



Original Paper

Phytodiversity of Species Used to Prepare "Tchonron" Sauce, A Cultural Dish of The Senoufo People, Northern Côte d'Ivoire

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Abstract— The Sénoufo, a people from the north of Côte d'Ivoire, are renowned for their consumption of leafy vegetables, particularly in the little-known 'TCHONRON' sauce. The aim of this study is to draw up a list of the leafy vegetables used in the preparation of this dish, in order to enhance their value and contribute to the sustainable management of these plant genetic resources. To this end, an ethnobotanical survey was carried out among 640 Senoufo indigenous people, using a questionnaire. A total of 40 leafy vegetable species belonging to 28 genera and 20 families were identified. In fact, the most represented families are Solanaceae, Amaranthaceae and Asteraceae. The majority of these species are herbs (58%). Of these species, 25% are introduced (exotic); they are used as substitutes for wild leafy vegetables by the population in times of scarcity. On the other hand, introduced species contribute to the diversity of leafy vegetables used in the preparation of "TCHONRON" sauce. In addition, the leafy vegetables used to prepare this local product are dominated by Guinean-Congolese and Sudanese-Zambezian (GC-SZ) species, representing 55% of all species inventoried. This study reveals that the leafy vegetables used to prepare the "TCHONRON" sauce are diversified, and that the consumption of this sauce, a product of the Senoufo region, is not only cultural, but also contributes to the prevention of several diseases.

Keywords— Côte d'Ivoire, Diversity, Leafy vegetables, Local product, Senoufo people

I. INTRODUCTION

In Africa, plants are local natural resources of great importance to human life and biodiversity [1]. In fact, to satisfy our many health and nutritional needs, we appeal to our immediate environment on which our survival depends [2–5]. Plant resources play an important role in the daily lives of rural populations [6,7]. In addition to cultivated plants, many little-known wild plants are of great socio-cultural importance and have nutritional and therapeutic properties [4,8,9]. The interest in the use of plant species by local populations can be explained

by the fact that some of these plants, which have therapeutic properties, are first and foremost, or for the most part, food plants [8,10]. Leaves, fruit, seeds and roots are the most widely consumed and used in the preparation of sauces. However, the organic nature of these leaves is of real interest to consumers in both rural and urban areas [4,11]. In addition to their importance, leafy vegetables are of considerable social and economic interest due to their relatively low cost, ease and speed of preparation, as well as their ability to reduce poverty and generate income in a relatively short space of time [8,11,12]. These useful plants are widely used in the modern and rural economy, as well as in traditional pharmacopoeia [13,14].

In Côte d'Ivoire, leafy vegetables do not generally feature prominently in people's diets [2]. However, they are extremely important for rural populations and especially for urban populations condemned to industrial foodstuffs. In addition, the Senoufo people are well known for their consumption of leafy vegetables, particularly in the 'TCHONRON' sauce, which they love [6,15]. Thanks to their high nutritional value, the leafy vegetables used in this dish combat and prevent metabolic diseases [15]. The potential of these leafy vegetables is an effective resource for managing the double nutritional burden from which Côte d'Ivoire suffers, marked by the galloping progression of malnutrition and metabolic diseases. Despite this importance, the threat of the disappearance of food plants, mainly due to changes in land use, pollution and climate change, is still very real [8,16,17], the question of availability and knowledge of these leafy vegetables in the savannah zone of Côte d'Ivoire remains a challenge [17]. In these areas, the best-known species are spared, while lesser-known species are not [8,17].

So far, ethnobotanical studies in Côte d'Ivoire have focused on inventories of food and medicinal plants and their therapeutic use in certain regions, such as the Fromager region and others [14,18,19]. However, all these publications provide no

information on the use of food plants by the Sénoufo. In addition, there is very little information on the availability and diversity of food plants in the north of the country [15,17]. In particular, those used to prepare the ‘TCHONRON’ sauce, many of which are neglected, forgotten or destroyed, especially in urban areas.

