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Participatory Ethnobotany in indigenous health: study conducted by a Pataxó Hãhãhãi ethnobotanist among his people, Brazil

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Abstract

Background The traditional medicine of the indigenous Pataxó Hãhãhãi (PH) people, Brazil, is in jeopardy because of the significant fragmentation of their biological and cultural aspects. In addition to providing plants that can treat the complaints that these people face, the current endeavor has attempted to retrieve and document their traditional and local medicine, which is nearly forgotten.

Methods Using the Participatory Ethnobotany approach, Pataxó Hãhãhãi, H.D.S. (author), an indigenous person who lives in the PH territory, led the project from outlining the objectives with his people to fieldwork. It was collectively decided to focus on the plants involved in the three most common complaints of the PH people: diabetes, worms, and hypertension. The plants recommended by the experts were collected, and data on their traditional and academic knowledge were compiled.

Results The Participatory Ethnobotany approach proved to be effective, as it facilitated impacts on several phases of the work. The 175 medicinal plants, as well as their ancient healing practices indicated by 19 experts, were recovered and registered. Forty-three species were indicated for those complaints, and 79% of them supported their use in the scientific literature.

Conclusion In an unprecedented way, an indigenous ethnobotanist retrieved and documented the plants and medicinal practices of his people, which were subjected to many attacks and fragmentations over the years. People learned about the recovery of plants for their three primary illnesses, making their use safe and efficient.

Keywords Pataxó Hãhãhãi, Participatory Ethnobotany, Indigenous medicine, Indigenous people

Background

The Pataxó Hãhãhãi (PH) people comprise diverse ethnic peoples with subtly distinct cultures, including Baenã, Pataxó, Hãhãhãi, Kamakã, Tupinambá, Kariri-Sapuyá, and Gueren [1]. There are approximately 3,608 individuals divided among 10 villages [2]. Located in the Caramuru Paraguassu Indigenous Territory (TI), southern Bahia, it has a current land area of 54,105 hectares [3].

They have a long history of cultural interactions with nonindigenous cultures. These interactions date back to the first contact with the state and notably occurred when the former Indian Protection Service (SPI)[1] was present in the region in approximately the 1920 s, as documented

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[1] The SPI is a federal agency created in 1910 whose mission was to protect indigenous people. The SPI was replaced by the National Indian Foundation (FUNAI) in 1967. Since 2023, FUNAI has been called the National Foundation for Indigenous Peoples.

by Carvalho et al. [4], Jacobina [5] and Paraíso [6]. After this contact, religious catechesis and other aspects of nonindigenous culture led to the fragmentation of crucial elements of the Pataxó Hãhãhãi culture, such as the language, spiritual practices and the conception of the *"Spirits of Light"*.[2] During that period, new diseases and diets that were unknown given the practices of the indigenous people were introduced, along with the loss of human life and the dissolution of families.

However, even before the arrival of the SPI in the 1920 s, Pataxó Hãhãhãi already inhabited and preserved its culture in this region. The oldest records of the ancestral existence of these indigenous people consist of funerary urns made of clay that were molded in the shape of pots and adorned with engravings on the edges, which date back approximately 600 years [7].

The oldest members of the indigenous community, as noted by Souza [8], reported that, after being expelled from their lands in 1948 and returning to the TI in 1982, the few indigenous people who still remained in the villages were forced to work for the invaders (*grileiros*). Several areas of the villages had been deforested by *grileiros*, who had transformed large portions of this native forest into pasture. These changes profoundly impact indigenous culture, resulting in the loss of many medicinal plants that were once abundant in this region.

Among PH indigenous people, most elders have knowledge about the use of medicinal plants, and although many previously native plant species are no longer found in the village, they learned how to use the newly introduced and exotic plants they encountered outside their village. Currently, traditional medicine is rarely used, especially among younger people who, when diagnosed with a disease, use synthetic medications as the main method of treatment.

Therefore, the aim of the present study was to retrieve and record the traditional and local medicine of the Pataxó Hãhãhãi people through the Participatory Ethnobotany approach by an indigenous person representative of these people (the author Pataxó Hãhãhãi, HDS). By using this approach, it became possible to support a project that truly met the needs of his people and, at the same time, contribute to the controversial international debate on intellectual property rights; that is, to the extent that indigenous peoples are able to document their knowledge in their own languages, they will be able to make decisions about what to do with it independently.

In addition, as collectively decided, this work also addresses plants involved in the three most common complaints that PHs currently face: diabetes, worm infestation, and hypertension, as well as to identify effective and safe ways to resume the use of these plants.

Methods

Ethical authorizations

Sixteen months were needed to obtain all the authorizations and/or records relevant to this project. Thus, before starting this study, the following legal steps were followed. (i) Submission to the Research Ethics Committee of the Federal University of São Paulo (CEP/UNIFESP), under number 4,286,316. (ii) Approval of the project and the Free and Informed Consent Form (ICF) by the National Commission for Ethics in Research (CONEP), with no. 4,416,365 and CAAE 33473120.7.0000.5505. (iii) Registration for the publication of data generated from this project in the National System for the Management of Genetic Heritage and Traditional Knowledge (SISGEN) under registration code ACDC680. (iv) A collection registry was established in the Biodiversity Authorization and Information System (SISBIO) with no. 81700–1 for the collection and transport of biological materials (plants).

Finally, all authorizations and declarations relevant to the execution of this project were requested, the necessary approvals were granted, and National Foundation for Indigenous Peoples (FUNAI) was responsible for granting the last authorization that allowed access to and the start of field activities in the TI. FUNAI authorization of the researcher to access the indigenous land took approximately 11 months, even though the researcher belongs to this group of people and resides in the research territory.

Participatory Ethnobotany

In the previous studies, we defined Participatory Ethnobotany as a research approach that places the community at the center of the entire process, from the definition of study objectives, study design, interviewee selection, registration of traditional knowledge, analysis and publication of recorded knowledge [9]. Using this approach, community members are trained from botanical and anthropological points of view, allowing them to conduct ethnobotanical surveys, including the collection of plants and records of the knowledge associated with them, with the technical support of the academy for taxonomic identification. The aim of this approach is to enable the community to better understand and use local resources. Thus, Participatory Ethnobotany encourages

[2] The"Spirits of Light"is described in Pataxó Hãhãhãi culture as a"gift given by God."It is a"spiritual knowledge"which allows PH to find solutions in nature itself to cure diseases. However, the"Spirits of Light"need care and attention through spiritual practices to aid in the healing processes. The lack of care for these spirits creates distance between them and the individuals who possess them.

Fig. 1 The Caramuru village in the Pataxó Hãhãhãi indigenous territory. **a** View from the top of the mountain range in Caramuru village. **b** State college. **c** A cabin in front of the school. Source: author's collection, 2021

more inclusive research, strengthens community empowerment and promotes environmental sustainability [10].

In short, Participatory Ethnobotany is more than a participatory method; it considers indigenous people as ethnobotanists and not as mere participants.

The Pataxó Hãhãhãi people

The TI is home to different ethnic families, and each ethnic group or village is represented by a leader. Many indigenous people work in family agriculture and with dairy and beef cattle, goats and pigs. In addition, these indigenous people also work in some informal and/or formal services in the education, health and street commerce sectors of neighboring municipalities.

