*Original Research Article*

*Corchorus oliterius* (kplala), *Spinacia oleraceae* (spinach), and *Amaranthus tricolor* (brombrou) Leaves Consumed in the City of Man, Côte d’Ivoire: Biochemical and Microbiological Characterization

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ABSTRACT

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| The objective of this study was first to identify the different species of leafy vegetables most consumed in the city of Man. Then to determine some biochemical parameters and finally to evaluate the microbiological quality of these leafy vegetables. To do this, a survey was initiated among the women of the said city. The survey conducted among the population made it possible to identify three leafy vegetables (*Corchorus olitirius, Spinacia oleracea* and *Amaranthus tricolor*) which are the most consumed. Parameters such as pH, moisture, ash, fibers, lipids and total carbohydrates as well as total aerobic mesophyll flora were analyzed in these leafy vegetables using standard and referenced methods. The frequency of consumption of leaves by the population surveyed revealed that 42% of the families questioned consume the leaves 2 or 3 times per week. The analyses carried out indicate that the leaves analyzed have pH values ranging from 5.33 ± 0.82 to 5.90 ± 0.65; moisture content ranging from 80.44 ± 0.97 to 90.28 ± 1.68%) and ash content ranging from 0.79 ± 0.01 to 0.95 ± 0.01%. Biochemical analyses indicate that leafy vegetables have high carbohydrates (70.17 ± 0.15 to 80.14 ± 0.31%), fibers (15.51 ± 0.21 to 0.75 ± 0.09%) and lipids (2.06 ± 1.01 to 9.4 ± 0.715) contents. Regarding the microbiological analysis, the Total Aerobic Mesophyll Flora reveals a satisfactory microbiological quality (3.81.10³ to 6.10³ CFU/mL). All these results have made it possible to highlight some compounds of dietary interest contained in these leaves. |

*Keywords: Microbiological quality, Leafy vegetables, Survey, Physicochemical analyses, Man (Côte d’Ivoire)*

1. INTRODUCTION

Sub-Saharan Africa is endowed with a great diversity of food plants. Among these are leafy vegetables (Konan et al., 2015). They play a major role in agriculture and food and generate significant income in both rural and urban areas (Mawunu et al., 2023). Leafy vegetables, the "security" food, are vegetables whose consumed part corresponds to the leaves of the plant, raw or cooked, and can be cooked in a thousand and one ways. From a nutritional point of view, these vegetables are very interesting since they are low in calories, but very rich in fiber, iron, calcium, omega-3, vitamins C and K, proteins, carbohydrates and even folic acid (Yao et al., 2020). These exceptional qualities make leafy vegetables foods that particularly meet the daily nutritional needs of humans. Thus, they contribute to improving the nutritional status of populations in both rural and urban areas, in developing countries such as Côte d'Ivoire, where these traditional vegetables can help solve many public health problems (Acho et al., 2014, Prinsloo et al., 2022).

In Côte d'Ivoire, various studies conducted on some leafy vegetables have focused on their nutritional and dietary values (Atchibri et al., 2012 ; Soro et al., 2012 ; Acho et al., 2014). Unfortunately, these local foods are neglected or forgotten, especially in urban areas. Some traditional leafy vegetables such as *Corchorus olitorius* “kplala”, *Spinacia oleracea* “spinach” and *Amaranthus tricolor* “brombrou” are cultivated for consumption (Bala et al., 2019 ; Diete et al., 2023 ; Rizar et al., 2023). Leafy vegetables occupy a prominent place in the diet. They are grown as market garden plants and sold in markets. The consumption of these leafy vegetables is linked to different regions. Thus, *Corchorus olitorius* "kplala" is consumed in the Center, *Amaranthus tricolor* "brombrou" in the North and *Spinacia oleracea* "spinach" in the West of Côte d'Ivoire. These leafy vegetables contain micronutrients (vitamins, minerals) that contribute to the well-being of the body (Lubo et al., 2022). However, their importance and role in the diet of urban populations are almost unknown. In addition, it should be noted that there is very little information on their diversity and consumption frequencies as well as their contribution to the diet in urban areas (Sangaré, 2009 ; Konan et al., 2015). The most commonly consumed leaves in the city of Man are undervalued from a nutritional and microbiological perspective. In Man, leafy greens are available in markets year-round at low cost and are an ingredient in many family meals consumed by the majority of households.

This study was conducted with this in mind, with the overall objective of characterizing some of the most commonly consumed leafy greens in the city of Man (western Côte d'Ivoire) in order to raise awareness among consumers and public authorities about the benefits of consuming these foods.