This work was undertaken with the aim of contributing to a better understanding of the leafy vegetables used in the preparation of the ‘TCHONRON’ sauce, in order to enhance their value and participate in the sustainable management of these plant genetic resources in the north of Côte d’Ivoire. The aim is to (i) list the different leafy vegetables used in the preparation of ‘Tchonron’ sauce and (ii) determine the biogeographical characteristics of these different leafy vegetable species.

II. MATERIALS AND METHODS

A. Study Area

The study was carried out in four savannah regions (Bagoué, Hambol, Poro and Tchologo) in northern Côte d’Ivoire (Figure 1).

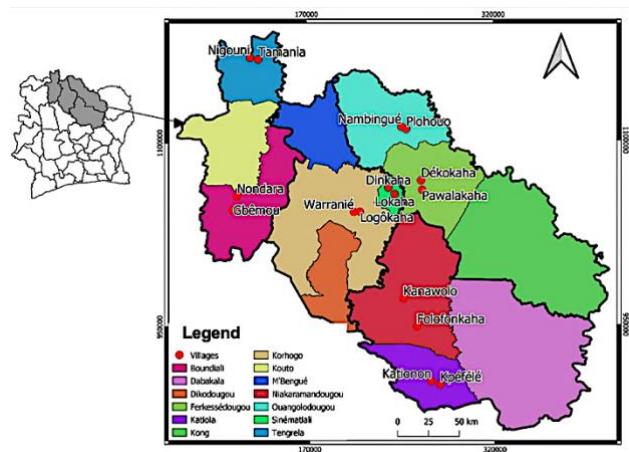


Fig. 1. Presentation of study area

The Savannah District (Bagoué, Poro and Tchologo), covering an area of 40,323 km², had a population of 1,607,497 in 2014 [20]. The climate is Sudanese, with two seasons dominated by a long dry season marked by the harmattan, which peaks between December and January [21].

The Hambol region straddles the divide between the Baoule climate (to the south) and the Sudanian climate (to the north), with the Sudanian climate predominating. The Hambol region covers a total area of 19,122 km². The population is estimated at 429,977 [20]. The above-mentioned regions are home to the indigenous Senufo populations of Côte d’Ivoire.

In addition, on the basis of a survey and literature review, eight departments were randomly selected, two from each region. Within each department, two villages were also randomly selected. The chief town of each department was chosen for urban areas. In all, eight towns and sixteen villages were visited for the survey, making a total of 24 localities (Table I).

TABLE I. LIST OF SURVEYED LOCALITIES BY REGION

Region	City or department	villages
Bagoué	Boudiali	Nondara Gbêmour
	Tengrela	Nigouni Tamania
Hambol	Katiola	Kationon Kpéfélé
	Niakaramandougou	Folofonkaha Kanawolo
Poro	Korhogo	Logokaha Warranié
	Sinématiali	Dinkaha Lokaha
Tchologo	Ferkessédougou	Dékokaha Pawalakaha
	Ouangolo	Plohoun Nambingué

B. Target Population

The survey took place in northern Côte d’Ivoire, among the Gour group. This group is mainly made up of three ethnic groups (Koulango, Lobi and Sénoufo). For this study, only the Sénoufo were interviewed. They are spread across four northern regions (Bagoué, Hambol, Poro and Tchologo). They originate from these regions and are generally attached to the ‘‘TCHONRON’’ sauce, especially the elderly.

C. Determining Sample Size

The sample size was calculated using the method described by Dagnelie [22] :

$$n = t^2 \times \frac{p(1-p)}{m^2} \quad (1)$$

with n = required sample size, t = 1.96 at the 95% confidence level, m = margin of error of 3.875%. In this work, the estimated proportion p of the population is 50%.

A representative sample of 640 people was thus obtained. A total of 640 people were interviewed, evenly distributed with 160 respondents per region.

D. Collection of Data

An ethnobotanical survey was carried out in the four selected regions, using a pre-established questionnaire. It took place between October 2019 and September 2021. The questionnaire was administered to 640 people. The respondents were all women, with the exception of a few men with in-depth knowledge of the subject. Respondents were randomly selected from various locations (markets, households, streets, fields), with the exception of men. The broad lines of the interview consisted in listing the different leafy vegetables used to make the ‘‘TCHONRON’’ sauce, their taste and the pathologies treated. Communication took place in the official language (French) or in the local language (Dioula, Tcheibara or Tagbanan), depending on the respondent's command of the language.