Within the territory, there is also a health clinic and a reference unit of the Secretariat of Indigenous Health (SESAI) in the city of Pau Brasil (approximately 4.0 km from Caramuru village (Fig. 1a)) with the capacity to provide primary health care for the indigenous people. There is one school (Fig. 1b) that serves all grades up to high school and technical education. There are also Christian and Catholic churches and indigenous huts (Fig. 1c) in the villages. The houses have piped water for domestic use, while drinking water is provided by SESAI, which occasionally uses water trucks to supply the homes of indigenous families. In addition, the indigenous groups have organized themselves into legal associations, to which they develop activities aimed at family farming, the management of fish farming, beekeeping, livestock, and the reforestation of lost forests.

The author of this study is able to speak about the knowledge of his culture, making recording this knowledge feasible, including in his own language when possible. As a researcher of the present study and a member of these people, the author can contribute internally in the discussions with the community. Even before the present study was conceived, there was motivation to develop a work that could in some way allow ancestral knowledge to add value to the healing practices. In addition to contributing data that could be used in a school environment, the results of this study could support the local health system by documenting the struggles of the Pataxó Hãhãhãi and inspire the young people from this community to immerse themselves in and understand even more aspects of their own culture.

Thus, the Pataxó Hãhãhãi leaders and elders were consulted to assess if there was a will to develop the present work that focused on the study of medicinal plants. With the approval and encouragement of the leaders of the indigenous community, the author then consulted health professionals in the village to identify the most commonly diseases that occur among the indigenous people. On this occasion (November 2019), the most common complaints at the community health center were hypertension, diabetes and worms. Next, data on traditional and local medicine, that is, the plants commonly used by indigenous people, were sought for these complaints. Data concerning the efficacy and safety of these plants were subsequently collected from the scientific literature. Since much of the knowledge on traditional medical practices was lost or altered when these people were evicted from their territory or when their territory was occupied, combining traditional and academic knowledge obtained in this manner could assist in supporting the efficacy and safety of these medicinal practices.

In addition to the plants involved in treating these three medical complaints, data on plants involved in the treatment of other diseases were also recorded during this study, totaling 175 species, contributing to the preservation of what remains of this traditional medicine; however, these data are not included in this publication.

Fieldwork

Field activities began in February 2022, one year and four months after all authorizations were obtained, and they concluded in November 2023, with a total of approximately 242 field days. In fact, the fieldwork took place every day, since the author is an indigenous person who lives in one of his people's villages. However, the interviewees who were experts about ancestral medicine were selected using the *snowball method* [11] on the basis of the indications of the indigenous people themselves. Some of these experts are widely recognized and respected among indigenous people because they have the ability to cure the most serious diseases that affect them, such as strong fever, respiratory diseases, snake bites and *wind diseases*.[3]

The ethnographic interviews were conducted with the 19 experts from the 10 villages, as shown in the saturation curve in Fig. 2. The researcher presented the questions, which were usually open-ended, and did not control the responses of the interviewees. Ideally, this type of interview should be used because the researcher had a substantial amount of time for fieldwork [11]. In the present study, the following two interview sheets were used: "Personal Aspects of the Respondents" (name, sex, age, from whom they learned about the use of plants, etc.) and "Ethnobotanical aspects" (name of the plant, part used, indication for use, method of preparation, route of administration, contraindication, etc.).

While information regarding the plants and their effects was being collected, ethnographic field methods and techniques, such as participant observation, notes in field diaries, and ethnographic interviews, were used [11, 13–15]. All these methods and techniques were performed by the researcher (Pataxó Hãhãhãi, HDS), who is a resident of Caramuru village. On average, three to four visits were made to the respondents, lasting between three and a half and four and a half hours each.

The periodical reports in the field diaries noted everything that was observed by the researcher at a given time in great detail [16]. Such annotations favor analyses between what was seen by the researcher and what was said and done by the interviewees regarding the particular use of a plant, expanding the possibility of analyzing and verifying the data collected during the study.

Botanical collection and taxonomic identification

Plant collection was preferably performed in the presence of the interviewee. When this was not possible, a sample of the plant species was presented to the interviewee for confirmation. Information regarding the geographical location of the plant was also recorded with the aid of a *Global Positioning System (GPS)* system. The plant samples were collected in triplicate by the wet method [17], which allows the plant material to be stored in the field for a longer duration without compromising its integrity. Newspapers saturated with 70% aqueous alcohol solution were used to collect the plants, which were then oven dried in the herbarium for three days at 60 °C.

After preparation, each sample was identified with the help of Professor Luiz Alberto Mattos (Systematic Botany) and herbarium technician Wagner Ferreira, both from the State University of Santa Cruz, Bahia. The scientific names were updated using the *Plants of the World* Database (https://powo.science.kew.org/).

Bibliographic survey

The plant species related to diabetes, high blood pressure and worms identified by taxonomists were the objects of a survey in the scientific literature published in the last 20 years. These studies verified the existence of pharmacological studies that supported the efficacy and safety of the identified species and whether they could be used to treat worms, diabetes and hypertension. In addition, to determine the geographical origin of each plant species, the Flora do Brazil (http://floradobrasil.jbrj.gov.br/), World Flora Online (http://www.worldfloraonline.org/),

[3] Wind sickness is related to cases of spills.