2. material and methods

**2.1 Plant Material**

The plant material consisted of three plants commonly consumed in the city of Man : *Corchorus olitorius* (pkala), *Spinacea oleracea* (spinach), and *Amaranthus tricolor* (brombrou) (Fig. 1).



**Fig. 1. Different leafy vegetables used**

A :*Corchorus olitorius* (pkala) ; B:*Spinacea oleracea* (spinach) ; C :*Amaranthus tricolor* (brombrou)

**2.2 Methods**

**2.2.1 Study Area**

The city of Man, the capital of the Tonkpi Region, covering an area of 2,893 km² (MIRAHDR Man, 2017), is located between 7°25'01" North latitude and 7°32'58" West longitude. It is located in western Côte d'Ivoire, 563.2 km from Abidjan.

**2.2.2 Survey Methodology**

The objective of the survey was to identify the leaves most commonly consumed by the population (50 households surveyed) spread across the neighborhoods of the city of Man (Market, Avocado, Libreville, Gbêpleu, Campus, Blokos, Koko), and to determine the methods of preparation and consumption.

**2.2.3 Sampling**

Leaf samples were collected from two (2) markets in the city of Man (Côte d'Ivoire). A total of 30 leaf samples were collected, with 15 samples per market. Each sample consisted of 72 g of leaves. Two leaf samples per market were taken twice a week from March to April. Once collected, the samples were transported to the laboratory in a cooler for analysis.

**2.2.4 Sample Preparation for Analysis**

The leaves were washed with water, weighed using an electronic balance (Sartorius™ Entris4202I-1S, Fisher Scientific, France), and then ground in stomacher bags. The resulting ground material was used for analysis.

**2.2.5 Physicochemical Analysis**

Moisture was determined by oven drying (AOAC, 1990). Ash content and pH were also determined using the AOAC method (1990). Titratable acidity was determined using the method described by French standard NF v05-101 (AFNOR, 1974). Total lipids were extracted from samples homogenized in chloroform-methanol-water (1:2:1, v/v/v) as described by Folch et al. (1957) and determined gravimetrically. Total carbohydrates were quantified using the method of Besle & Pitiot (1976). Fiber content was determined using the AOAC method (1990).

**2.2.6 Microbiological Analysis**

*2.2.6.1 Preparation of Stock Suspension and Decimal Dilutions*

Sample, stock suspension, and decimal dilution preparation were performed according to the international standard ISO 6887-1 (1999). Samples were analyzed immediately after collection.

*2.2.6.2 Enumeration of Total Mesophilic Aerobic Flora*

The enumeration of total mesophilic aerobic flora was performed according to the international standard ISO 4833 (2003).

3. results

**3.1 Consumer Survey Results**

Following the household survey, the results show that 100 % of respondents are women and have a high level of familiarity with leafy vegetables. These are consumed cooked. The occupational level of the women surveyed in the city of Man is distributed as follows : (33 %) of women are housewives, (57 %) of women are traders and (10 %) are civil servants (Fig. 2).

**Fig. 2. Occupation of the Women Surveyed**

A variety of leafy vegetables was identified in the Man area (Fig. 3). These included sweet potato leaves (16%), taro leaves (2%), spinacea leaves (18%), cassava leaves (8%), corchorus leaves (25%), sorrel leaves (4%), amaranth leaves (11%), and okra leaves (16%). The most commonly consumed leaves were kplala leaves, *Spinacia oleracea*, okra, sweet potato, and *Amaranthus*.

**Fig. 3. Representative histogram of leafy vegetables known in the city of Man (West, Côte d’Ivoire)**

To obtain these leaves, the results revealed that 70% of the households surveyed obtain them by purchase and 18% of the households cultivate them and 12% from the grower (Fig. 4).

**Fig. 4. Diagram of leaf collection**

In terms of consumption frequency, 42% of the families surveyed consume the leaves 2 or 3 times per week, 28% consume them at least twice a month, 15% consume them for an indefinite period and 15% consume them once a week (Fig. 5).

**Fig. 5. Consumption frequency graph**

**3.2 Results** **Physicochemical Parameters of Leafy Vegetables**

The physicochemical analysis data are shown in Table 1. The moisture content of kplala, spinach, and brombro leaves showed respective contents of 80.44 ± 0.97%; 90.28 ± 1.68%; and 87.68 ± 0.19%.