E. Data Processing

Survey data were processed using EpiData3.1 software. Recoding was carried out using SPSS 20.0 software to build up the database, then the data were transferred to EXCEL 2016 spreadsheet software. After botanical identification of the

different species at the Centre National de Floristique (CNF) of the Université Félix HOUPOUËT-BOIGNY, the data were grouped in tabular form and the percentages of the different parameters were calculated.

Floristic aspect

The raw results were subjected to two types of analysis, qualitative and quantitative. Qualitative analyses involved counting the total number of species, genera and families, vernacular names, biological types, chorological affinities, morphological and biological type. Quantitative analyses focused on specific diversity.

Citation frequency (CF)

The level of use of the species to prepare the "TCHONRON" sauce is expressed by the frequency with which each plant species is cited. This frequency is the number of times an item (plant) appears in lists of plants given by a respondent. The frequency of quotation makes it possible to estimate the credibility of the information received and the level of plant knowledge of the survey community (Kouakou et al., 2020; Ambé, 2001). This index also makes it possible to assess the veracity of the information received, especially concerning food plants. The frequency of citation of a species (FC) is given by the following formula:

$$CF = \frac{n \times 100}{N} \quad (2)$$

with n: the number of respondents citing the plant; N: the total number of people interviewed during the survey in a given area.

The species are then divided into the following classes:

1. $0\% \leq FC \leq 25\%$; little-used species;
2. $25\% \leq FC \leq 50\%$, moderately used species.
3. $50\% \leq PC \leq 100\%$, highly used species.

Diversity estimation

a) Shannon-Wiener and Piélou equitability indices

The Shannon-Wiener index was used to estimate diversity, taking into account the number of leafy vegetable species consumed and their proportion or abundance in the different regions. The formula for the Shannon index is as follows [23] :

$$H' = \sum_{i=1}^s -\left(\frac{n_i}{N}\right) \times \ln\left(\frac{n_i}{N}\right) \quad (3)$$

with n_i : the number of time a species has been cited in a given region ; ranging from 1 to s (total number of species) and $N = \sum n_i$ to appreciate the diversity of leafy vegetable species used in the preparation of the "TCHONRON" sauce.

The Shannon-Wiener index was accompanied by Piélou's [24] equitability index. It reflects the degree of diversity achieved in relation to the theoretical maximum [25]. It is the ratio of the Shannon-Wiener index (H') to the maximum theoretical index in a region (H_{max}). This index can vary from 0 to 1. It is maximum when all leafy vegetable species in a region have the same frequency of use in the preparation of "TCHONRON" sauce. It is minimal when a single leafy

vegetable species dominates all the leafy vegetables used. It is expressed by the following formula:

$$E = H' / H_{max} = H' / \ln(S) \quad (4)$$

b) Jaccard similarity index

Jaccard's similarity index [26] was used to calculate the similarity rate between the different regions in order to build a similarity matrix. It was calculated using the following formula:

$$S_j = N_{xy} / ((N_x + N_y) - N_{xy}) \quad (4)$$

with N_x : the number of species in region x; N_y : the number of species in region y; N_{xy} : the number of species common to regions x and y.

F. Statistical and Data Analysis

Two types of statistical analysis were used in this study. Descriptive analyses (graphs and tables) and inferential analyses (one-factor analysis of variance) were carried out using XLSTAT software, version 2014. Descriptive statistics were used to translate the uni- and bi-variate data into graphs, means and proportions with standard deviations. The analysis of variance (ANOVA) test was used to compare the values of the Shannon-Wiener and Piélou equitability indices. The normality of the distribution of the data and the equality of the variance were checked using the Shapiro-Wilka and Levene tests respectively, before carrying out the ANOVA test. The ANOVA was then completed by the Tukey test, when it showed a significant difference. This test shows which means differ from each other. These tests were performed at the 5% threshold.