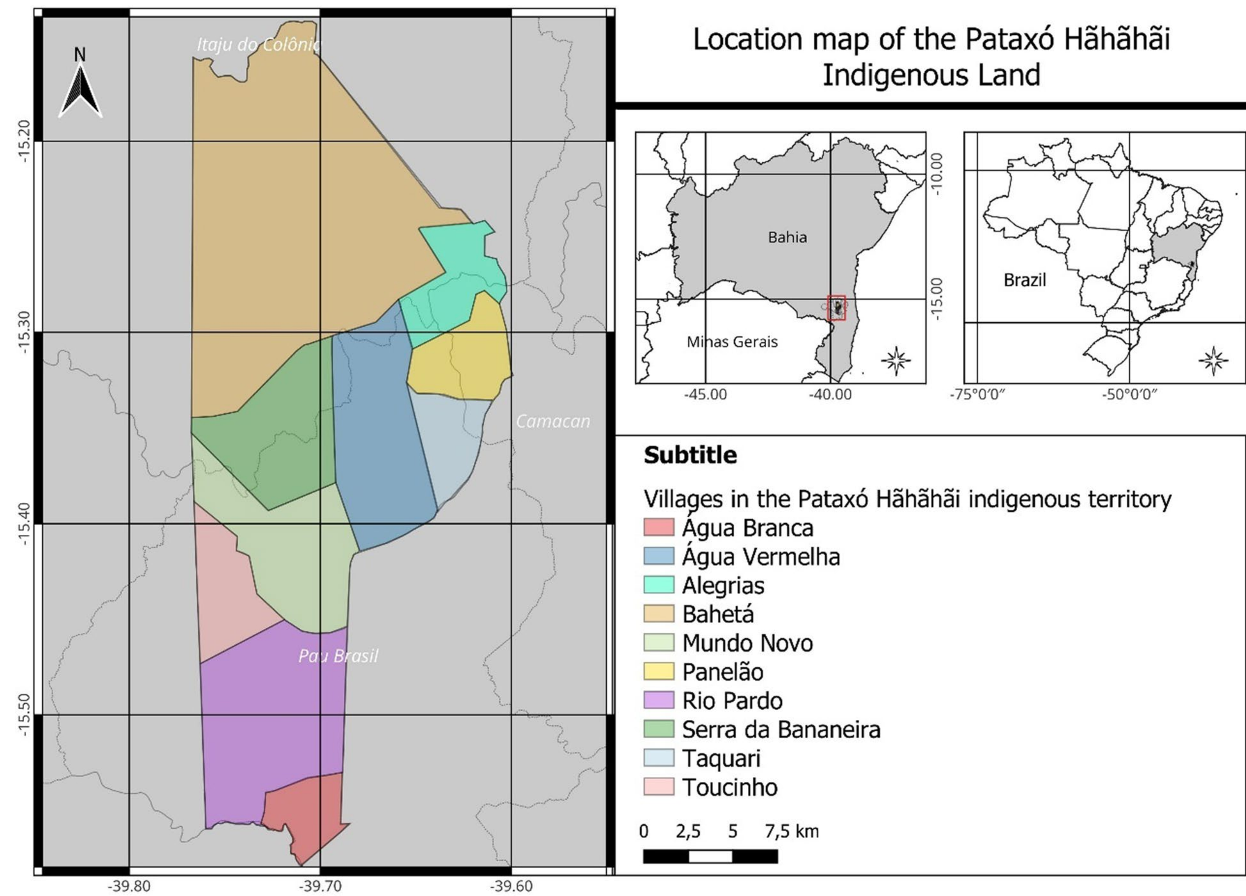

Fig. 2 Pataxó Hãhãhãi indigenous territory in the state of Bahia (BA), Brazil. The villages within the territory are marked. Source: adapted from [12]

and Missouri Botanical Gardens (http://www.mobot.org/) databases were consulted.

Scientific database searching was performed according to the Boolean search method with three terms referring to the scientific name of each species, *("genus") AND ("epithet") AND ("medicinal use")*, for efficacy study searches, and the term *"acute toxicity"* was also included for the safety study searches; for example, *"Aloe* AND *vera AND anthelmintic".* The inclusion criteria for the articles were as follows: (1) the scientific name was in the title of the article; (2) the article was written in English; (3) the article was published in the last two decades; (4) the article was a review article or original article; and (5) the study involved a pharmacological and/or toxicological investigation of the species in question.

Data analysis

Both the quantitative data, which were collected on the forms during the ethnographic interviews, and the qualitative data, which were recorded by participant observations and in field diaries, were analyzed and discussed with the community. The field diary notes were subjected to content analysis [18, 19], condensed and coded to facilitate the identification of thematic categories. Such quantitative and qualitative analyses were used for global data analysis, allowing inferences and interpretations to be made with the aid of descriptive statistics.

On the basis of the ethnobotanical data collected, graphical analyses were used to scale and visualize the patterns in the data on the medicinal plants retrieved from the literature, as well as to construct accumulation and rarefaction curves of the plant species via the *vegan* package in R Studio software (version 402).

Results and discussion

Participatory Ethnobotany approach

According to Chambers (1994), participatory research began to be accepted by academia only in the 1990 s, since most researchers were afraid to write about this approach, as they feared for their scientific credibility [20]. For participatory research to be acknowledged, a great deal of work was done globally by scholars, non-governmental organizations, and public policy since the 1970 s [21]. If in the 1990 s people questioned the "mystery" of why it took so long for the academic community to recognize the creative and analytical abilities of the indigenous peoples, how should we react when we realize that this "mystery" echoes to the present day? Stern (2019) alerts us to the fact that even today there is strong resistance on the part of some researchers to accepting participatory research involving local peoples [22]. Chambers (1994) reinforce this idea, reporting that beliefs, behaviors, and attitudes that demonstrate the superiority of outside researchers have the effect of causing local peoples to doubt their own capabilities [20].

The participatory approach still appears to be poorly understood and/or applied, despite some authors'efforts to demonstrate that knowledge from one culture cannot overlap with that of another culture because doing so would lead to"epistemicide."Additionally, these authors support the notion that no traditional society is knowledge-deficient [20, 22]. But this paradigm is changing, giving way to participatory research, which has gained ever-increasing recognition in recent decades [23–27].

Although some studies make significant contributions to participatory research, they do not involve locals in all phases of an ethnobotanical study. For example, in rural schools in Paso Viejo, Argentina, an ethnobotanical study connected children to local family knowledge, demonstrating the potential of ethnobotany to strengthen cultural identity. Despite community participation in workshops and trials, the objectives and systematization of the analyses were conducted by researchers from outside the local Community [28]. In the Yaegl Aboriginal community in Australia, a participatory action research project on medicinal plants was conducted. Local residents acted as co-producers, collaborating and validating the work at various stages. Although the research was conducted in a dynamic, flexible, and cooperative manner, the objectives and tools were initially defined by the research group [29]. In the ethnobotanical study in Boumba, Niger, the authors demonstrated strong cultural immersion by communicating in the local language and maintaining prolonged involvement with the community. They valued local knowledge with methodological flexibility adapted to the context. However, the objective and final analyses did not have local co-authorship [30]. Finally, Sharma et al. [31] demonstrated that women from indigenous communities in the Sub-Himalayan region consented to provide information on medicinal plants because a native researcher was involved, which made communication easier. However, the participation of local residents was limited to the field phase, with no involvement in problem formulation, objective definition, or analysis of results [31].

It is important to consider that locals have varied degrees of involvement and participation in these studies. "What has been the actual role of the local peoples in defining the goals of the work?", "To what degree have local peoples been involved in all stages of the development of participatory research?". Lastly, "To what extent have local people been encouraged to record their own knowledge as ethnobotanists and not only as "informants"?

The idea of Participatory Ethnobotany is in line with these discussions. As previously defined by us, this approach aims to go beyond the mere participation of locals in a study conducted by academic researchers. It considers members of a traditional population as ethnobotanical researchers. In this sense, it is much more than a participatory research methodology. Instead of merely having an outside researcher collecting data from the community through a key informant without attempting to equip the individual with the skills necessary to conduct their own research, analysis, planning, and coauthorship, it would be interesting to use participatory research in this instance to allow members of the traditional community to conduct scientific research [9].

Following the adoption of the guidelines established in the Nagoya Protocol, Ticktin et al. [32] and Etkin and Ticktin [33] also stress the importance of community members'active participation at every stage of the research process. They point out that co-research, which actively involves community researchers in all stages of work and publication, is more effective when conducted with the participation of local peoples and where the actors are not the object of study but actively participate in both research and returning the information to the original owners.

In order to achieve this approach, pilot studies [9, 34–37] were conducted together with two nonacademic Quilombola communities in the Atlantic Forest, Brazil. They were trained in cultural anthropology and botany methods so that they could carry out ethnobotanical studies with members of their communities, from the objective design until the data analysis.

This approach provided specific and innovative illustrations of a novel strategy centered on the growth of extensive collaborative ethnobotanical research. Another study, which comes closer to this approach, is the one conducted by Hitziger et al. [38] among Kaqchikel (highland) and Q'eqchi'(lowland) Mayans in Guatemala. The participation of local residents was not restricted to the field stage; they were involved in multiple phases of the research, including participant selection, methodological planning, data collection and validation, and adapted dissemination of the results.

The author and researcher of the present study (Pataxó Hãhãhãi, HDS) is an academic and an indigenous Pataxó Hãhãhãi person. His dedication to the Participatory

Ethnobotany approach is facilitated by his experience in both realities—the coexistence of university researchers and his everyday life in the indigenous hamlet with his family and ethnic relatives. One of the advantages observed is that since the researcher is a local member speaking among"relatives,"there is no fear of being"right or wrong"about a particular topic because, to the indigenous people, every member of a people is a relative; in fact, it is as though they are one large family. This approach also gives autonomy to the indigenous people in the development of research projects, enabling them to feel free to address the issues that most interest them. Another noteworthy observation was the absence of the indigenous pseudo-ignorance artifact, which Chambers [20] identified as stemming from external researcher's intellectual superiority complex in their behavior and attitudes.

