéré and Wobè use the same name which is «kplé». The languages Bété and Dida call it «Sioko» (table 3). All the other languages have different names. This diversity for the name of *I. wombolu* seeds is also observed among people from West and Central Africa. For example, they are named «Ogwi» in Benin and «Ewewe» in Gabon (Ainge and Brown, 2001).

#### Consumption of *I. wombolu* seeds

##### Reasons of the consumption of *I. wombolu* seeds

*I. wombolu* seeds are widely consumed (96.6% of participants). Three categories of consumers were identified. The first group (61.1% of participants) is composed of people who cook the seeds for cultural attachment. The second group (32.6% of participants) is characterized by the adoption of eating habit, as in the case of Attiéké that is now a common food in Ivory Coast, while it was originally found only in the eating habits of people from the Southern Ivory Coast (Assanvo, 2008). The third group (2.9% of participants) eats the seeds for curiosity. Finally, the percentage of non-consumers was estimated at 3.4%. Thus, the main reasons for their use are the cultural attachment and the adoption of eating habit. The distribution of people according to the reason of the consumption of *I. wombolu* seeds has defined two groups (table 4). The first consisted of the people from the forest area («Krou» and «Mandé du Sud») who eat them more than 94% for cultural reason. The second was represented by three groups of the savannah zone («Gur», «Akan» and «Mandé du Nord») who eat the seeds of the plant as adopted eating habit (73.9% of the participants «Gur», 56.5% of the participants «Akan» and 52.6% of the participants «Mandé du Nord»). Among the non-Ivorian participants, 60% eat *I. wombolu* seed for cultural reason.

#### Utilization of *I. wombolu* seeds

The seeds of *I. wombolu* are mainly used as a thickening condiment. The characteristic enjoyed by people in their use is their mucilaginous properties in sauces. The seeds are never eaten raw. It is important to mention that they are roasted or sun-dried and then crushed in a mortar to obtain a powder that will be used in cooking to provide the desired mucilaginous sauces. This way to use *I. wombolu* seeds was found in Nigeria and other countries in West and Central Africa, where the use of the extracted crude fat as a cooking oil also was reported (Ainge and Brown, 2001; Lapido, 2000; Lapido *et al.*, 1996; Kengni *et al.*, 2011).

**Table 2:-Distribution of participants according to the cultural group**

| Cultural group | Language | Gender |      |       | % |
|----------------|----------|--------|------|-------|---|
|                |          | Female | Male | Total |   |
| Akan           | Abbey    | 16     | 5    | 21    |   |
|                | Abidji   | 2      | 0    | 2     |   |

|               |              |            |           |            |             |
|---------------|--------------|------------|-----------|------------|-------------|
|               | Abouré       | 1          | 0         | 1          |             |
|               | Abron        | 10         | 2         | 12         |             |
|               | Adjoukrou    | 1          | 1         | 2          |             |
|               | Agni         | 15         | 9         | 24         |             |
|               | Ahizi        | 0          | 1         | 1          |             |
|               | Akyé         | 22         | 17        | 39         |             |
|               | Alladjan     | 1          | 0         | 1          |             |
|               | Appolo       | 2          | 0         | 2          |             |
|               | Baoulé       | 156        | 30        | 186        |             |
|               | Ebrié        | 6          | 1         | 7          |             |
|               | <i>Total</i> | <i>232</i> | <i>66</i> | <i>298</i> | <i>46.3</i> |
| Krou          | Bété         | 60         | 16        | 76         |             |
|               | Dida         | 14         | 2         | 16         |             |
|               | Gnaboua      | 4          | 0         | 4          |             |
|               | Guéré        | 32         | 12        | 44         |             |
|               | Kroumen      | 1          | 1         | 2          |             |
|               | Néyo         | 1          | 0         | 1          |             |
|               | Wobè         | 17         | 5         | 22         |             |
|               | <i>Total</i> | <i>129</i> | <i>36</i> | <i>165</i> | <i>25.6</i> |
| Mandé du nord | Dioula       | 4          | 0         | 4          |             |
|               | Koyaka       | 13         | 1         | 14         |             |
|               | Mahou        | 2          | 0         | 2          |             |
|               | Malinké      | 5          | 0         | 5          |             |
|               | <i>Total</i> | <i>24</i>  | <i>1</i>  | <i>25</i>  | <i>3.9</i>  |
| Mandé du sud  | Gagou        | 2          | 0         | 2          |             |
|               | Gouro        | 52         | 18        | 70         |             |
|               | Mona         | 1          | 0         | 1          |             |
|               | Ouan         | 1          | 1         | 2          |             |
|               | Yacouba      | 29         | 18        | 47         |             |

