Acta Botanica Brasilica - 34(2): 256-265. April-June 2020.
doi: 10.1590/0102-33062019abb0233

What are the drivers of popularity and versatility of medicinal plants in local medical systems?

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Received: July 2, 2019
Accepted: December 13, 2019

ABSTRACT

The cultural importance of medicinal plants has been measured in terms of popularity (number of people who know a plant) and versatility (number of therapeutic indications mentioned for a plant). Previous works have provided evidence about some drivers of medicinal plant importance, such as attributes of availability, efficiency, palatability and taste. The present study tested whether local perception of efficiency, availability (ease of acquisition), palatability (degree of pleasantness), and taste influence the popularity and versatility of medicinal plants in two rural communities of Buíque, Brazil. Free-listing was applied to identify the medicinal plants known/utilized in the communities, while semi-structured interviews were performed to collect more information about the plants. Informants participated in exercises to score the plant-parts that they knew and used. Statistical analysis was performed through multiple linear regressions, with none of the models retaining all variables as explanatory for popularity and versatility. However, availability and efficiency jointly explained versatility in one of the communities, while palatability was inversely related to versatility and popularity in the other. This study demonstrated that the studied individuals select plants differently, which makes exposing the driving forces of such differences a challenge.

Keywords: ethnobiology, local pharmacopoeias, quantitative ethnobotany, seasonally dry tropical forests, socioecological systems

Introduction

Several studies have measured the importance of medicinal plants in terms of their popularity (Ali-Shtayeh *et al*. 2000; Nortje & Van-Wyk 2015) and/or versatility (Cartaxo *et al*. 2010; Ribeiro *et al*. 2014; Saraiva *et al*. 2015). Besides being used to address theoretical issues (*e.g.* to understand what makes some plants more important than others), measures of popularity and versatility may also be used to determine the conservation status of plant species and to indicate promising species for bioprospecting efforts. The differences between popularity and versatility reside in the fact that, while the first measures the quantity of people who know a given plant (Ali-Shtayeh *et al*. 2000), the second indicates the number of therapeutic indications mentioned for it (Albuquerque *et al*. 2007).

Previous studies have provided clues to some factors that may influence the selection of medicinal plants, such as availability (Lucena *et al*. 2007), efficiency (Araújo *et al*. 2008), taste (Medeiros *et al*. 2015), and palatability (Drewnowski & Gomez-Carneros 2000; Albuquerque 2006). These studies, however, have evaluated the influence of these factors in isolation since their research questions did not require a joint analysis. However, a few studies have aimed at identifying a set of criteria that together influence

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medicinal plant popularity and/or versatility (Santos *et al.* 2018). Such joint analysis is important because it can increase the explanatory power of a model. Furthermore, some individual factors may only show influence on medicinal plant use when considered together with other variables. Most information in the literature on the joint influence of ecological and intrinsic factors on medicinal plant importance is rather anecdotic.

In addition, these studies generally considered use value as indicative of importance (see Phillips & Gentry 1993; Rossato *et al.* 1999), which is a measure that combines popularity and versatility. Considering that a popular plant may also be versatile or vice-versa, but also may be only popular or only versatile, since they are different measures, we proposed to evaluate popularity and versatility separately.

Another important aspect that was not contemplated in some previous studies is local perception, especially regarding factors related to efficiency and availability. Therefore, if we consider that the way people perceive nature may guide their strategies and mechanisms of selecting natural resources, it is necessary to measure the efficiency, availability and palatability of a plant in terms of how people perceive them.

In relation to evidence for the factors indicated by ethnobotanical studies, the main theoretical framework used in the literature as an attempt to understand the relationship between environmental availability of a resource and its local importance is the Ecological Apparency Hypothesis (see Phillips & Gentry 1993). However, a systematic review that searched for general patterns among studies found that, when use-categories where evaluated separately, availability measured by phytosociological parameters did not explain medicinal plant importance (Gonçalves *et al.* 2016). Moreover, some researchers suggest that the perception of availability may be influenced by accessibility. Therefore, an abundant species may be perceived as unavailable if it occurs far from households (Albuquerque *et al.* 2015), which suggests that perceived availability may be a more efficient metric for testing apparency than "phytosociological availability".

The perception of efficacy has been evidenced as an important characteristic in medicinal use since it has been one of the main factors indicated by people for the selection of medicinal plants for the treatment of several diseases (Albuquerque *et al.* 2007; Júnior *et al.* 2011). In addition, some researchers have found a relationship between the local importance of some medicinal plants and their pharmacological efficiency in the context of antimicrobial activity (Omar *et al.* 2000; Siqueira *et al.* 2012), indicating that people know how to recognize the most efficient species.