III. RESULTS AND DISCUSSION

A. Richness and Floristic Composition of the Species Used to Prepare "TCHONRON" Sauce

During this study, 40 plant species belonging to 28 genera and distributed within 20 families were listed. They have been identified as used in the preparation of the "Tchonron" sauce. The most represented families are Solanaceae (7 species or 17.5%), Amaranthaceae (6 species or 15%), Asteraceae (4 species or 10%) and Cucurbitaceae with 3 species or 7.5%.

The number of leafy vegetable species obtained in this study is roughly equal to that obtained by Yao *et al.* [6] in their study on the contribution of leafy vegetables to population nutrition in urban areas of Côte d'Ivoire. However, in this study, only the leafy vegetables used in the preparation of the "TCHONRON" sauce were taken into account, unlike the studies by Yao *et al.* [6] which concerned all leafy vegetables consumed by the population surveyed. Nevertheless, the number of species (40) used to make this dish is impressive and shows the importance of this dish in Senoufo culture. There are also many other leafy vegetables that we encountered, but which did not attract any interest in our present study. This could be explained by the fact that the number of towns visited in our study is greater than those covered by Yao *et al.* [6] to which villages were added. In the

latter's studies, he also revealed that Solanaceae and Amaranthaceae are the most represented families, with more species consumed as leafy vegetables.

TABLE II. NUMBER OF GENERA AND SPECIES PER FAMILY USED TO PREPARE "THONRON" SAUCE

Family	Number of genera	Number of species
Solanaceae	2	7
Amaranthaceae	2	6
Asteraceae	3	4
Cucurbitaceae	3	3
Fabaceae	2	2
Malvaceae	1	2
Moraceae	1	2
Portulacaceae	2	2
Acanthaceae	1	1
Araceae	1	1
Asclepiadaceae	1	1
Brassicaceae	1	1
Cleomaceae	1	1
Convolvulaceae	1	1
Euphorbiaceae	1	1
Limaniaceae	1	1
Moringaceae	1	1
Nyctaginaceae	1	1
Onagraceae	1	1
Passifloraceae	1	1
Total	28	40

Floristic composition of the species used to prepare "TCHONRON" sauce

Considering the morphological forms, 58% of the leafy vegetables used for preparation of the "TCHONRON" sauce are herbaceous. They are followed by lianas and shrubs with the same percentage of 18%. Shrubberies represent only 8% of the species used for the preparation of "TCHONRON" (Figure 2). Our results are in agreement with those of Agbankpé et al [27] and Yao et al. [6] who consider that the preponderance of herbaceous species is a characteristic common to the different savannah formations. Moreover, the most represented families (Solanaceae, Amaranthaceae, Asteraceae) are mainly grasses.

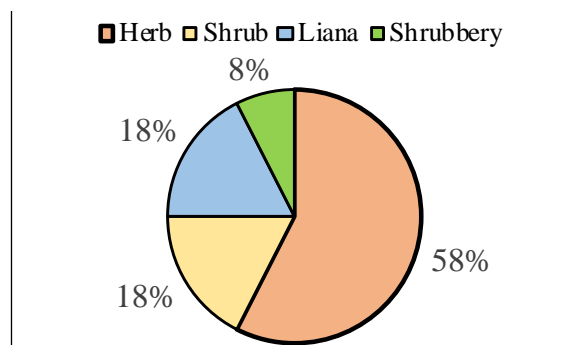


Fig. 2. Spectrum of the different biological forms of the plants used to prepare the "TCHONRON" sauce

Regarding the biological types of leafy vegetable species, 62.5% of these species are perennial plants and the most dominant, unlike annual species which represent only 37.5% of the leafy vegetable species used by the population in preparation of "TCHONRON" sauce (Figure 3).