|            |              |     |     |     |       |
|------------|--------------|-----|-----|-----|-------|
|            | <i>Total</i> | 85  | 37  | 122 | 18.9  |
| Gur        | Sénoufo      | 15  | 1   | 16  |       |
|            | Tagouana     | 7   | 2   | 9   |       |
|            | <i>Total</i> | 22  | 3   | 25  | 3.9   |
| undeclared |              | 8   | 1   | 9   | 1.4   |
| Total      |              | 500 | 144 | 644 | 100.0 |

**Table 3:-**Distribution of participants according to the language, knowledge and name of *Irvingia wombolu* seeds

| Language and nationality | People who know the seeds (%) | Name            |
|--------------------------|-------------------------------|-----------------|
| Abbey                    | 100.0                         | Boborou         |
| Abidji                   | 100.0                         | Rogbo/warogbayé |
| Abouré                   | 0.0                           | Unknown         |
| Abron                    | 91.7                          | Unknown         |
| Adjoukrou                | 100.0                         | Kekel           |
| Agni                     | 91.7                          | Kaklou          |
| Ahizi                    | 100.0                         | Unknown         |
| Akyéou Attié             | 100.0                         | Behebien        |
| Alladjan                 | 100.0                         | Unknown         |
| Appolo ou N'zima         | 100.0                         | Unknown         |
| Baoulé                   | 99.5                          | Kaklou          |
| Bété                     | 100.0                         | Sioko           |
| Dida                     | 100.0                         | Sioko           |
| Dioula                   | 75.0                          | Unknown         |
| Ebrié                    | 100.0                         | Ahimih          |
| Gagou                    | 100.0                         | karo            |
| Gnaboua ( Niaboua )      | 100.0                         | sako            |
| Gouro                    | 100.0                         | Karou           |
| Guéré                    | 100.0                         | Kplé            |
| Koyaka ou Koyara         | 100.0                         | Unknown         |
| Kroumen                  | 100.0                         | Unknown         |

|                    |       |             |
|--------------------|-------|-------------|
| Mahou ou Mahouka   | 100.0 | Unknown     |
| Malinké ou Maninka | 80.0  | Unknown     |
| Mona ou Mouan      | 100.0 | Unknown     |
| Néyo               | 100.0 | Unknown     |
| Ouan               | 100.0 | Unknown     |
| Sénoufo            | 100.0 | Unknown     |
| Tagouana           | 100.0 | Unknown     |
| Wobé               | 100.0 | Kplé        |
| Yacouba ou Dan     | 100.0 | Kplé        |
| Burkinabe          | 100.0 | Bombolou    |
| Malian             | 100.0 | Unknown     |
| Guinean            | 100.0 | Kpaha       |
| Nigerien           | 100.0 | Tagra       |
| Nigerian           | 96.2  | Apan/Ogbono |
| Togolese           | 100.0 | Attokouman  |
| Beninese           | 100.0 | Assokui     |

**Table 4:-**Distribution of participants in cultural groups according to the reason for the consumption of *Irvingia wombolu* seeds

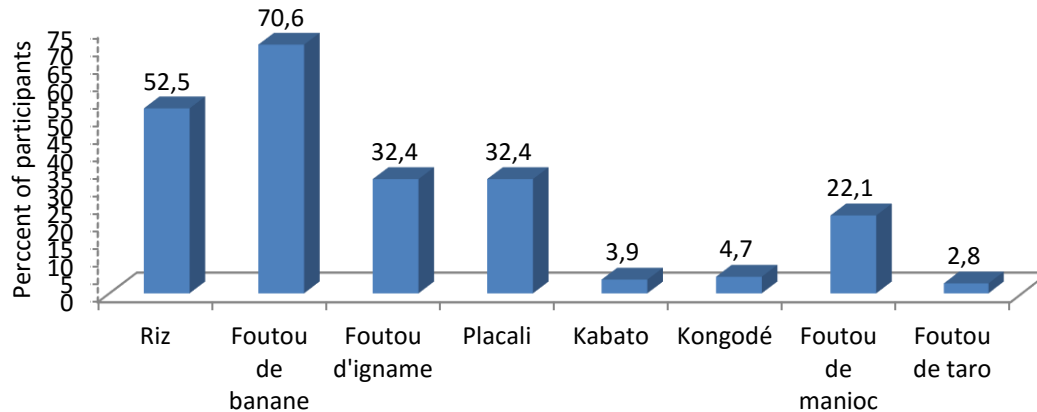
| Cultural group | Reason for the consumption of <i>I. wombolu</i> seeds |                           |
|----------------|-------------------------------------------------------|---------------------------|
|                | Cultural attachment<br>(%)                            | Adopted food habit<br>(%) |
| Akan           | 24.6                                                  | 56.5                      |
| Krou           | 97.0                                                  | 1.8                       |
| Mandé du Nord  | 47.4                                                  | 52.6                      |
| Mandé du Sud   | 94.2                                                  | 5.0                       |
| Gur            | 17.4                                                  | 73.9                      |
| Non-Ivorian    | 60.0                                                  | 32.0                      |
| Undeclared     | 11.1                                                  | 88.9                      |