Regarding the variable taste, several studies in the context of medicinal plants have suggested that there is a relationship between the perception of bitter taste and medicinal uses. This is because species that are used to treat a specific set of diseases have been associated by local populations with this taste (Brett 1998; Ankli *et al.* 1999), and most of the medicinal plants mentioned by people had a bitter taste (Heinrich *et al.* 1992; Brett 1998; Medeiros *et al.* 2015).

In relation to palatability, understood here as the degree of pleasantness of a plant, studies focused on food plants have suggested that people tend to reject bitter-tasting foods and prefer sweet-tasting foods (Anderson 1995) due to an association between bitter taste and toxic compounds (Glendinning 1994). Because plants with many bioactive compounds tend to be bitter or astringent (Drewnowski 1997; Drewnowski & Gomez-Carneros 2000) and are, therefore, more likely to be toxic, evolutionary mechanisms for survival have been developed over time that lead people to avoid frequent consumption of these species as food through the unpleasant association with bitter and astringent taste (Drewnowski & Gomez-Carneros 2000; Yamaguchi & Ninomiya 2000; Kim *et al.* 2006). These plants of toxic potential, eaten as food, may coincide with those of medicinal potential because they also have important bioactive secondary compounds, as has been registered by several studies with a medicinal focus (Ankli *et al.* 1999; Macedo *et al.* 2007; Araújo *et al.* 2008). Thus, the cause of bitter taste being related to unpleasantness might have been modulated by food use, however, with repercussions for medicinal use. Thus, according to this logic, plants of greater medicinal potential would present unpleasant tastes.

There is, however, a counterpoint to this idea, by which some researchers suggest that some medicinal plants may be privileged in terms of citations and uses because they have more pleasing tastes, such as exotic medicinal plants that can replace native plants with less palaTable tastes (Albuquerque 2006; Estomba *et al.* 2006).

Considering all of the above mentioned evidence regarding the factors that can influence the selection of medicinal plants, we analyzed the perceptions of residents of a semi-arid region in northeastern Brazil to answer the following question: Do people's perceptions of the availability, efficiency and palatability of medicinal plants influence the popularity and versatility of these plants in local medical systems?

Materials and methods

Study area

This study was performed in the rural communities of Igrejinha and Batinga, in the municipality of Buíque, located within Catimbau National Park (8º24'00''–8º36'35''S; 37º0'30''–37º1'40''W), in the state of Pernambuco, Brazil. The municipality encompasses an area of 1,329,883 km² and has a population of 52,105 inhabitants, with 30,910 rural and 21,195 urban (IBGE 2010).

Catimbau National Park is an integral conservation unit that was created in December 2002. It encompasses an area of approximately 62,300 hectares, which varies in terms of relief, with mean annual precipitation ranging 480-1000 millimeters (Rito *et al.* 2016). The park covers a large area of the municipalities of Buíque, Ibimirim, Sertânia and Tupanatinga (IBAMA 2016) and is 295 km distant from the state capitol of Recife (Bragagnolo *et al.* 2016).

The study area is located in a Caatinga environment (IBAMA 2016). A study performed in this area recorded 129 tree species distributed among 31 botanic families, of which the most representative were: Fabaceae (28 % of species), Euphorbiaceae (14 %) and Myrtaceae (8 %) (Rito *et al*. 2016). The same study also document variation in plant species along a precipitation gradient, with groups of species occurring throughout the gradient, while other groups were particularly abundant at either one or the other precipitation extremes; there were also species associated with higher vegetation cover and others related to sites with greater chronic disturbance.

The community of Igrejinha is the most populous with 171 inhabitants, including 78 adults and 93 children and young people. The community of Batinga has 71 residents, including 38 adults and 33 children and young people.

The inhabitants of Batinga and Igrejinha resided in the area prior to it becoming a national park, so they are familiar with the natural resources in the area and use plant species for several purposes, including medicinal use. In spite of legislation that forbids residences in national parks, the dwellers still live there because they were not indemnified when the park was created.

Batinga and Igrejinha neighbor each another, with distance of approximately eight kilometers between them. In Batinga, vegetal resources are collected in "manga", an area relatively close to the residences. The vegetation aspect of this community is verdant, even during drier periods, possibly due to the high humidity in this area. Most of the areas in Igrejinha were converted into clearings and are less conserved. Most collecting of resources by the residents of this community is done at another location called Brocotó, which is quite distant from the residences.