The pH analysis of the leaves showed that spinach had the highest pH (5.90 ± 0.65), followed by kplala leaves (5.41 ± 0.07) and brombro leaves (5.33 ± 0.82). The acidity of these three leaves (kplala, spinach, and brombro) was 25 ± 3.65 meq/100 g, respectively. 25.25 ± 3 meq/100 g and 23 ± 0.98 meq/100 g.

Ash analysis showed that spinach had the highest ash content (0.95 ± 0.01%) and pklala leaf the lowest (0.79 ± 0.01%).

**Table 1. Physicochemical parameters of leaves**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Leaves | pH | Acidity | Humidity | Ash |
|   |    | meq/100 |  % |  % |
| Pklala | 5 .41± 0.07  | 25 ± 3.65  | 80.44 ± 0.97 | 0.79 ± 0.01 |
| Spinach | 5.90 ± 0.65  | 25 .25 ± 3  | 90.28 ±1.68  | 0.95 ± 0.01  |
| Brombrou | 5 .33 ± 0.82  | 23 ± 0.98  | 87.68 ± 0.19  | 0.83 ± 0.04  |

**3.3 Macronutrients of Leafy Greens**

Statistical analysis revealed a difference in the lipids contents of the analyzed samples (Table 2). According to Tukey's HSD test, the lipids contents of pklala, spinach, and brombrou leaves were 2.06 ± 1.01%, 3.75 ± 1.2%, and 9.4 ± 0.71%, respectively. The brombrou leaf had the highest content (9.4 ± 0.71%), and the pklala leaf had the lowest content (9.4 ± 0.71%).

Furthermore, the analysis revealed a high level of carbohydrates content in the analyzed samples. Thus, the lipids contents of pklala, spinach, and brombrou leaves were 70.17 ± 0.15 %, 70.17 ± 0.15 %, and 70.17 ± 0.15 %, respectively. 80.14 ± 0.31% and 75.86 ± 0.06 % which are different. In addition, kplala leaves (70.17 ± 0.15%) have the lowest value while spinach leaves have the highest value (80.14 ± 0.31%). (Table 2).

Unlike carbohydrates and lipids, fiber content varies from one leaf to another. Thus, kplala, spinach and brombrou leaves have respective contents of 15.51 ± 0.21% ; 2.75 ± 0.09 % and 8.50 ± 0.15 %. Pklala leaf showed the highest value (15.51 ± 0.2 1%) and brombrou leaf showed the lowest value (0.75 ± 0.09 %).

**Table 2. Leaf macronutrients**

|  |  |  |  |
| --- | --- | --- | --- |
| Leaves | Lipids | Carbohydrates | Fibers |
|   | %  | %  | % |
| Pklala | 2.06 ± 1.01 | 70.17 ± 0.15  | 15.51 ± 0.21  |
| Spinach | 3.75 ± 1.2  | 80.14 ± 0.31  | 2.75 ± 0.09  |
| Brombrou | 9.4 ± 0.715  | 75.86 ± 0.06  | 8.50 ±0.15 |

*Mean ± S.E.M = Mean values ± Standard error of means of six experiments*

**3.4 Microbiological Parameters of Leaves**

The microbiological quality analysis revealed an average load of Total Mesophilic Aerobic Flora of satisfactory microbiological quality (SMQ) for the three leaf types (Table 3). These values ranged from 3.81x103 to 6x103 CFU/mL. For the pkala leaf, the results revealed a satisfactory microbiological quality of 6x103 CFU/mL. For the spinach leaf, the results revealed a SMQ of 4.34x103 CFU/mL. For the brombrou leaves, the results revealed a satisfactory microbiological quality of 3.81x103 CFU/mL.

**Table 3. Total Mesophilic Aerobic Contamination Level of Leaves**

|  |  |  |
| --- | --- | --- |
| **Leaves** | **Total Mesophilic** | **Recommended** |
|   | **Aerobic (CFU/mL)** | **Standard (CFU/mL)** |
| Pklala | 6x103 | ˂ 5. x105 |
| Spinach | 4.3x103 | ˂ 5. x105 |
| Brombrou | 3,81.103 | ˂ 5. x105 |

4. DISCUSSION

Following the survey results, more than 70% of women surveyed in this city obtain leafy vegetables through market purchases. Harvesting and market gardening are the two main sources of leafy vegetables, with market gardening predominating. These results are consistent with those of Kanda et al. (2009), who showed in their research that the main source of leafy vegetables is market gardening. According to these authors, this type of supply helps maintain the diversity of leafy vegetables.

The survey results showed that 100% of families are familiar with leafy vegetables. According to Dongmo et al. (2005), the diversity and knowledge of leafy vegetables are linked to consumer demand and, in particular, to the great diversity of cultural communities.