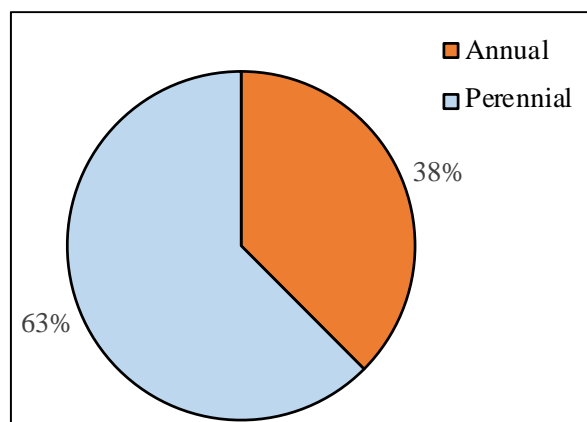


Fig. 3. Breakdown of species used to prepare "TCHONRON" sauce by biological type (perennial or annual)

In terms of phytogeographical distribution, leafy vegetables used to prepare "TCHONRON" sauce are of diverse and varied origin. The percentage distribution of phytogeographical types encountered during our survey by world is shown in figure 4. Pantropical species, with a percentage of (33%), are the most preponderant, followed by African species, which account for (30%) of the species used in preparation of "TCHONRON" sauce. Our observations concur with those of Bikandu *et al.* [28], who point out that the preponderance of GC-SZ species is a feature common to the different formations of the Sudanian savannah.

Figure 5 specifies the distribution of leafy vegetable species on the African continent. The leafy vegetables which make the transition between the Guinean-Congolese and Sudano-Zambézi phytogeographical regions (GC-SZ) are the most represented among the various leafy vegetables used for the preparation of the "TCHONRON" sauce with a total of (55%). By the same chorological affinity, introduced leaf vegetable species (i) occupy second place with a representation of (25%) and are followed by Guinean-Congolese (GC) which totals (15%) leaf vegetables. The relatively low percentage is that of the Sudano-Zambezi species (SZ) which represents (5%) of the leafy vegetables used. Our results are in line with those of Agbankpé et al. [27] and Yao *et al.* [6], who consider that the preponderance of herbaceous species is a feature common to different savannicultural formations. Moreover, the most represented families (Solanaceae, Amaranthaceae, Asteraceae) are mostly herbs. In addition, this phytogeographical region is home to transitional Guineo-Congolese and Sudano-Zambézi (GC-SZ) species, which account for 55% of the leafy vegetables used to prepare "TCHONRON" sauce. Our observations concur with those of Yao *et al.* [6], who point out that the preponderance of GC-SZ species is a feature common to the different formations of the Sudanian savannah.

B. Characteristic of the species used to prepare the "TCHONRON" sauce

The populations of northern Côte d'Ivoire consume more traditional leafy vegetables for taste and health benefits. Of all the leafy vegetables collected, 77.5% were identified by local populations as leafy vegetables with a neutral taste (Annexe). They represent the largest proportion. In second position, we have leafy vegetables with a bitter taste whose proportion is

(12.5%), followed by acidulated with a rate of 5%. Finally, salty and spicy leafy vegetables with a percentage of 2.5% each (Figure 6).

Of the 40 leafy vegetables listed, 52.5% are grown in market gardens, home gardens and fields. They are followed by wild or spontaneous leafy vegetables, of which only 40% are harvested. Cultivated/wild leafy vegetables account for the smallest proportion, 7.5% (Figure 7).

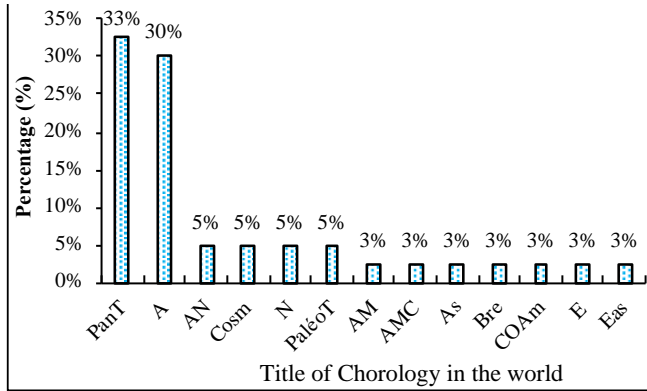


Fig 4. Worldwide chorological spectrum of species used to prepare "TCHONRON" sauce