The main source of informed income for the majority of people in Igrejinha and Batinga is the assistance offered by *Bolsa Família* (federal assistance program for low income families), since the practice of agriculture has decreased due to the rain regime that affects the region. However, the main crops grown in the rainy season are beans, maize and cassava. In addition, some animals, such as goats, cattle and birds, are raised by some residents for both personal consumption and commercialization.

Neither of the communities has a family health unit (USF), and only Batinga has a regular school with elementary education I. Thus, residents of Igrejinha have to travel to Catimbau Village (about 10 kilometers) to access these services or to the Buíque headquarters. The people of Batinga identify with the indigenous Kapinawá ethnic group, but the area is outside the boundaries of the indigenous lands documented and recognized by FUNAI (National Indian Foundation), which are south of the Park.

Ethical and legal aspects and selection of informants

The present study was approved by the Research Ethics Committee of the University of Pernambuco (UPE) (document nº: 1.998.673), according to Resolution 466/2012 of the National Health Council for conducting research with human beings. Authorization for the development of scientific activities and collection of botanical material in Catimbau National Park was obtained from ICMBio/SISBIO (nº 55152-1).

Informants were selected through a census, during which all households were visited in order to recruit the largest possible number of people living in the two communities. Therefore, people of the aforementioned communities who were 18 years of age or older, and who signed the Free and Informed Consent Term, participated in the study.

Data collection

In order to establish a bond of trust with the members of the community, a pilot campaign was executed in January 2017 involving conversations with some local leaders to disseminate the objectives and stages of the research. Ethnobotanical data were collected between January and July of the same year, with collections implemented in two stages. In the first stage, all residences were visited and, for those who accepted to participate in the study, the free-listing technique employed to identify medicinal plants known in the communities. The guiding question was: Which medicinal plants do you know? With the information obtained from the free list, semi-structured interviews were conducted (see Albuquerque *et al.* 2014), which included questions about the therapeutic indications attributed to the plants, the parts used for each use, and their respective collection sites. Socioeconomic data on the informants were also obtained, such as: name, gender, date of birth, occupation, place of origin, educational level, length of residence, etc. In this stage, 52 residents (out of a total of 78 over 18 years old) were interviewed in Igrejinha and 29 (out of 38) in Batinga. Only people who were not found after three visits by the researchers at different times and days of the week or who refused to participate in the study did not participate in this stage.

With the list of medicinal plants known by the informants of the two communities (n= 127), 20 medicinal plants were chosen by lottery for the next stage. This number of plants was selected because, while it is adequate for statistical analysis, it is not so large as to make the interviews tiresome and unfeasible for the interviewees. The following criteria were considered in the selection of medicinal plants to be included in the lottery: 1) plants mentioned in either of the two communities; 2) plants with more than one citation and more than one therapeutic indication; and 3) plants with specific denominations (Imburana-de-cambão, Imburana-de-cheiro, for example). A total of 63 plants met these criteria, of which 20 were randomly selected without replacement using *BioEstat* 5.0 software (Ayres *et al.* 2007).

In order to assure that all plants were different ethnospecies, and to eliminate potential synonyms, 12 local experts from each community, who were previously identified during the semi-structured interviews by the number of plants they cited, were consulted. These experts determined whether all selected plants were, in fact, different from each other in terms of ethnospecies and/or whether they had other denominations in the community.

With the confirmation that the 20 medicinal plants were different from each other in terms of ethnospecies, they were presented to all the informants who participated in the first stage, independently of whether they cited those plants or not.

In this second stage, the names of plant-parts were read to the informants. The plant-part unit adopted in this study means that different parts of the same ethnospecies are treated as different units, since scores (*e.g.* palatability) may vary among parts. Thus, the same plant may have different parts used to treat the same disease (Babosa-root and Babosa-leaf to treat influenza, for example), different diseases (for example, Babosa-root to treat cough and Babosa-leaf for treatment of gastritis) or both.

After reading the names of each plant-part, a semi structured interview was applied, in which the informants were initially asked if they could recognize a given plant-part as medicinal, if they had used it for the specified indications, if it was mixed with other plant ingredients when prepared and if it had a taste (and if so, what taste). For the known and used plant-parts, the informants were asked to assign scores regarding their perception about the factors of availability (ease of acquisition) and palatability. Specifically, for the efficiency factor, scores were assigned considering plant-part-therapeutic indication (Jatobá-bark-anemia, for example). This procedure was adopted only for this factor since people's perception of efficiency can vary both in terms of the part used and the diseases treated by a particular plant part. In this case, a plant-part can be recognized by the same person to treat various diseases, and receive different scores.