### Foods served with *I. wombolu* sauces

The most common foods are rice and pounded boiled-plantain called banana foutou (52.5% and 70.6% of participants, respectively). Three other foods are moderately used. There are yam foutou (pounded boiled-yam), placali (cooked crushed-cassava) and cassava foutou (pounded boiled-cassava). The least used are Kabato (paste made from corn flour, which is then cooked), Kongodé (cooked crushed-fermented cassava) and taro foutou which is pounded boiled-taro (figure 5). In Cameroon, the cooking habits are similar (Awono and Manirakiza, 2007).

### Place of consumption of *I. wombolu* seeds

The consumption of *I. wombolu* seeds is still limited to the family. The majority of participants (87.2%) eat them at home. They are also, sometimes, eaten in traditional restaurants commonly called «maquis» (3.2% of participants).



**Figure 5:**-Percent of participants surveyed according to foods served with soups prepared with *Irvingia wombolu* seeds

### Rate and time of consumption of *I. wombolu* seeds

The rate of consumption of *I. wombolu* seeds varies from one cultural group to another (table 5). People from the forest zone («Krou» and «Mandé du Sud») eat them more frequently than those from the savannah zone («Gur», «Akan» and «Mandé du Nord»). This difference can be explained by the fact that the cultural attachment is the main reason for the consumption of *I. wombolu* seeds in the groups «Krou» and «Mandé du Sud». There is also a high consumption rate among the non-Ivorian participants (4.4 times per month on average).

*I. wombolu* seeds are preferentially eaten at dinner (84.2% of participants). But 61.8% of participants eat them also at lunch.

### Appreciation of *I. wombolu* seeds

*I. wombolu* seeds are very appreciated (82% of participants), not only because they are rich in fat, easy to digest and have white cream color, but specially because in cooking, they confer to sauces mucilaginous and flavoring properties (table 6). The mucilaginous property is also reported by the people in Cameroon as the reason for the appreciation of the seeds (Tchoundjeu *et al.*, 2005; Kengni *et al.*, 2011).

**Table 5:**-Frequency of the average monthly consumption of *Irvingia wombolu* seeds according to the cultural group

| Cultural group | Number of consumption (Average per month) |
|----------------|-------------------------------------------|
| Akan           | 2.2                                       |
| Krou           | 5.2                                       |
| Mandé du Nord  | 2.1                                       |
| Mandé du Sud   | 4.7                                       |
| Gur            | 1.5                                       |
| Non-Ivorian    | 4.4                                       |

### Other uses of *I. wombolu* seeds

A low proportion of participants (15.2%) reported using the seeds for medical and cosmetic purposes, in addition to the use in cooking. In Cameroon, the seeds are used for medical purposes to treat a variety of diseases and to relieve pain (Kengni *et al.*, 2011).

### Supply, packaging, price and selection criteria of *I. wombolu* seeds

#### Sources of supply and packaging of *I. wombolu* seeds

According to 93.6% of the participants, the main source of supply is the urban market. *I. wombolu* seeds are not yet sold in supermarkets.

According to 92.3% of participants, *I. wombolu* seeds are sold in urban markets, arranged in heaps on shelves in the open air. The sale of the seeds packed in transparent plastic bags was mentioned by 19% of participants. In Cameroon, as well as in some countries in West and Central Africa, the seeds are also sold exposed to the open air in rattan baskets or packaged in the form of cakes made from the ground seeds (Tchoundjeu *et al.*, 2005; Kengni *et al.*, 2011).

#### Price of *I. wombolu* seeds

The price of *I. wombolu* seeds varies during the year. For example, during the harvest time (December-January-February), a heap of seeds on the shelves at the urban market has on average 15 seeds and it is sold at 110 CFA francs on average (table 7).