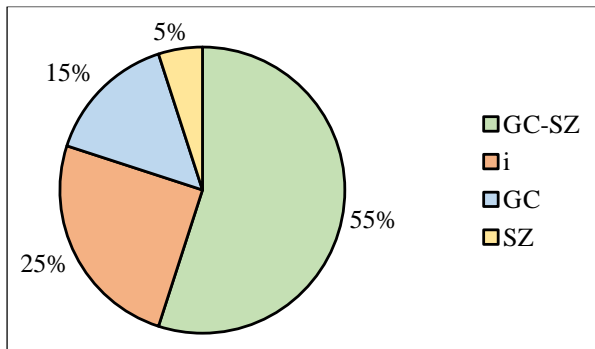


Fig. 5: Chorological spectrum according to Africa of the species used to prepare the "TCHONRON" sauce

*Legend: SZ: Sudano-Zambezi species; GC-SZ: Guineo-Congolese and Sudano-Guinean; SZ: Sudano-Guinean species; i: introduced species; GC: Guinean-Congolese species.

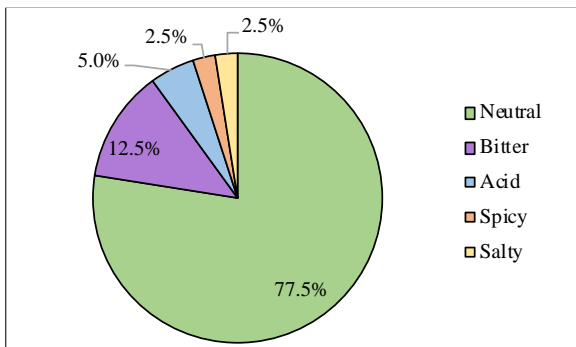


Fig. 6: Circular diagram of the proportions of the flavors of leafy vegetables used to prepare the "TCHONRON" sauce

Investigations enabled us to identify 40 leafy vegetables used by the Senoufo people to prepare this sauce. The number of leafy vegetable species obtained in this study is roughly equal to that obtained by Yao *et al.* [6] in their study on the

contribution of leafy vegetables to population nutrition in urban areas of Côte d'Ivoire. However, in this study, only the leafy vegetables used in the preparation of the "TCHONRON" sauce were taken into account, unlike the studies by Yao *et al.* [6] which concerned all leafy vegetables consumed by the population surveyed. Nevertheless, the number of species (40) used to make this dish is impressive and shows the importance of this dish in Senoufo culture. There are also many other leafy vegetables that we encountered, but which did not attract any interest in our present study. This could be explained by the fact that the number of towns visited in our study is greater than those covered by Yao *et al.* [6], to which villages were added. Furthermore, in this study, around 48% of the leafy vegetables inventoried were wild, unlike those of Yao *et al.* [6], who obtained only 26% wild species. This may be due to the fact that village populations have more opportunities to acquire wild leafy vegetables, as they are in direct contact with wild species. As "TCHONRON" sauce is a local product of the Senoufo people, the species used to make it would undoubtedly be of wild origin. However, 25% of introduced species are used as substitutes for wild leafy vegetables by the local population (Figure 6). The aim is to perpetuate this cultural value, handed down by our ancestors in the face of the scarcity of certain local species. In the same context, the population uses leafy vegetables from market gardening to overcome the lean period during drought [29]. It's a kind of resilience strategy for the Senoufo people in the face of climate change.

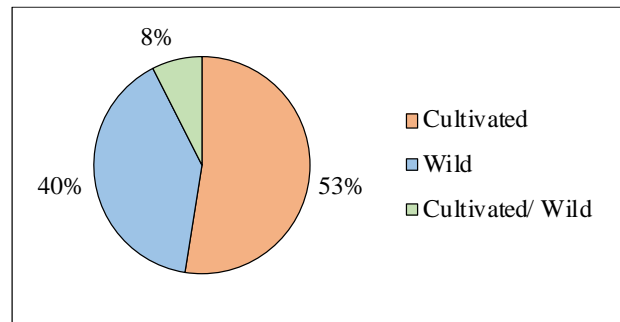


Fig. 7: Diagram of the distribution of the percentages of the status of the leafy vegetables used to prepare the "TCHONRON" sauce