The assignment of scores to each plant-part followed a scale of one to four (low to high) and different parts of the same plant (Babosa-root, Babosa-leaf, for example) could receive distinct scores regarding the factors. As most of the informants were illiterate, the scores corresponded to the following categories: bad (one), regular (two), good (three), and excellent (four). The scores were attributed only to the plant-part recognized and used effectively by the informants, and present in the scoring exercise; that is, additional information about the plant-part or other plants was not registered at this moment.

In this stage, 30 residents in Igrejinha and 20 in Batinga were interviewed. A total of 22 informants in Igrejinha and nine in Batinga did not participate in this stage, alleging unavailability or were not located after three visits by the researchers. Only plants mentioned by the informants and selected from the raffle (20 medicinal plants) were considered in this study.

A guided tour was performed (see Albuquerque *et al.* 2014) between June and November with key informants with great knowledge of the local vegetation, who were selected from observations during the interviews. This step aimed to collect plants for botanical identification.

Species identification was performed by specialists at Instituto de Pesquisa Agropecuária (IPA) and Universidade Federal de Pernambuco (UFPE). Voucher specimens were deposited in Herbário Dárdano de Andrade-Lima (IPA) and Herbário Sérgio Tavares (HST) of Universidade Federal Rural de Pernambuco (UFRPE).

Data analysis

The Relative Importance (RI) Index (Bennett & Prance 2000) was calculated to identify the most versatile species. According to this index, the most versatile species has the greatest number of assigned medicinal properties and body systems. It is calculated by the following formula:

$$RI = NBS + N$$

where RI = Relative Importance; NBS = Number of Body Systems; NP = Number of Properties.

The formulas for the factors are:

1) $NBS = NBSS \div NBSVS$, where: NBSS is the number of body systems treated by a given species and NBSVS is the total number of body systems treated by the most versatile species (NBSVS); 2) $NP = NPS \div NPVS$, where: NPS is the number of properties assigned to a given species and NPVS is the total number of properties assigned to the most versatile species.

The therapeutic indications associated with the 20 plants chosen by lottery and previously mentioned by the informants in the two communities were classified according to the disease classification system of the World Health Organization (WHO 2017) for the calculation of versatility.

The popularity of plants was measured by calculating the ratio between the number of informants who cited some medicinal use for the plant and the total number of informants.

Calculations of popularity and versatility, as well as the calculation of the means of the scores referring to the factors of palatability and perceived availability, were performed in terms of the plant-part unit used. For the efficiency factor, considering the different scores for the same plant-part when there are several therapeutic indications, the average of the plant-part averages was calculated.

Calculations of popularity and versatility considered information on known and/or used plant-parts. As for the calculation of the averages for the scores related to perceived information, only the plant-parts effectively used by the interviewees were considered in the analyses, since only from direct contact with a plant-part could informants assign scores on the perception they possessed for efficiency, palatability and availability.

Since some plant-parts did not have information provided from informants of both of the communities, because they were not recognized and used by one or the other, the number of plant-parts that were applied in the analyses differed between the communities (18 plant-parts in Batinga and 15 in Igrejinha).

Data for dependent variables (popularity, versatility) were transformed into Naperian logarithm (Ln) for better statistical adjustment. Multiple linear regression analysis was used to analyze whether local perception of palatability, availability and efficiency influenced (one) popularity and (two) versatility of medicinal plants. Values for the popularity and versatility indexes were used as measures of the dependent variables (popularity, versatility), while average scores of local perception of each factor obtained from the scoring exercises were used for the independent variables (palatability, availability and efficiency). These analyses were performed for each community. Multiple linear regression analysis was followed by the *Stepwise* technique to obtain the best model, based on the lowest Ataike information criterion (AIC), to explain popularity and versatility. Due to the low number of bitter-tasting plant-parts for the two communities, multiple regression analysis of taste types was not feasible. Thus, this variable was not included in the regression models.

All statistical analyses were performed with R software, version 3.4.1 (R Development Core Team 2017).

Results

General characterization

The plant-parts recognized by the informants in the second stage of this study, as well as their respective scientific names and values for popularity and versatility by community, are presented in Table 1.