**Table 6:-**Distribution of participants according to the reasons of appreciation of *Irvingia wombolu* seeds in the cultural groups

| Rubric        | Qualification          | Akan (%) | Krou (%) | Mandé du Nord (%) | Mandé du Sud (%) | Gur (%) | Non-Ivorian (%) | Undeclared (%) | Participants (%) |
|---------------|------------------------|----------|----------|-------------------|------------------|---------|-----------------|----------------|------------------|
| Aspect        | Rich in fat            | 77.5     | 91.5     | 78.3              | 83.6             | 60.0    | 86.3            | 88.9           | 82.1             |
|               | other                  | 11.9     | 6.1      | 4.3               | 11.5             | 12.0    | 7.8             | 0.0            | 9.7              |
| Color         | Creamy White           | 63.5     | 69.1     | 78.3              | 74.6             | 64.0    | 84.3            | 100.0          | 69.3             |
|               | other                  | 27.6     | 33.9     | 8.7               | 25.4             | 24.0    | 9.8             | 0.0            | 26.3             |
| consistency   | mucilaginous           | 74.7     | 92.7     | 78.3              | 86.1             | 76.0    | 94.1            | 88.9           | 82.8             |
|               | elastic                | 5.5      | 12.1     | 0.0               | 11.5             | 8.0     | 2.0             | 0.0            | 7.7              |
|               | liquid                 | 14.0     | 1.2      | 4.3               | 0.8              | 4.0     | 2.0             | 0.0            | 6.8              |
|               | other                  | 0.0      | 0.0      | 0.0               | 0.0              | 0.0     | 0.0             | 0.0            | 0.0              |
| Smell         | good                   | 81.2     | 98.2     | 82.6              | 95.9             | 92.0    | 94.1            | 100.0          | 89.5             |
|               | scentless              | 0.0      | 0.0      | 0.0               | 0.8              | 0.0     | 0.0             | 0.0            | 0.1              |
|               | other                  | 10.6     | 3.0      | 4.3               | 3.3              | 4.0     | 2.0             | 0.0            | 6.3              |
| Taste         | Slightly sweet         | 39.6     | 24.8     | 4.3               | 30.3             | 36.0    | 27.5            | 100            | 33.0             |
|               | sweet                  | 0.7      | 0.0      | 0.0               | 0.8              | 4.0     | 0.0             | 0.0            | 0.6              |
|               | Without a strong taste | 45.7     | 71.5     | 73.9              | 66.4             | 36.0    | 66.7            | 0.0            | 57.1             |
|               | sour                   | 0.3      | 0.0      | 0.0               | 0.8              | 0.0     | 2.0             | 0.0            | 0.4              |
|               | bitter                 | 2.7      | 2.4      | 0.0               | 2.5              | 4.0     | 2.0             | 0.0            | 2.5              |
|               | other                  | 3.1      | 2.4      | 0.0               | 1.6              | 4.0     | 0.0             | 11.1           | 2.5              |
| Digestibility | Easy to digest         | 90.8     | 98.8     | 82.6              | 98.4             | 80.0    | 94.1            | 100.0          | 93.8             |
|               | Avoid flatulence       | 51.5     | 66.1     | 69.6              | 68.9             | 56.0    | 66.7            | 33.3           | 59.7             |
|               | Avoid constipation     | 22.5     | 47.9     | 65.2              | 45.9             | 28.0    | 54.9            | 11.1           | 36.6             |
|               | other                  | 1.7      | 1.2      | 0.0               | 0.8              | 0.0     | 0.0             | 0.0            | 1.2              |

Off season, the number of seeds in a heap decreases (12 seeds) and the price increases (145 CFA francs). This fluctuation in the price according to the period is also observed in Cameroon (Ainge and Brown, 2001; Awono and Manirakiza, 2007).

### Selection criteria of *I. wombolu* seeds

The most important criteria mentioned by consumers for the purchase of the seeds were the smell and the good sanitary quality. The smell of the seeds allows assessing their degree of fermentation. The importance of the smell as a criterion for the purchase was also mentioned by consumers in Cameroon (Awono and Manirakiza, 2007).