C. Therapeutic uses of leafy vegetables used for the preparation of "TCHONRON" sauce

The populations of northern Côte d'Ivoire consume more A total of 17 illnesses were listed according to the frequency with which they were cited (Figure 8). Consumption of the leafy vegetables used to prepare "TCHONRON" sauce helps to alleviate certain illnesses, the most frequently cited of which are malaria and anaemia, with a proportion of (22.5%) each. These are followed by diabetes, diarrhoea, hypertension and gastrointestinal infections with a rate of (17.5%) per condition. Other The other pathologies are less cited. Our results are in line with those of Yao *et al.* [6] and Hadonou-Yovo *et al.* [7] who state that leafy vegetables are only consumed to treat various illnesses such as malaria, anaemia, infections, etc. This is explained by the fact that, in dietary terms, these leafy vegetables make a major contribution to balanced diets and improved consumer health. This medicinal usage is therefore an added value for the consumption of these leafy vegetables.

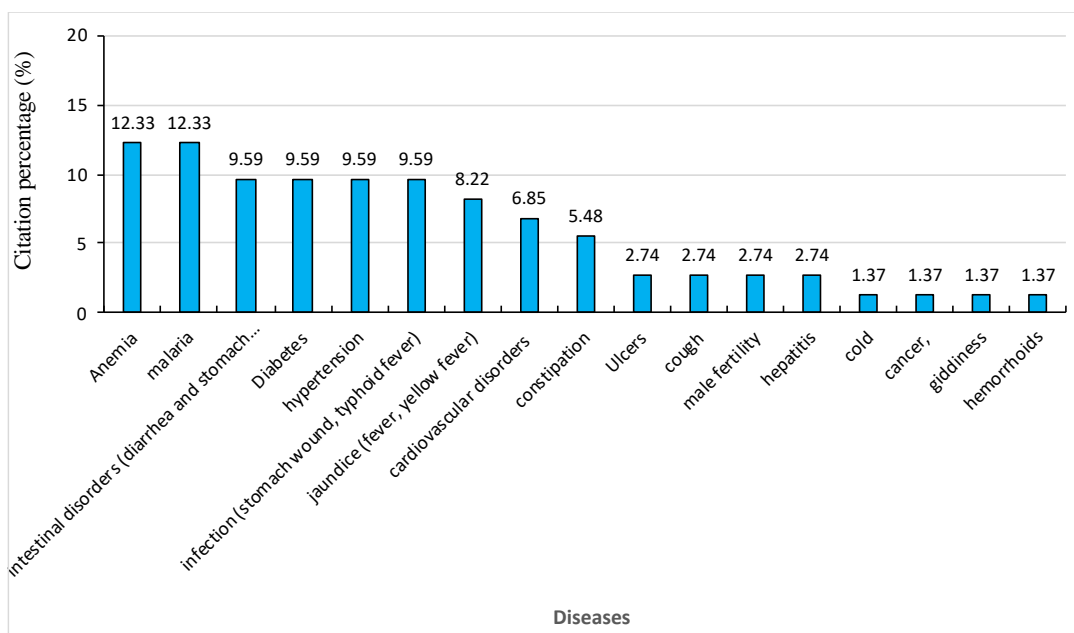


Fig. 8: Diagrams of distribution of leaf vegetable citation frequencies according to the conditions treated

D. Specific diversity of species used to prepare TCHONRON sauce

Shannon-Wiener (H') and Pielou equitability indices (E) of the different regions have been compiled in Table 2. The calculated Shannon indices vary from one region to another. The highest diversity value is 3.388 ± 0.051 and is observed in the Hambol region. Unlike the Hambol region, the Tchologo region records the lowest diversity index with a value of 2.957 ± 0.077 . The Poro and Bagoué regions show average diversity. With regard to the equitability index which emphasizes the distribution of leafy vegetables used for the preparation of the "TCHONRON" sauce in the regions, it should be noted that all the regions have a fairness index close to 1 (Table 2). This reflects a homogeneity in the distribution of these leafy vegetables in each region ($P = 0.48$ and $F = 8.76$). The similarity matrix reveals similarities in the use of certain leafy vegetables in "TCHONRON" sauce between several regions. The lowest rate of similarity (46.15%) is obtained between the populations of the Tchologo and Hambol regions. However, the highest similarity rate (68.75%) was observed between of Hambol and Poro populations.