In relation to popularity and versatility of the studied plant-parts, few presented outstanding high values for either popularity or versatility. Some species were notable in local importance, both for popularity and versatility. Among the plants mentioned by the informants, the most popular for Batinga were: *Hymenaea courbaril* (bark) (0.90), *Periandra mediterranea* (root) (0.85), *Aloe vera* (leaf) (0.85), *Lippia origanoides* (leaf) (0.65) and *Mentha pulegium* (leaf) (0.60). The most versatile for Batinga were: *Aloe vera* (leaf) (2.00), *Hymenaea courbaril* (bark) (2.00), *Commiphora leptophloeos* (bark) (1.67), *Lippia origanoides* (leaf) (0.92) and *Periandra mediterranea* (root) (0.83). The most popular plants for Igrejinha were: *Aloe vera* (leaf) (0.90), *Tocoyena formosa* (bark) (0.83), *Periandra mediterranea* (root) (0.77), *Hymenaea courbaril* (bark) (0.73), *Commiphora leptophloeos* (bark) (0.60) and *Croton conduplicatus* (bark) (0.60). The most versatile for Igrejinha were: *Aloe vera* (leaf) (2.00), *Commiphora leptophloeos* (bark) (1.21), *Hymenaea courbaril* (bark) (1.08), *Lippia origanoides* (leaf) (0.92), *Croton conduplicatus* (bark) (0.83) and *Periandra mediterranea* (root) (0.67).

Influence on popularity and versatility

All models showed good suitability (low AIC values), as shown in Table 2. Descriptive statistical information is provided in Table 3. None of the models maintained all three variables (palatability, availability and efficiency) as explanatory of popularity or versatility of medicinal plants in the two communities studied.

Although none of the models maintained the three variables as explanatory of popularity or versatility of studied plants in Igrejinha or Batinga, perceived availability (ease of acquisition) associated with perceived efficiency explained versatility in the community of Batinga. This suggests that medicinal plants that have greater efficiency and are easier to find are more versatile, according to local perception.

In Igrejinha, only the palatability variable remained in some models (see Tab. 2) to explain either versatility or popularity of plants; however, this explanatory variable exerted an inverse relationship. Thus, the less pleasant the taste the greater the popularity and/or versatility, suggesting that medicinal plants that have less pleasant tastes are perceived as more important. Furthermore, when plant-parts that were effectively used and that were not part of mixtures were analyzed for taste, bitter and astringent tastes were predominately classified as unpleasant and regular, receiving the lowest grades (one and two), while sweet and sour tastes were predominantly classified as pleasant, with a higher grade (three).

Discussion

Influence on popularity and versatility

It was not possible to make direct scientific comparisons with the literature because most of the previous studies did not evaluate popularity and versatility separately (especially for the availability factor). Furthermore, they did not consider people's perceptions of the factors analyzed in this study, besides not performing joint analyses of the predictors of plant importance. Thus, here we aim to infer some of the reasons for the results obtained in the present study.

Our results demonstrated that, although none of the models kept all three variables together as explanatory of popularity and/or versatility, two of the three independent variables — availability and efficiency — that were indicated separately in previous ethnobotanical studies (Lucena *et al*. 2007; Araújo *et al*. 2008), remained in at least one explanatory model of versatility, although not of popularity.

Efficiency was already expected to be explanatory since it has been found by several studies to be a factor that can influence the selection of medicinal plants (Albuquerque *et al*. 2007; Araújo *et al*. 2008; Júnior *et al*. 2011). There was, however, no consensus in the literature regarding how availability relates to the importance of medicinal plants (Lucena *et al*. 2007; 2012; Gonçalves *et al*. 2016). Nonetheless, the present study found availability to be an important factor, in association with efficiency, for the versatility of medicinal plants.

It is possible that availability influenced versatility more here than in other studies because: 1) perceived availability has more influence on versatility than availability measured by phytosociological parameters, which were employed

Table 1. List of plant-parts cited by the informants of the communities of Batinga and Igrejinha, municipality of Buíque, Pernambuco, Brazil, and their respective values for popularity and versatility.