**Table 7:**-Price of almonds of *Irvingia wombolu* seeds according to the harvest time

| Period                                   | The unit of measurement               | The unit price (CFA francs) |
|------------------------------------------|---------------------------------------|-----------------------------|
| Harvest time (December-January-February) | Kilogram                              | 2 876                       |
|                                          | A heap (15 amandes)                   | 110                         |
|                                          | The empty box of tomato paste, 2200 g | 2 807                       |
| Off season                               | Kilogram                              | 4 409                       |
|                                          | A heap (12 amandes)                   | 145                         |
|                                          | The empty box of tomato paste, 2200 g | 4 430                       |

### Availability and consumption of *I. wombolu* seeds during the non-harvest time

#### Availability of *I. wombolu* seeds during the non-harvest time

*I. wombolu* seeds are available throughout the year. However, their quality is better at the harvest time (December-January-February). Indeed, off season, they are crushed, greenish and fermented. This comment was also made in Cameroon (Tchoundjeu *et al.*, 2005).

#### Consumption of *I. wombolu* seeds during the non-harvest time

Off season, 80.1% of participants continue to eat *I. wombolu* seeds. The main reason is the cultural attachment. However, the rate of consumption is reduced because of the increase in prices and the deterioration of the quality. It would be important to develop methods for the conservation of the seeds to maintain their organoleptic and nutritional properties. This recommendation was also made in Cameroon for consumers (Tchoundjeu *et al.*, 2005).

### Physicochemical study of *Irvingia wombolu* seeds

The results presented in *table 8* show that *I. wombolu* seeds were slightly hydrated: 2.65% («Lagunes» area) and 2.66% («Fromager» area). They were rich in fat with values equal to 69.44% (Lagunes) and 70.56% (Fromager). These values are comparable to those published by Ekpo *et al.*, (2007). They are superior to those of other non-timber forest products (NTFPs) underexploited as *Terminalia catappa*, *Ricinodendron heudelotii* and *Canarium schweinfurthii* (*table 9*). It is important to note that *I. wombolu* seeds were richer in fat than several oilseeds species classified as conventional, such as cotton, soybean, and sunflower (*table 10*). Because of their high content in crude fat, they are an important resource for the diversification of cooking oils for domestic and industrial uses. The protein content (*table 8*) of the seeds without their integument was 6.51% (Lagunes) and 7.30% (Fromager). Ash content of the seed integument (*table 11*) was 5.86% (Lagunes) and 6.40% (Fromager). Thus, one can say that *I. wombolu* seeds have a protein content ranging between 12.37 and 13.7%. Compared to other NTFPs such as *R. heudelotii*, *A. hybridus* and *T. catappa* (*table 9*) and the oilseeds classified as conventional (*table 10*), *I. wombolu* seeds are not an excellent source of vegetable proteins. The total carbohydrates content was 19.05% (Fromager) and 17.06% (Fromager). The proportions for the seeds of some NTFPs such as *C. albidum* and *D. edulis* (*table 9*) are considerably higher than those of *I. wombolu*. However, it should be noted that the nutritional balance is restored because foods served with *I. wombolu* seeds sauces are rich in carbohydrates. This is specially the case for yam, cassava and rice, for which carbohydrates contents vary respectively from 70.4 to 72.9%, 80 to 91% and 84.80 to 87.60% (Agbor Egbe and Treche 1995; Assanvo, 2008; Muzafarov and Mazhidov, 1997). Ash content (*table 8*) of the seeds without their integument was 2.34% (Lagunes) and 2.39% (Fromager). Ash content of the seed integument (*table 11*) was 1.76% (Lagunes) and 1.84% (Fromager), that is to say a total value of 4.1%. (Lagunes) and 4.23% (Fromager), reflecting a low content in minerals.

**Table 8:-**Physicochemical characteristics of *Irvingia wombolu* seeds

| Nutrients                   | Area                      |                           |
|-----------------------------|---------------------------|---------------------------|
|                             | Lagunes                   | Fromager                  |
| Moisture (%)                | <sup>a</sup> 2.65 ± 0.02  | <sup>a</sup> 2.66 ± 0.03  |
| Crude fat (%D.M.)           | <sup>a</sup> 69.44 ± 0.44 | <sup>b</sup> 70.56 ± 0.63 |
| Protein (%D.M.)             | <sup>a</sup> 6.51 ± 0.12  | <sup>b</sup> 7.30 ± 0.08  |
| Total carbohydrates (%D.M.) | <sup>a</sup> 19.05 ± 0.45 | <sup>b</sup> 17.06 ± 0.66 |
| Ash (%D.M.)                 | <sup>a</sup> 2.34 ± 0.16  | <sup>a</sup> 2.39 ± 0.12  |