Elders with knowledge of medicinal plants were therefore consulted in the many villages inside the 54,100-hectare indigenous region. The villages are situated relatively far apart from each other, and the fact that many of these elders reside in remote and hidden areas meant that it required considerable effort to access them, even for a local researcher. Because the study was planned with the interests of the community in mind, ancient people had little trouble providing information, and it was possible to observe that they have a wealth of knowledge and practical experience in healing as well as other important cultural areas such as food sovereignty, cultural identity, and spirituality. The researcher and interviewee spent dozens of hours sharing stories and experiences during the first interviews. As a result, it was possible to pay close attention to every word that each respondent said, regardless of their age, level of sentence construction complexity, or the length of time it took to finish each word. No distrust was observed between the interviewee and the researcher, given the critical role of trust in field research. Prior studies note that distrust can undermine data collection quality [39]. Nor was there any prejudice favoring external knowledge over ancestral wisdom—a bias that had previously occurred due to researchers'neglect, as noted by Chambers (1994) [20]. All participants recognized that the investigator, who listened attentively, was also co-author of the very events they described.

For the local researcher, recording the knowledge of his people is also a very important experience because it gives him the opportunity to learn more about his ancestors and his own culture. This is because simple interviews in scientific research can reveal many stories that are stored in the memory of each member of his people.

To contribute to other researchers in the development of Participatory Ethnobotany, the benefits and challenges of the current study are highlighted here.

1. Since the researcher is a member of the community and his family is well-known, the experts'loyalty and trust in him were established, negating the need for the first step of any fieldwork—the development of reciprocal trust.
2. The researcher's communication was also made easier because he is a representative of the people.
3. It is also easier to record the work using photographs and videos because these activities can be intimidating when done by people outside the culture.
4. The researcher always felt appreciated for the reasons listed above, with the exception of one interviewee who posed multiple questions on the work since, in the past, a non-indigenous researcher interviewed him and then disappeared without giving any feedback.
5. The researcher knew who the experts in therapeutic practices and medicinal plants were. Contact with them was made easier because they all knew his parents and grandparents.
6. Since few young people currently pay attention to ancient people, the researcher felt quite welcomed by everyone. They were happy to be heard since their knowledge was acknowledged. These discussions with the elderly were highly beneficial since they brought to their attention the long-forgotten history of herbs and therapeutic methods.
7. The outlining of the work objectives could be carried out by the people involved, according to their demands.
8. Because he lived in the area and had no interaction with people from other cultures, the researcher was able to conduct the study even throughout the COVID-19 outbreak, after social isolation ended.

One extremely beneficial outcome of the researcher's use of the Participatory Ethnobotany approach was his increased awareness of his own past. When elders were interviewed, this continued to happen. For instance, they talked of their grandfather, a highly revered and well-known leader among those people.

However, the researcher also faced challenges in developing this approach because he was part of the local community. The most challenging aspect of his position, in his opinion, was watching his people as an outside observer, as advised by anthropological methodologies. In this way, he found it challenging to record notes in his field diary regarding what might be pertinent because, to him, everything seemed familiar and commonplace. Reports from the author's (Pataxó Hãhãhãi, HDS) personal field diary are included below:

"How can I view the commonplace differently?

What would I find intriguing if I weren't from here? I made an effort to picture myself as someone from the"outside."It was a workout. In order to synthesize the concepts, I taped the interviews and listened to them multiple times. Because I had a lot of free time, I was able to review all of this and discover something new about what I already considered to be normal. Since I could listen to each recorded interview multiple times, I had time on my side. It was beneficial to me."

Another very interesting challenge was the fact that even though the researcher is an indigenous person and lives in the village where the study was conducted, it took almost a year for him to receive permission from FUNAI to enter the study area. This shows how difficult it is for Brazilian researchers to conduct research among indigenous people in Brazil, even if they are indigenous.

Finally, according to the aforementioned points, these experiences demonstrate that it is possible to train community members, irrespective of their educational attainment, to register their own traditional knowledge in order to empower their community with regard to the utilization of resources in their living environment and to ensure intellectual property rights over their own knowledge.

Table 1 Sociocultural characteristics of the 19 Pataxó Hãhãhãi interviewed

Characteristic	Percent of the 19 total indigenous people interviewed
Sex	
Male	47%
Female	53%
Age	
49–62 years	16%
63–75 years	47%
76–88 years	37%
Educational access	
Had access*	42%
Did not have access	58%
Occupation	
Family farmer	42%
Retired	58%
Source of knowledge	
Mothers and fathers	48%
Grandparents/elders	24%
Spirits of light	14%
Aunts and uncles	7%
Observations	3%
Other	3%

* In the Mobral programme or up to elementary school

The ancient traditional and local medicine of the Pataxó Hãhãhãi people and their healing practitioners

Nineteen medicinal plant experts were selected and interviewed. In addition to their knowledge of plants, six of them are referred to as prayers and are considered the current healing practitioners. They are widely acknowledged and revered by the indigenous people for their ability to treat the most severe illnesses that they face, including severe fever, respiratory conditions, snake bites, and *wind diseases,* because they could study and practice traditional medicine alongside the ancients.

The study included 19 interviewees (10 women and 9 men) aged 50 to 85 years, seven of whom were elderly (77–85 years old). Their accounts revealed substantial contrasts between past and present healing practices. As expected, elders played a crucial role in local healing traditions—a finding consistent with Müller et al.'s observations [30]. That's why 84% of respondents were at least 62 years old (Table 1) and that, despite being forced to leave their land in 1948 and return in 1982 [8], they were able to learn about the medical procedures of their traditional medicine from their parents and relatives.

In terms of income, 58% of the respondents were currently retired, and among them, 47% were women. The other 42% of the respondents continue to work in family farming, the majority of whom are men (88%) (Table 1).

The eldest people typically offer the prayers as part of the medical treatment process. However, praying was much more common in the past, in addition to teas and baths, to combat diseases such as *wind sickness*, *evil eye*, and childbirth. Herbs commonly used in these rituals include elderberry *(Sambucus australis)*, artimijo *(A. vulgaris* L.*)*, and leaves of the forest, among others.

During the retaking of the land, from 1982, prayers of protection were always said to help the warriors fight against the land grabbers and protect the village. Additionally, at that time, indigenous people could not travel and did not have access to doctors, so the elderly people cured the children with forest remedies after they were asked Mother Nature for permission or singing or were praying during medicine preparation. The person saying the prayer needed a bath with scented flowers that gave off pleasant aromas to cleanse the body, according to the interviews.

Upon returning to their ancestral lands after being expelled for 40 years, these communities not only lacked access to healthcare, transportation, schools, infrastructure, and urban services in their villages, but also faced challenges in identifying plants capable of treating new diseases contracted through contact with non-indigenous populations. Conditions such as obesity, diabetes, and hypertension—being novel diseases—fell outside the scope of traditional medical knowledge. This situation highlights the adaptive potential of indigenous medical systems, as observed in other communities. A notable example is the adaptation of Maya indigenous pharmacopeia [38], whose rapid transformations led the author to propose a new framework: using "local herbal therapies" for contemporary adaptations while reserving the term "traditional" for ancient knowledge systems.