The average consumption frequency of leaves per week per individual in this study area is two to three times per week. This consumption frequency is higher than the consumption frequency observed by Konan et al. (2015) who showed that the consumption frequency of leafy vegetables per month per individual in Abidjan and Bouaké was five times compared to 10 times in Korhogo. Certain factors can influence the consumption of leaves, including their availability, taste and ease of cooking. These observations were already mentioned by Dansi et al. (2008) during their work on Traditional leafy vegetables and their use in Benin Republic.

All the families surveyed consume these leafy vegetables prepared in a cooked state in the form of a sauce. A study by Agbankpé et al. (2014) carried out in Benin showed that leafy vegetables are prepared fresh or dried (powders) and then consumed as a side vegetable (sauce) or used as a herbal tea.

The survey results of this study also showed that 70% of the households surveyed obtain leafy vegetables by purchasing them at the market to be used for making food sauce. These results are different from those of Chweya and Eyzaguire (1999) who showed during their studies that some leaves are used for medicinal purposes and are only consumed to treat various diseases such as malaria, intestinal parasites, infections.

The physicochemical analysis of the different leafy vegetables revealed a great variability for most of the parameters studied. At the pH level, the values obtained range from 5.33 ± 0.82 to 5.90 ± 0.65. These results are different from those found by Yao et al. (2020) in leafy vegetables grown in Daloa which have higher pH values (6.22 ± 0.02 to 6.67 ± 0.01). This difference in results could be linked to the soil composition of Daloa which would be different from that of Man.

Regarding the moisture content, the analysis shows that the contents of the leafy vegetables studied are between 80.44 ± 0.97 % and 90.28 ± 1.68 %. The high moisture content of these products indicates that these leaves are very perishable. These results are consistent with those found by Dorosz (1999) who found values between 70 and 90 % in leafy vegetables.

The ash levels are higher than those obtained by Oulai et al. (2014) for *Amaranthus hybridus* (8.59 %) and *Ceiba pentandra* (25.67 %) consumed in the North of Côte d'Ivoire. Similarly, these results are lower than those of Prisacaru et al. (2017) who found ash contents of 2.82 % during their work on green leafy vegetables. The ash contents considered lower in this study turn out to be higher than the high values obtained by Yao et al. (2020) for the leafy vegetables studied (0.79 to 0.95 %). As such, the three leafy vegetables studied in this study can be considered as sources of minerals.

Regarding macronutrients, the study showed that the leaves of the city of Man are rich in lipids (2.06 ± 1.01 to 9.4 ± 0.71%). These values are higher than those reported by Ndong et al. (2007) in leafy vegetables (0.2 to 1 mg/100 g). Regarding carbohydrates, the leaves of the city of Man are very rich in carbohydrates and their values vary between 70.17 ± 0.15% and 80.14 ± 0.31%. These leaves, rich in carbohydrates and lipids, are sources of energy. These leafy vegetables contain fiber (2.75 ± 0.09 to 15.51 ± 0.21%). This richness of leafy vegetables in fiber could facilitate intestinal transit. The consumption of leafy vegetables is therefore of interest in promoting digestion.

Microbiological analysis of « pklala », « spinach » and « brombrou » leaves showed the presence of spoilage germs. Thus, the search for Total Aerobic Mesophilic Flora gave results ranging from 3.81.10³ to 6x10³ CFU/mL. Total Aerobic Mesophilic Flora is an indicator of the general level of hygiene of a product. This flora provides information on factors such as the environment, cross-contamination during handling, the environment, packaging and preservation of the product (Dossa, 2019). While these germs do not have a major impact on consumer health, they cause significant economic losses due to product spoilage. The Total Aerobic Mesophilic Flora contained in the leaves of this locality meets the standard, which is 5.105 CFU/g minimum.

**5. CONCLUSION**

The objective of this study was to characterize the most consumed leaves in the city of Man (Western, Côte d'Ivoire). Survey results showed that this city abounds in a multitude of leaves. The most consumed are « pklala », « spinach », and « brombrou ». The main sources of leafy foods produced in the city are the markets. Vendors of these foods are unaware of the proportions of components and their nutritional value. The study showed that the three leafy vegetable species studied in this study are used in human nutrition. These leafy vegetables are rich in lipids and carbohydrates, but also in fiber, and contain significant amounts of minerals (ash). Microbiological analysis revealed that these leaves contain total mesophilic aerobic germs. This study highlighted some compounds of nutritional interest contained in these leaves.

**Disclaimer (Artificial intelligence)**

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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