Values with the same letter on each line are not significantly different

The values shown are the average of 3 replicates ± standard deviation

D.M.: Dry Matter

**Table 9:-**Chemical composition of the seeds of some non-timber forest products

| PFNLs                                        | Content (%) |         |         |                     |          |
|----------------------------------------------|-------------|---------|---------|---------------------|----------|
|                                              | Crude fat   | Protein | Ash     | Total carbohydrates | Moisture |
| <sup>a</sup> <i>Irvingia gabonensis</i>      | 62.67-73.82 | 8.90    | 2.32    | 15.77-24.80         | 2.55     |
| <sup>b</sup> <i>Amaranthus hybridus</i>      | 10.57       | 18.29   | 4.44    | -                   | 9.93     |
| <sup>c</sup> <i>Chrysophyllum albidum</i>    | 12          | 13.13   | 1.25    | 50.98               | 5.5      |
| <sup>d</sup> <i>Dacryodes edulis</i>         | 17.28       | 6.68    | 2.59    | 70.84               | 3.95     |
| <sup>d</sup> <i>Terminalia catappa</i>       | 47.82       | 18.39   | 5.69    | 25.61               | 4.22     |
| <sup>e</sup> <i>Ricinodendron heudelotii</i> | 44.13-54.7  | 24.72   | 10.5-16 | 0.8-5.6             | -        |
| <sup>f</sup> <i>Canarium schweinfurthii</i>  | 56.4        | -       | -       | -                   | -        |

a: Matos *et al.*, 2009; Ogunsina *et al.*, 2012; b: Dhellot *et al.*, 2006; c: Akubugwo and Ugbogu, 2007; Ochigbo and Paiko, 2011; d: Akanni *et al.*, 2005; e: Kapseu and Tchiegang, 1995; Kengni *et al.*, 2003; Kouamé and Gnahoua, 2008; f: Abayeh *et al.*, 1999.

**Table 10:-**Some chemical characteristics of the seeds of some usual oilseeds

| Oilseeds                 | Crude fat (%) | Protein (%) | Ash (%) | Carbohydrates (%) |
|--------------------------|---------------|-------------|---------|-------------------|
| <sup>a</sup> Cotton seed | 18-20         | 25          | -       | -                 |
| <sup>a</sup> Soya bean   | 18-20         | 33.2        | 4.7     | -                 |
| <sup>b</sup> Cashew      | 43.9          | 18.2        | 2.54    | 30.2              |
| <sup>a</sup> roundnut    | 45-50         | 25.8        | -       | -                 |
| <sup>a</sup> Palm nut    | 44-53         | -           | -       | -                 |
| <sup>a</sup> Sunflower   | 35-45         | 26.5        | 3.3     | -                 |
| <sup>a</sup> Coconut     | 65-68         | -           | -       | -                 |

a: O'Brien, 2009; Vierling, 2008; b: Janick and Paull, 2008

**Tableau 11:-**Protein and ash content of the integument of *Irvingia wombolu* seeds

| Nutrient    | Area                     |                          |
|-------------|--------------------------|--------------------------|
|             | Lagunes                  | Fromager                 |
| Protein (%) | <sup>a</sup> 5.86 ± 0.08 | <sup>b</sup> 6.40 ± 0.07 |
| Ash (%)     | <sup>a</sup> 1.76 ± 0.20 | <sup>a</sup> 1.84 ± 0.20 |

Values with the same letter on each line are not significantly different

The values shown are the average of 3 replicates ± standard deviation

### Conclusion:-

The survey revealed that *I. wombolu* seeds are consumed and enjoyed by a relatively large part of the populations living in Ivory Coast. People who eat them more are essentially from the forest areas but also from the savannah areas. Their main use was as a thickening condiment to give the desired mucilaginous property and a pleasant smell to sauces. While they continue to cook the seeds off season, consumers have reported their lower quality during this period. Thus, it could be great to conduct a comparative study on the physicochemical and nutritional properties of the seeds during the harvest time and off season and to develop methods for the conservation of the seeds to maintain their organoleptic and nutritional properties. The study of the physicochemical properties of *I. wombolu* seeds from the regions of «Lagunes» and «Fromager» in Ivory Coast revealed that they are a good source of crude

fat. The low contents recorded for protein and total carbohydrates could be offset by the contribution of other foods such as fish, meat and foods rich in carbohydrates (yam, cassava and rice) that are served with sauces prepared with the seeds. It also emerged from this study that it may be better to eat the seeds without removing their integument for increasing the intake of minerals. Their low water content helps maintain their quality after a long storage cycle.

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