During the interviews, many reports of the loss of plants that were used for traditional medicine by these people in the past were discussed. Some interviewees highlighted the clear perception of change in the TI, which was indiscriminately exploited during the 40 years of occupation by the *land grabbers* who transformed what was previously dense forest into pastures [8]. In view of this, some of these reports can be seen below:

> *"It lost a lot... and some herbs that it used to be from the forest, nobody finds it anymore..." Marta Xavier de Oliveira (85 years old)*
> *"Where are the forests? There were only colognes and mangoes [pasture]... and our medicines? (...) plants are a gift from God..." Maria Creuza Fernandes (69 years old).*

As the interviewees explained, until the early 1940 s remedies were commonly prepared in the form of baths or teas from the leaves or bark of plants from the forest. For this purpose, they used a pestle, clay pots, and plant parts that simulated gourds where the leaves were macerated, and finally, animal bones were used to cut the vegetables. In addition, it was common to say prayers or be accompanied by someone with spiritual wisdom.

As shown in Table 1, most of the respondents had no education (58%), and births occurred with the help of midwives. The author (Pataxó Hãhãhãi, HDS) perceives the contrast between the past and the present for some of the plants, which were previously abundant but can no longer be found, as well as the absence of deliveries performed by midwives. In particular, this practice was very important because the midwives prepared pregnant women by saying prayers and preparing herbal baths and a controlled diet. Pregnant women were expected to exert minimum effort on and avoid other tasks, such as housework. After giving birth, they should rest (guard) before returning to daily activities. The aforementioned author argues that today's young people do not have these memories.

Today, with all the losses that these people suffered during the process of expulsion and land reclaim, in addition to the recent phenomenon of the internet that resulted in globalizing processes, the predominant medicine in the villages is non-indigenous. This issue becomes even more serious when we consider the youngest, who, like any young person in other societies, have become a kind of hostage to the social media available on cell phones, which not only takes up their time but also their cultural convictions. In a participatory study, Müller et al. noted that young participants struggled to identify, name, and categorize the plants utilized in their own neighborhood. In this regard, the writers emphasize that knowledge of plants is linked to the application of the regional healing custom [40].

Despite all these challenges, the 19 interviewees indicated 175 plants as a repertoire of traditional and local medicine that they have practiced since the past (plant (not species) accumulation curve Fig. 3). Those that belong to the three complaints that most affect these people today are highlighted below.

The three most frequent complaints: worms, high blood pressure and diabetes

Some studies conducted in Brazil have shown how indigenous peoples that are in close contact with non-indigenous people, mainly in urban spaces, can have their health affected by adopting a non-traditional diet. A study conducted by us among the Guarani people in the state of São Paulo [41] recorded the perception of the elderly regarding the acquisition of three new diseases—obesity, high blood pressure, and diabetes—as a result of the change in food items (they started eating stuffed cookies, soft drinks, pasta, and sugar) and the way they prepared their food (from raw/cooked in the past to fried in the present). Another study [42] described the eating habits and lifestyle of 95 women belonging to 21 indigenous peoples living in Manaus, state of Amazonas, and their association with hypertension. The prevalence of systemic arterial hypertension was 40%, and 68.5% had excess weight, with 29.1% having class I obesity. They consumed a lot of salt, sugar, and industrialized foods, and 88.4% were sedentary. Additionally, Xavante individuals have a significant cardiovascular risk based on several factors examined, according to Soares et al. (2018) [43]. Authors discuss that Xavante people's social, cultural, economic, and environmental changes resulted in a decrease in physical activity and a shift in eating habits, with a greater intake of packaged foods that are heavy in fat, sugar, and sodium.

According to the concerns of the local health professionals as well as the people themselves, the three most common complaints among the indigenous people of PH today are diabetes, hypertension, and worms. The last two are associated with the diets of non-indigenous people. Due to the violence and cultural fragmentation experienced by PH, their diet notably changed, as the quality of their food decreased, while their stress and

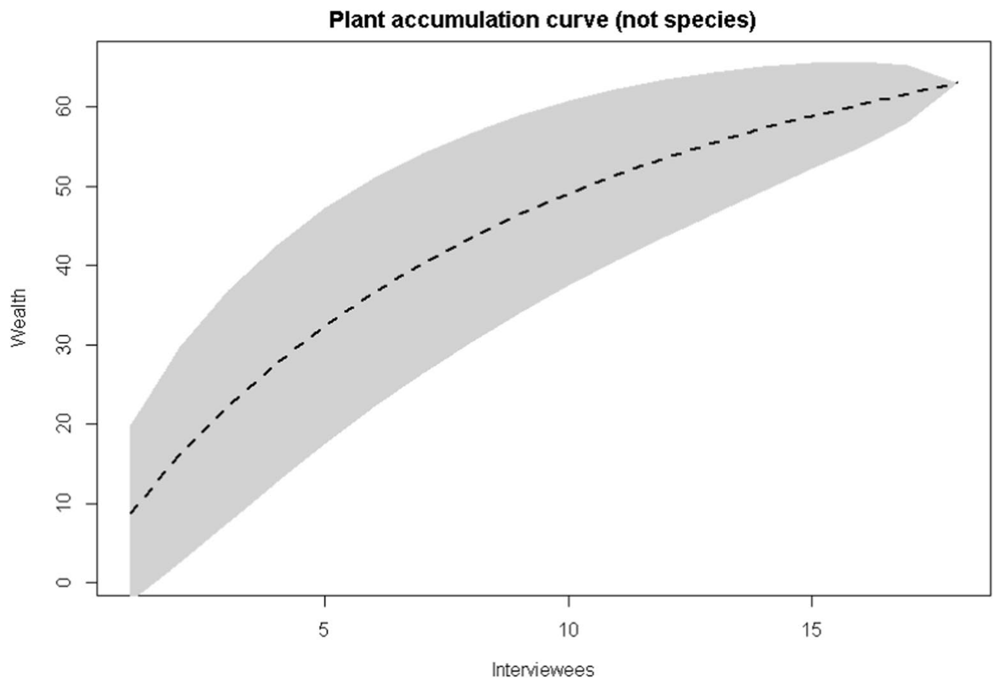

Fig. 3 Accumulation curve based on respondent ratio (19) and new plant records (63)

concerns about challenges, diseases, and persecution increased. Prior to this time, the indigenous people stressed the value of eating well, citing garden-grown fruits and vegetables. In order to address these three issues, they also used medicinal herbs; 63 of them were mentioned in this context. Table 2 shows that only 43 of the 63 plants mentioned could be identified to the species level, and as shown in Figs. 4 and 5, most of their knowledge was not shared among the interviewees. Only 1 to 7% of the knowledge was shared by 74% of the respondents. In addition, most plants (81%) were cited by only 1 to 3 indigenous people. The most widespread information was available for the following plant species: mastruz *(Dysphania ambrosioides* (L.) Mosyakin & Clemants*)*, sweet potato *(Operculina macrocarpa* (L.) Urb.), lemongrass *(Cymbopogon citratus* (DC.) Stapf.*)*, lemon balm *(Lippia alba* (Mill.) NEBr. ex Britton & P. Wilson), pumpkin *(Cucurbita pepo* L.*)*, lavender *(Aloysia gratissima* (Gillies & Hook.) Tronc.*)*, São-Caetano melon *(Momordica charantia* L.*)*, turmeric *(C. longa* L.*)*, aloe vera *(Aloe vera* (L.) Bum. f.*)*, capeba *(Piper umbellatum* L.*)* and moringa *(Moringa oleifera* Lam.*)*.

As shown in the rarefaction curve of plant citations by the respondents (Fig. 4), four respondents gave the most plant citations, between 12 and 24. This may be related to the fact that the PH people have different indigenous cultures and/or that the indigenous groups are not geographically close, which may lead to reduced diffusion of such knowledge among individuals. Another factor that may contribute to the low dispersal of knowledge regarding plants may be related to the heterogeneous geography in the territory, since the transitional biome between the Atlantic Forest and Caatinga villages promotes distinct vegetation among certain villages.