Furthermore, the low use of wild leafy vegetable species is due not only to the cultural expression that disappears with modernization, but also to the transformation of natural areas into cultivated zones, during which spontaneous plants are not spared. This situation has contributed to the degradation of biodiversity and the low number of spontaneous food plants in Côte d'Ivoire [6,14]. The development of market gardening in both urban and rural areas is increasing the number of leafy vegetable species consumed. This justifies the high values of the Shannon indices (3.160 ± 0.066). Unfortunately, the expansion of market gardening in this savannah zone is reducing the consumption of wild leafy vegetables, to the benefit of market-grown leafy vegetables, which are available at any time of year. As a result, wild leafy vegetables are rare, little known and consumed infrequently.

The similarity matrix reveals similarities in the use of certain leafy vegetables in "TCHONRON" sauce between several regions. The lowest rate of similarity (46.15%) is obtained between the populations of the Tchologo and Hambol regions. However, the highest similarity rate (68.75%) was observed between of Hambol and Poro populations (Table 3).

It's true that ethnobotanical survey results have shown a diversity of leafy vegetables used in the preparation of "TCHONRON" sauce, but the fact that cultivated leafy vegetables dominate those in the wild should be a major concern. However, the Shannon indices calculated vary from region to region. This is explained by the fact that people have their own preferences and choices based on a number of parameters, such as taste. Eating behavior depends on a variety of sensory factors, but biochemical ones are predominant (Pénicaud & Brondel, 2022). The morphological type that dominates among the species used in the preparation of "TCHONRON" sauce is grass. It accounts for 58% of the leafy vegetables used to prepare this sauce.

TABLE 2. AVERAGE VALUES OF THE SHANNON-WIENER AND PIELOU EQUITABILITY INDICES BY REGION

Region	Shannon Index (H') \pm Standard Deviation		Pielou equitability index (E) \pm Standard deviation	
Tchologo	2,957	\pm 0,077 ^c	0,930	\pm 0,024 ^a
Bagoue	3,102	\pm 0,070 ^b	0,976	\pm 0,022 ^a
Poro	3,195	\pm 0,065 ^b	0,969	\pm 0,020 ^a
Hambol	3,388	\pm 0,051 ^a	0,961	\pm 0,015 ^a
Statistical parameter of ANOVA ¹				
df	3		3	
F	22,20		8,76	
P	< 0,001		0,48	

¹df : degree of freedom; F: statistical value of the ANOVA test; P: p-value, the probability of the ANOVA test

TABLE 3. JACCARD'S SIMILARITY MATRIX (%) OF REGIONS

	Bagoue	Hambol	Poro	Tchologo
Bagoue	100			
Hambol	51,52	100		
poro	60	68,75	100	
Tchologo	50	46,15	51,35	100

IV. CONCLUSIONS

are major consumers of leafy vegetables. It also identified 40 species of leafy vegetables used in the preparation of the "TCHNORON" sauce. Of these leafy vegetables, 52% were cultivated, compared with 40% spontaneous, which highlights the threat of extinction hanging over spontaneous plants if nothing is done to promote and popularize these indigenous species. It's worth noting that the majority of these leafy vegetables have a neutral taste, which facilitates their acceptance by the population. In Senoufo country, the consumption of "TCHONRON" sauce is not only cultural but also preventive against various ailments. Indeed, the leafy vegetables used to prepare the "TCHONRON" sauce play an essential role in households and in the treatment of certain ailments. Faced with the problem of transcendental metabolic diseases, this study is just one stage in a scientific approach to better knowledge of the "TCHONRON" sauce, which will continue with the effective valorization of the nutritional and therapeutic potential of the leafy vegetables used in its preparation, but particularly of spontaneous leafy vegetables. In this sense, it would also be beneficial to deepen research into the phyto-chemistry of some of the spontaneous leafy vegetables used to prepare "TCHONRON" sauce, in order to identify the secondary metabolites responsible for the active principles that improve consumer health. In this way, we can achieve one of the objectives of the World Health Organization (WHO), which is to promote not only plants with nutritional and therapeutic potential, but also a healthy diet for effective public health.

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