Plant-part	Family	Scientific name	Voucher Herbarium	Level	Popularity	Versatility
Abacate-leaf	Lauraceae	*Persea americana* Mill.	HST22158	Batinga	0.25	0.33
Alcaçuz-leaf	Fabaceae (Papilionoideae)	*Periandra mediterranea* (Vell.) Taub.	IPA91648	Igrejinha	0.03	0.21
Alcaçuz-root	Fabaceae (Papilionoideae)	*Periandra mediterranea* (Vell.) Taub.	IPA91648	Igrejinha	0.77	0.67
				Batinga	0.85	0.83
Babosa-root	Xanthorrhoeaceae	*Aloe vera* (L.) Burm. F.	**	Igrejinha	0.13	0.38
				Batinga	0.40	0.33
Babosa-leaf	Xanthorrhoeaceae	*Aloe vera* (L.) Burm. F.	**	Igrejinha	0.90	2.00
				Batinga	0.85	2.00
Beladona-leaf	Verbenaceae	*Lippia origanoides* Kunth	HST22159	Igrejinha	0.23	0.92
				Batinga	0.65	0.92
Canafístula-bark	Fabaceae (Caesalpinaceae)	*Senna spectabilis* var. *excelsa* (Schrad.) H.S.Irwin & Barneby	IPA22166	Igrejinha	0.13	0.21
				Batinga	0.05	0.25
Capeba-root	*	*	*	Igrejinha	0.13	0.50
				Batinga	0.25	0.33
Caroá-root	Bromeliaceae	*Neoglaziovia variegata* (Arruda) Mez	IPA91701	Batinga	0.25	0.33
Erva doce-seed	Apiaceae	*Pimpinella anisum* L.	HST22160	Igrejinha	0.07	0.21
				Batinga	0.25	0.25
Feijão brabo-bark	Capparaceae	*Cynophalla flexuosa* (L.) J.Presl	HST22165	Igrejinha	0.03	0.21
Hortelã pimenta-leaf	Lamiaceae	*Mentha pulegium* L.	**	Igrejinha	0.40	0.50
				Batinga	0.40	0.50
Imburana de cambão-bark	Burseraceae	*Commiphora leptophloeos* (Mart.) J.B.Gillett	HST91627	Igrejinha	0.60	1.20
				Batinga	0.55	1.66
Jatobá-bark	Fabaceae (Caesalpinaceae)	*Hymenaea courbaril* L.	IPA91630	Igrejinha	0.73	1.08
				Batinga	0.90	2.00
Jenipapo-bark	Rubiaceae	*Tocoyena formosa* (Cham. & Schltdl.) K.Schum.	IPA91611	Igrejinha	0.83	0.38
Louco-leaf	Plumbaginaceae	*Plumbago scandens* L.	HST22163	Batinga	0.10	0.33
Louco-root	Plumbaginaceae	*Plumbago scandens* L.	HST22163	Batinga	0.45	0.25
Quebra faca do sertão-bark	Euphorbiaceae	*Croton conduplicatus* Kunth	**	Igrejinha	0.60	0.83
				Batinga	0.25	0.50
Quebra pedra-root	Phytollacaceae	*Phyllantus niruri* L.	HST2216	Batinga	0.40	0.33
Rabo de raposa-root	Cactaceae	*Cereus albicaulis* (Britton and Rose) Luetzelb	**	Batinga	0.40	0.58
Sabugueira-flower	Adoxaceae	*Sambucus nigra* L.	HST22162	Igrejinha	0.30	0.29
				Batinga	0.40	0.33

* Ethnospecies not incorporated into the herbarium / not identified because it was not found in the collection areas.
**Not collected (identified in the field)

Table 2. Explanatory models obtained through multiple linear regression analysis of data from the communities of Batinga and Igrejinha, municipality of Buíque, Pernambuco, Brazil.

Analysis description	Intercept	AIC	Estimate (b)		
			Efficiency	Availability	Palatability
Popularity - Igrajinha	0.3056	6.51	-	-	-0.7487
Versatility - Igrejinha	0.3482	-9.24	-	-	-0.4524
Popularity - Batinga	-1.037	-9.70	-	-	-
Versatility - Batinga	-3.9535	-13.48	0.6785	0.4885	-

Table 3. Descriptive statistics with means, standard deviations and coefficients of variation obtained for data from the communities of Batinga and Igrejinha, municipality of Buíque, Pernambuco, Brazil.

Analysis description	Number of observations	Mean	Standard deviation	Coefficient of Variation (%)
Popularity – Igrejinha	15	-1.53	1.21	79.53
Versatility – Igrejinha	15	-0.76	0.74	97.66
Availability – Igrejinha	15	2.59	0.62	23.99
Efficiency – Igrejinha	15	3.18	0.43	13.47
Palatability – Igrejinha	15	2.45	0.63	25.93
Popularity – Batinga	18	-1.04	0.74	71.71
Versatility – Batinga	18	-0.67	0.71	106.43
Availability – Batinga	18	2.25	0.77	34.11
Efficiency – Batinga	18	3.23	0.39	12.17
Palatability – Batinga	18	2.54	0.71	27.96

in most of the other studies; and/or 2) availability being addressed in isolation, and being a secondary influential factor, would only be expressed in conjunction with efficiency (primary interference factor). Thus, among plants with a similar medicinal indications, those that are more available would have more uses discovered.