The rarefaction plot of the 63 plants (non-species) presented in Fig. 6 shows the distribution to highlight the most cited plants, where the horizontal axis corresponds to the total number of citations for each plant, and the vertical axis indicates to the number of respondents who cited that plant.

Although moringa *(M. oleifera)* and São Caetano melon *(M. charantia)* received the same number of total citations, the use of *M. charantia* was more widespread among the indigenous people because 6 interviewees cited *M. oleifera*, whereas only 4 cited *M. charantia*; thus, a slight upward shift on the vertical axis occurred. Additionally, matruz *(D. ambrosioides)* is the most well-known plant among the indigenous population and is present in different therapeutic formulations.

The above factors limit the access of some indigenous people to certain plants, as plant availability depends on the region in which their village is located. In addition, one should consider the various transformations undergone by the territory and the experiences of the indigenous people due to *land grabber* invasion, which

Table 2 Forty-three plant species cited by 19 Pataxó Hãhãhãi to treat verminosis, diabetes, and hypertension

Family	Scientific name (collection number)	Popular name	Part used	Therapeutic use(s) (emic terms)	Preparation
Amaranthaceae	◘Celosia argentea L. (HDS015)	velvet	Flowers/fruits	Worms	Decoction
Amaryllidaceae	◘Allium fistulosum L. (HDS056)	garlic	Leaves	Fever/worms	Alcohol extraction
Anacardiaceae	◘Spondias purpurea L. (HDS006)	ciriguela	Leaves	Hypertension	Decoction
Annonaceae	◘Annona muricata L. (HDS026)	soursop	Leaves	Hypertension	Decoction
Bixaceae	◘*Bixa orellana L. (HDS022)	annatto	Leaves	Diabetes	Decoction
Bromeliaceae	◘*Ananas comosus (L.) Merr. (HDS013)	pineapple	Fruits	Diabetes	In natura
Cactaceae	◘*Pereskia aculeata Mill	ora-pro-nobis	Leaves	Hypertension	In natura
Caricaceae	◘Carica papaya L. (HDS01)	purple-windpipe	Flowers	Worms/diabetes	Decoction
Chenopodiaceae	◘*Dysphania ambrosioides (L.) Mosyakin & Clem-ants (HDS012)	mastruz/mastruço	Leaves	Worms	Decoction
Convolvulaceae	◘*Operculina macrocarpa (L.) Urb. (HDS064)	purge-potato	Tubers	Worms/intestinal cleansing	Decoction
Costaceae	◘*Costus spiralis (Jacq.) Roscoe. (HDS029)	monkey-cane	Stems	Hypertension	In natura
Cucurbitaceae	◘Cucurbita pepo L. (HDS014)*	pumpkin	Fruits	Worms/spots on the skin	In natura
	◘Momordica charantia L. (HDS005)	São-Caetano-melon	Seeds	Cancer/worms/diabetes	In natura
	◘Sicyos edulis Jacq. (HDS011)	chayote	Leaves	Hypertension	Decoction
Fabaceae	◘Bauhinia monandra Kurz. (HDS025)	cow's-hoof	Leaves	Diabetes	Decoction
	◘Tamarindus indica L	tamarind	Stems	Diabetes	Aqueous extraction
Lamiaceae	◘Coleus amboinicus Lour. (HDS021)	peppermint	Leaves	Hypertension	Pilada
	◘Leonotis nepetifolia (L.) R. Br. (HDS09)	cordon-of-San-Francisco	Leaves	Diabetes	Decoction
	◘Melissa officinalis L. (HDS030)	coraminha/melissa	Leaves	Hypertension	Decoction
	Mentha aquatica L. (HDS055)	spring-water	Leaves	Hypertension	In natura
	◘Mentha pulegium L. (HDS031)	dusting-of-dust	Leaves	Hypertension/worms	In natura
	◘Mentha X piperita L. (HDS058)	mint	Leaves	Worms/stomach ache/cough	Pilada
	◘Sage rosmarinus Spenn. (HDS051)	rosemary	Leaves	Hypertension/cough	Decoction
Lauraceae	◘Cinnamomum verum J. Presl. (HDS024)	cinnamon	Leaves/bark	Hypertension	Decoction
Liliaceae	◘Aloe vera (L.) Bum. f. (HDS007)	aloe	Leaves	Worms	Pilada
Malpighiaceae	◘Malpighia glabra L. (HDS017)	acerola	Leaves	Hypertension	Decoction
Malvaceae	Gossypium arboreum L. (HDS033)	cotton	Leaves	Worms	Pilada
Moraceae	◘Morus nigra L. (HDS010)	blackberry	Leaves	Hypertension	Decoction
Moringaceae	◘Moringa oleifera Lam. (HDS018)	moringa	Leaves	Diabetes	Decoction
Myrtaceae	◘Psidium guajava L. (HDS016)	guava-tree	Leaves	Hypertension	Decoction
Papaveraceae	◘Argemone mexicana L. (HDS019)	holy-car	Roots	Malaria/diabetes	Decoction
Piperaceae	◘*Piper umbellatum L. (HDS08)	capeba	Leaves	Healing/liver/diabetes	Chewed
Poaceae	◘Cymbopogon citratus (DC.) Stapf. (HDS032)	lemongrass	Leaves	Hypertension	Decoction
	◘*Genipa americana L. (HDS023)	genipap	Fruits	Worms	Decoction
Rutaceae	◘Citrus × cf. aurantium L	water-orange	Leaves	Hypertension	Decoction
	◘Citrus × limon (L.) Osbeck	lime	Leaves	Hypertension	Decoction
Solanaceae	*Capsicum rabbani Sendtn. (HDS002)	bird-pepper	Leaves	Worms	Decoction
	◘*Solanum nigrum L. (HDS027)	Santa-Maria	Seeds	Worms	In natura
Typhaceae	◘*Typha domingensis Pers	cattail	Roots	Worms	Decoction
Verbenaceae	◘*Aloysia gratissima (Gillies & Hook.) Tronc. (HDS004)	lavender	Leaves	Hypertension	Decoction
	◘*Lippia alba (Mill.) N.E.Br. ex Britton & P. Wilson (HDS003)	lemon-balm/lemon balm	Leaves	Hypertension	Decoction
Zingiberaceae	◘Alpinia zerumbet (Pers.) B.L.Burtt & R.M. Sm. (HDS028)	cologne	Leaves	Hypertension	Decoction
	◘Curcuma longa L. (HDS042)	saffron	Roots	Diabetes	Decoction

[*] Native species; ◘Species on which efficacy and safety studies are available (Supplementary

degraded the territory and forced the Pataxó Hãhãhãi to live on the urban periphery.

The 43 plant species belong to 29 botanical families, with Lamiaceae (17%), Cucurbitaceae (7%), Solanaceae (5%), Rutaceae (5%), Fabaceae (5%) and Verbenaceae (5%) having the greatest number of species (44%), whereas the other families had only one identified species. Notably, most of the recipes (95%) use the aerial parts (leaves, fruits, flowers and seeds) of the plants, which allows disease management without eliminating individual plants from the environment aiding in the sustainable use of these resources [40].

Twenty out of 43 plants have been shown to alleviate hypertension, 15 to treat worms and 11 to control diabetes. Some of these plants, including squash (*C. pepo* L.) and sweet potato (*O. macrocarpa* (L.) Urb.), can also be used to treat other conditions, such as skin blemishes and bowel cleansing, in addition to being indicated for treating worms. Furthermore, the same species has been indicated to treat more than one of the three complaints; for example, São Caetano melon (*M. charantia* L.) was indicated for the treatment of both diabetes and worms.

With respect to their use, 66% of the plants are used in recipes involving decoction-type teas, whereas 20% are prepared in *natura* (chewed or pounded); i.e., the direct consumption of fresh leaves. This preparation preference can be explained by the greater ease of extraction of plant components from their soft parts (leaves, fruits and flowers). All 43 species are used orally, although pumpkin can also be used topically. The oral route is preferred because of its convenience and easy administration. These results agree with those reported by Kasali et al. [40], who studied ethnomedicinal uses of plants in forty countries.

The safety and efficacy data obtained from the scientific literature for the plant species indicated by the indigenous people for the three most frequent complaints were compiled and are available in the supplementary material, Table 1S and Table 2S.

Of the 43 plant species indicated for the three complaints, only 34 had pharmacological data found in the scientific literature (Table 2S, supplementary material), and 100% of them had pharmacological evidence supporting the PH uses (Fig. 7).

Thus, considering both traditional and academic data, for the treatment of worms, from the 15 species indicated, the most recommended are *D. ambrosioides* (mastruz; a plant naturalized in Brazil with 11% of the citations), followed by *O. macrocarpa* (potato purée; native with 7%), *A. vera* (aloe; cultivated with 3%) and *C. pepo* (pumpkin; cultivated with 3%). Among the 20 species associated with hypertension, *C. citratus* (lemongrass, a naturalized plant with 3% of the citations) and *L. alba* (lemon balm, native with 3%). Finally, from the 11 species indicated for the treatment of diabetes, the *M. oleifera* (moringa, a cultured species with 4% of the citations) and *M. charantia* (São Caetano melon, naturalized with 4%) are the most recommended. Studies in the scientific pharmacological literature supported the traditional use of all these species (Table 2S and Fig. 7).

Importantly, these data suggest that native plant species are commonly used among indigenous peoples, however, many exotic or naturalized species are also part of their daily use (67%). This is primarily due to the displacement of Indigenous peoples from their territories, which not only forced many people to learn how to use plants from outside their villages but also fragmented their cultural knowledge, led to the loss of native plants, and even resulted in the loss of indigenous lives. Many native plants were uprooted as forests were converted into pastures by land grabbers, while other plant species

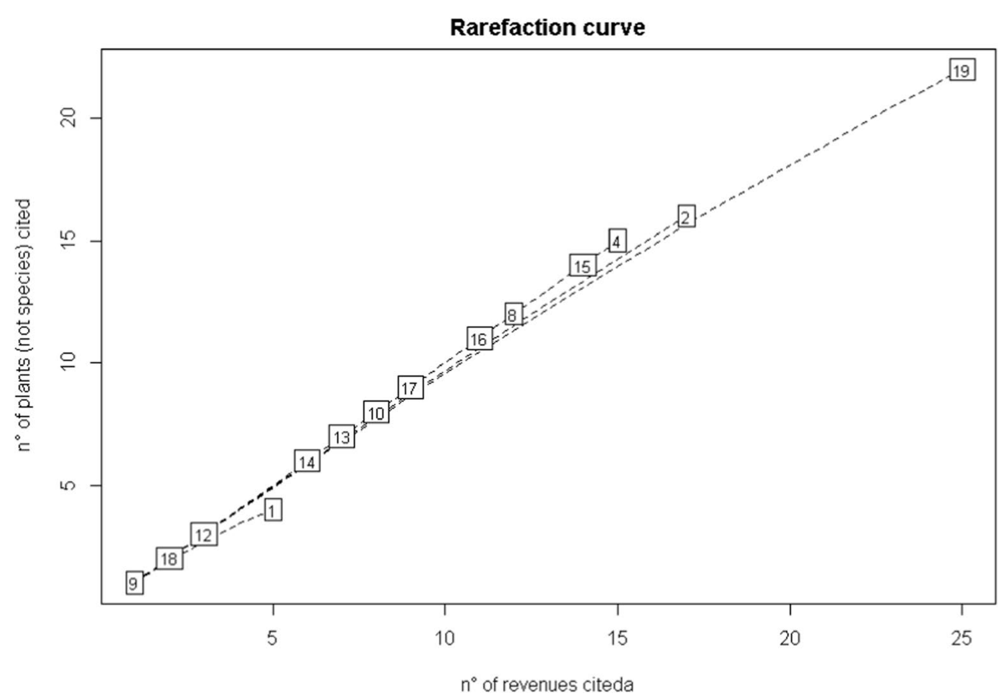

Fig. 4 Rarefaction curve of the citations of 63 plants (non-species) by the 19 interviewees

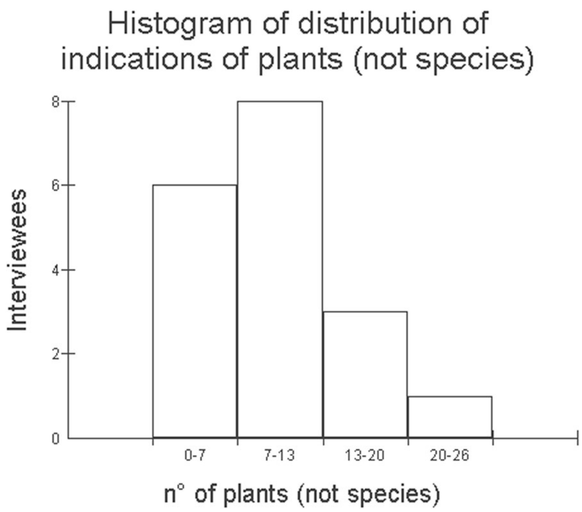

Fig. 5 Histogram of the distribution of the indications of 63 plants (non-species) by each interviewee

were introduced to indigenous peoples by past colonizers. As shown in Fig. 7, few scientific studies have been conducted on native plant species. However, the exotic or naturalized species used by the PH, which are more widespread in society, may explain why a significant portion of them have been the subject of pharmacological research.

Lastly, it is critical to draw attention to the hesitancy with which several interviewees used plants in their therapeutic practices. Some explained that it is very important to consider material quality when preparing a medicine and that attention should be given to teaching the steps of each recipe. In particular, warnings were given regarding the dosages of eight plant species including: *i)* leaves of the mastruz *(Dysphania ambrosioides)*, *ii)* leaves of the spearmint *(Coleus amboinicus)*, *iii)* leaves of the water-of-alevante *(Mentha aquatica)* and *iv)* leaves of the pennyroyal *(Mentha pulegium)*, *v)* root of the carro-Santo *(Argemone mexicana)*, *vi)* tuber of the purga potato *(Operculina macrocarpa)*, *vii)* flower of the purple-colored papaya *(Carica papaya)* and *viii)* seeds of the melon-of-São-Caetano *(Momordica charantia)*. Among these, *A. mexicana* and *M. charantia* are contraindicated for pregnant women, whereas *D. ambrosioides* and *O. macrocarpa* are restricted to children under 4 years of age.

As part of this work, a book and an audiovisual containing data and photos of the plants, experts, elders, and medical practices that were retrieved and recorded by the researcher are being produced with the participation of some young people from the villages. A booklet with the plants involved in the treatment of those three most frequent complaints is being prepared so that these people can use them effectively and safely. Furthermore, a medicinal plant bed was established in the PH territory so that its use can be revived among the members of this people.