Some studies executed in areas of Caatinga (Lucena *et al.* 2007; 2012) have tested the relationship between availability and importance of medicinal plants using the Ecological Apparency Hypothesis as a model, and Use Value, a measure of importance that combines popularity and versatility giving them the same weight, although many researchers tend to associate only with popularity. Most of these studies did not find a direct relationship between availability and use through phytosociological parameters, either with relative frequency (Lucena *et al.* 2007) or with any other parameter of the medicinal use category (Lucena *et al.* 2012; Gonçalves *et al.* 2016). The direct relationship between availability (and efficiency) and versatility identified in the present study, from the perspective of people's perceptions, may indicate that, for the medicinal category, a greater familiarity with a resource, due to the greater chance of finding more available plants, actually influences the number of uses that will be discovered for the plant and not necessarily on the number of people who know them. At this point, for this category, the probabilistic explanation proposed by Phillips & Gentry (1993) aligns with the results of the present work, considering that the authors advocate that greater availability amplifies the number of uses discovered for a species.

Regarding the local context, in one of the studied communities — Igrejinha — availability and efficiency were not maintained in any of the models to explain popularity nor versatility, with palatability being the variable explaining medicinal plant importance. This suggests that people in neighboring environments and surrounded by the same resources may have different perceptions about particular resources and make different uses of them. Thus, different factors can influence the selection of plants and, consequently, their degree of importance. Therefore, although the present results show a relationship between some of the variables that have been indicated in ethnobotanical studies, such as availability (Lucena *et al.* 2007) and efficiency (Araújo *et al.* 2008), these variables do not seem to be universal. Indeed, human groups in similar local contexts can use different criteria and strategies to select the same resources. Since in one of the communities — Batinga — none of the factors tested influenced popularity, either in combination with other factors or in isolation, an effort is needed to test for factors other than those studied here to explain the popularity of species. The frequency of occurrence of a disease, which was not evaluated in the present study, has been indicated in the literature as a predictor of medicinal plant popularity (Júnior *et al.* 2011; Júnior & Albuquerque 2015; Santoro *et al.* 2015), and may be added to future joint analyses. It is possible, for example, that perceived efficiency and availability have their predictive power amplified for a set of species associated with the most frequent diseases, since a frequent disease would require more collection events, which could lead people to direct efforts to more available and efficient species.

Our findings on the perception of palatability indicated that, in Igrejinha, it influenced the popularity and versatility of medicinal plants in terms of the most unpleasant tastes. In this community, bitter and astringent tastes were evaluated more poorly (classified predominantly as bad or regular) in terms of their palatability. Plants with many bioactive compounds tend to be bitter or astringent (Drewnowski 1997; Drewnowski & Gomez-Carneros 2000) and are, therefore, more likely to be toxic. As a result, evolutionary mechanisms for survival have been developed over time to motivate people to avoid frequent consumption of these species as food by associating bitter and astringent tastes as unpleasant (Glendinning 1994; Yamaguchi & Ninomiya 2000; Drewnowski & Gomez-Carneros 2000; Kim *et al.* 2006).

However, high bioactivity that leads to toxicity can also lead to medicinal effects and, bearing in mind the respective proportions of what is ingested, people may consider unpleasant tastes as those with more medicinal potential. Therefore, our findings align with what was expected within a logic of gustatory perceptions that have been modulated by food use and that reverberate in medicinal use. However, our findings do not corroborate what has been suggested in the literature; that is, medicinal plants may be privileged in terms of citations and uses because they have more pleasant tastes (Albuquerque 2006; Estomba *et al.* 2006).

Still, in the context of medicinal plants, taste can be considered a clue to the selection of medicinal plants related to cultural learning (Medeiros *et al.* 2015), in which the identification of the taste of the plant can make it possible to associate another attribute with it, such as its efficiency, for example. In this sense, it is possible that the mechanism that brings some tastes to be classified as unpleasant has a connection with the level of bioactivity that plants can store. Thus, perhaps unpleasant tastes are functioning as indicators of the presence of bioactive compounds of great medicinal importance and, for one of the communities (Igrejinha), this efficiency indication was more adequate for explaining popularity and versatility than perceived efficiency itself.