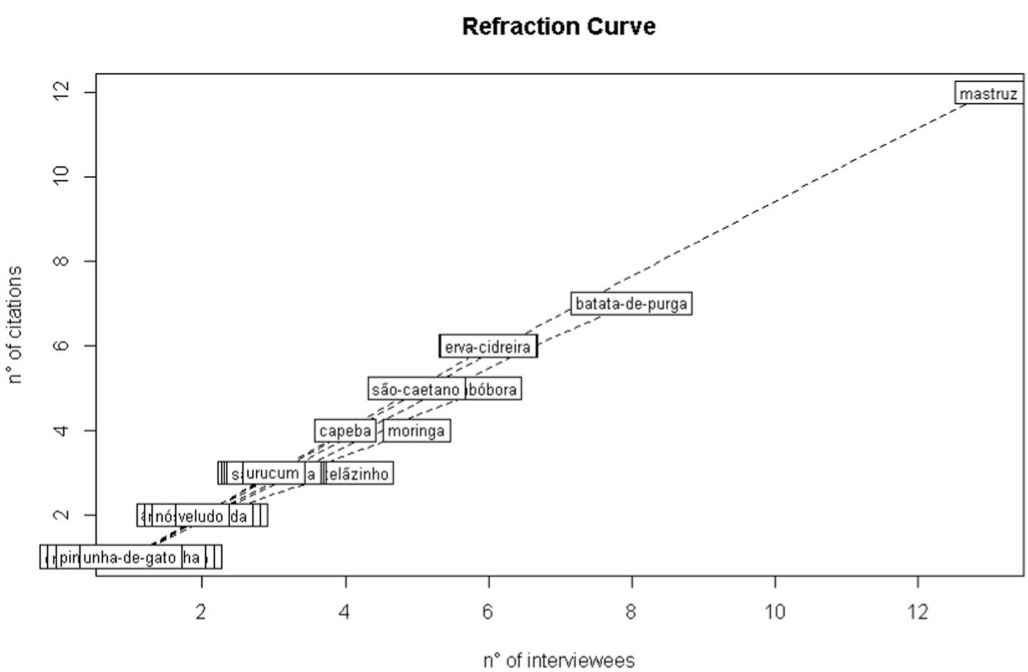

Fig. 6 Rarefaction curve of the 63 plants (not species) cited by the 19 interviewees

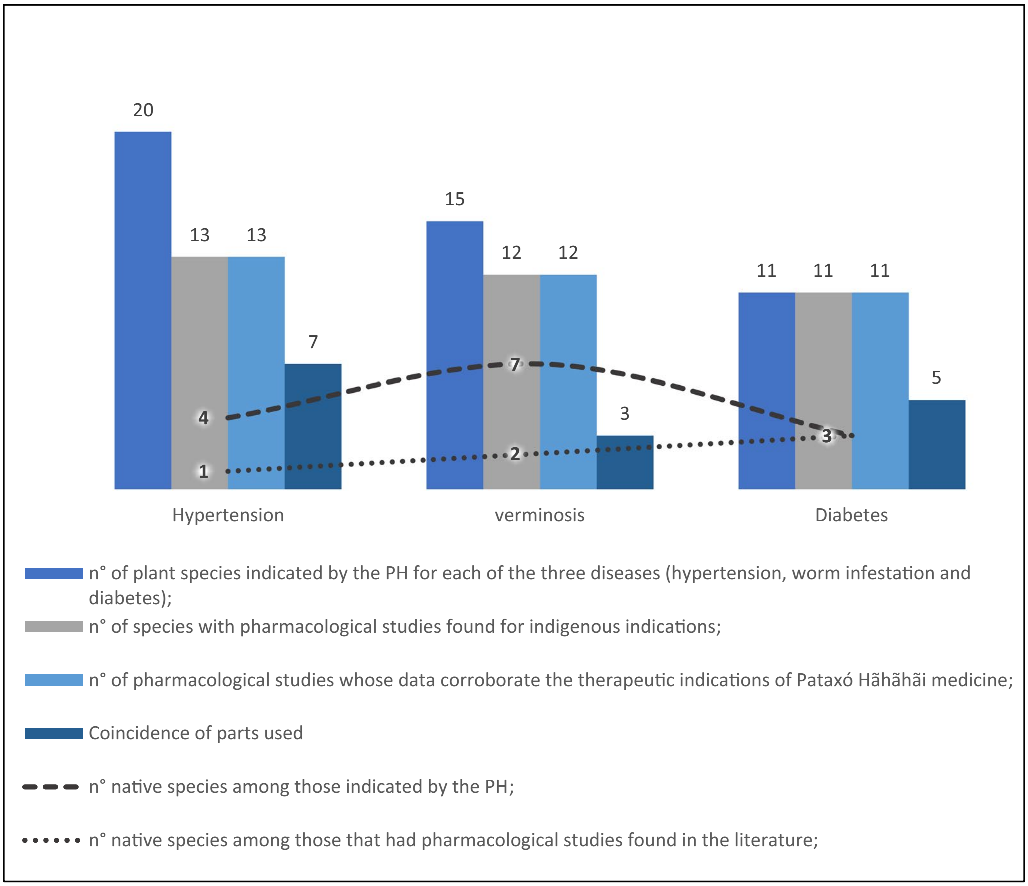

Fig. 7 Comparison of plant species cited by Pataxó Hãhãhãi and pharmacological studies in literature

Conclusions

Although the therapeutic practices of the Pataxó Hãhãhãi people, as well as the associated plants, have experienced numerous attacks and fragmentations over time, some of them could be recovered and recorded during this work by a representative of these people, using the Participatory Ethnobotany approach. However, their ability to adapt, such as by managing numerous nonnative plants (67%) for the treatment of diseases, has been crucial for these indigenous people, as many of their natural resources were previously brutally removed. The focus on the plants used for the three main complaints that affect them today in this study allows them to be used safely.

The training of an indigenous ethnobotanist in an unprecedented way was made possible by the implementation of the Participatory Ethnobotany approach, which also had both helpful and challenging effects at various stages of the project. It is expected that future studies carried out by other indigenous people, using this approach, will be able to provide new elements in order to improve it. This is because one of the most relevant contributions of this approach lies in delving deeper into the issue of the right to intellectual property, which could perhaps be one of the possible solutions to this worldwide controversial issue.

Abbreviations

CAAE	Certificate of presentation of ethical appreciation
CEP	Research ethics committee
CONEP	National commission for ethics in research
FUNAI	National foundation for indigenous peoples
ICF	Free and informed consent form
PH	Pataxó Hãhãhãi
SESAI	Secretariat of indigenous health
SISBIO	Biodiversity authorization and information system
SISGEN	National system for the management of genetic heritage and traditional knowledge
SPI	Indian protection service
TI	Caramuru Paraguassu Indigenous territory
UNIFESP	Federal university of São Paulo

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s13002-025-00782-4.

Additional file 1.

Additional file 2.

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Author contributions
Pataxó Hãhãhãi, H. D. S. contributed to the conception, writing and development of the project with the Pataxó Hãhãhãi indigenous community. Rodrigues, E. contributed to the project guidance and acquisition of funding. All authors contributed to the writing (review and editing). The final manuscript was approved by both authors.

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Data availability
No datasets were generated or analyzed during the current study.

Declarations

Ethics approval and consent to participate
This ethnobotanical study was approved by the Research Ethics Committee of the Federal University of São Paulo (CEP/UNIFESP).

Consent for publication
Prior to data collection, permission to conduct the study was obtained. The study's subjects provided written or oral consent before each interview and each focus group discussion.

Competing interests
The authors declare no competing interests.

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