Evidence that reinforces this idea comes from several studies in the context of medicinal plants that have shown, predominantly, that plants with bitter taste (Brett 1998; Heinrich *et al.* 1992; Medeiros *et al.* 2015) and, secondarily, plants with astringent taste (Leonti *et al.* 2002; Molares & Ladio 2009) are used to treat various diseases. Additionally, several studies have found that bitter taste in plants is associated with a variety of chemical compounds with potential for the treatment of various diseases, such as alkaloids (Drewnowski 1997) and phenols, especially flavonoids (Drewnowski & Gomez-Carneros 2000), and high molecular weight phenolic compounds, such as tannins, in the case of astringent taste (Drewnowski & Gomez-Carneros 2000), which also has pharmacological potential (Macedo *et al.* 2007). These compounds have also been found predominantly in medicinal trees of the Caatinga (Almeida *et al.* 2005; Alencar *et al.* 2009), which are indicated by local people to treat various therapeutic indications.

Several ethnobiological studies have found that species that are used to treat a variety of different diseases are associated with bitter taste by local populations and that most medicinal plants were indicated by people as having this taste (Brett 1998; Ankli *et al.* 1999; Medeiros *et al.* 2015), suggesting that bitter-tasting plants could have greater popularity and/or versatility. Nonetheless, we could not determine whether or not bitter taste exerts an influence on popularity and/or versatility because the low number of studied species with this taste precluded statistical analysis. Thus, it is necessary to develop other studies to test the existence of such a relationship.

Limitations of this study

Variation in the data for some explanatory variables was relatively low. This limited variation may be related to the small scale of possible scores (one to four) attributed to plant-parts. Thus, people in either community may have attributed the same scores to the same factor for several plant-parts. In this sense, statistical analysis may have failed to capture delicate associations. Perhaps a larger scale of scores (zero to 10, for example) could have detected greater variation in the contexts studied.

Palatability and availability varied the most. The limited variation in the efficiency variable may have been occurred because averages of averages were calculated for the analyses since, for this factor, people assigned scores according to the therapeutic indication treated by a certain plant-part, and thus a plant part may have had several indications from the same person. Since the unit for all other explanatory and dependent variables was plant-part, it was necessary to calculate the average of the averages of the scores for these cases.

Finally, the low number of plant-parts used in this study, as well as the small sample universe, further limits additional generalizations.

Conclusions

All factors (availability, palatability and efficiency) acted, at some point, to explain popularity and/or versatility, sometimes inisolation (palatability) and other times together (efficiency and availability). The differences in explanatory variables for popularity and versatility reinforces the importance of investigating such phenomena individually and in a multifactorial context.

We identified that medicinal plant selection does not occur randomly in the contexts studied since local perception about availability, in association with efficiency, influenced the versatility of medicinal plants in one of the contexts, and palatability (popularity and versatility) in the other. Although we did not find remarkable differences between the studied communities that would justify the distinctions in our findings, we think that new research questions and methods could help fill this gap. The next step would be to obtain a better understanding of local differences concerning the attribution of tastes and what guides local perceptions of efficiency and availability so that phytochemical and phytosociological parameters could be assessed.

Besides understanding the logic behind the role of palatability, efficiency and availability, future studies should also focus on including novel variables. The frequency of occurrence of diseases treated by plants may be an interesting factor to include in a multifactorial approach. We expect that plants used for more frequent diseases would have higher popularity.

In general, we expect that with the development of new studies in different socio-environmental contexts, context-dependent characteristics would boost or reduce the importance of availability, palatability and efficiency. For the moment, our study indicates that there may be strong differences among the factors that guide the selection of medicinal plants, even in communities that are located near each other and that are relatively similar from a socio-environmental point of view.

The results obtained here raise some questions that may be interesting targets for future studies. Does the perception of a resource as more or less palaTable depend on the compounds that it presents? If different variables (availability and efficiency; palatability) can act in the selection of plants in communities that are relatively near each other, what factors can make availability, palatability and efficiency gain or lose authority in explaining the selection of medicinal plants? Can bitter taste influence the popularity and versatility of such plants? In order to answer these questions, several studies in different socio-environmental contexts are needed.

Acknowledgements

The authors thank the communities of Igrejinha and Batinga for their kind support to the research. They also thank the National Council for Scientific and Technological Development (CNPq) for granting a Master's scholarship to RAC and a Productivity grant to PMM (grant number 302786/2016-3). Thanks to the INCT Ethnobiology, Bioprospecting and Nature Conservation, certified by CNPq, with financial support from FACEPE (Foundation for Support to Science and Technology of the State of Pernambuco—Grant Number: APQ-0562–2.01/17).

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