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Disease-Consensus Index as a tool of selecting potential hypoglycemic plants in Chikindzonot, Yucatán, México

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Abstract

There is a general lack of adequate methods to quantitatively assess the importance of specific medicinal plants in a culture. In Mexico like in many other countries type 2 diabetes is an increasing health problem and the use of medicinal plants to treat this disease is widespread. In the present study we propose a mathematical tool for analysing ethnopharmacological field data, with the ultimate aim to select species with most prominent impact on a community to treat a single disease. Using this tool in a Yucatec Mayan community we demonstrate that *Malmea depressa* (*Baill.*) *R.E.* Fr. and *Cecropia peltata* L. are culturally most salient hypoglycemic plants in this community.

Keywords: Disease-Consensus Index; Hypoglycemic plants; Type 2 diabetes; Traditional medicine; Ethnobotany; Maya; Mexico

1. Introduction

Type 2 diabetes is one of the most important health problems in Mexico (SSA, 2005) and is commonly treated using a large variety of medicinal and health food plants (Andrade-Cetto, 1995; Andrade-Cetto and Heinrich, 2005). In Mexico at least 306 species from 235 genera and 93 families are used to treat diabetes. On a world-wide level, it is the most common endocrine disorder. The World Health Organization (WHO, 2004) estimates that in Mexico the number of diabetic people will increase from 2.2 million in 2000 to more than 6 million in 2030, about 281%, world wide this figures will increase on an average of 214%.

Diabetes also is the first cause of mortality among the Mexican population (SSA, 2005). Because of the complications linked to diabetes like heart disease, retinopathy, kidney disease, and neuropathy, it is also a common cause of chronic morbidity and disability among the working population. The term diabetes mellitus describes a metabolic disorder of multiple etiologies and is characterized by chronic hyperglycemia with disturbances of carbohydrate, fat and protein metabolism resulting from defects in insulin secretion, insulin action, or both. The causes of Type 2 diabetes are either predominantly insulin resistance with relative insulin deficiency or predominantly an insulin secretion defect with or without insulin resistance (WHO, 1999).

The biguanide metformin is an example of a drug modelled on the basis of the natural product guanidine obtained from the French lilac; *Galega officinalis* L. traditionally used as an anti-diabetic (Witters, 2001). In ethnobotanical driven drug development project searching for novel therapeutic entities clear selection criteria are needed (Cordell and Colvard, 2005; Patwardhan, 2005).

One way is always the quantification of the species use as exemplified in the works of Trotter and Logan (1986) (cf. Phillips, 1996). With regard to Mexico, Heinrich et al. (1998) stated: "when we examined the use of medicinal plants there are two alternatives: consensus and variation". They analyzed semi-quantitative ethnobotanical data from several studies with the Nahua, Zapotec and Maya and developed the Factor

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Informant Consensus (F_{IC}[2]). The factor was used to highlight plants of particular intra- and intercultural relevance and the agreement in the use of plants for the treatment of gastrointestinal problems between the selected cultures was particularly strong.

Since the F_{IC} analyzes the general use of plants and classifies the illnesses in broad disease categories (several diseases based on the organ systems in one category), the main limitation of this approach has been the lack of analysis on the level of one single disease/syndrome. In order to select species which are relevant for the treatment of one specific disease like diabetes, we developed the Disease-Consensus Index (DCI[2]), and tested its usefulness using diabetes as an example in the community of Chikindzonot, Yucatán, where ethnobotanical studies had been conducted previously (Heinrich et al., 1998; Ankli et al., 1999; Ankli, 2000). Specifically, the aim of the present work is to select the culturally most important species used by diabetic people in a single area to treat the disease and to assess how useful this approach is to prioritise species for further ethnopharmacological studies.

2. Background

2.1. Chikindzonot, Yucatán

The municipality of Chikindzonot is located in the centre of the state of Yucatán, at 20°03′–20°27′ North and 88°43′–88°20′ West at 33 m above sea level. The climate corresponds to tropical monsoon with summer rains and a mean annual temperature of 25.9 °C. The type of vegetation is medium–high subtropical rainforest (Rzedowski, 1978). Species such as *Swietenia macrophylla* King (caoba), *Cupressus arizonica* Greene (cedro), *Ceiba pentandra* (L.) Gaertn. (ceiba), *Ceiba parvifolia* Rose (pochote), and *Bursera simaruba* (L.) Sarg. (chakah) are typical for this region.

The municipality includes the following core communities: Chikindzonot, Ekpedz and Chan-Chichimilá (CESEM, 2005). According to INEGI (2005) Chikindzonot's population is 3511 inhabitants (1784 men and 1727 women). About 2963 inhabitants are recorded as native speakers of Maya. The most important economical activity in the area is agriculture (65.6%); followed by small-scale traders (17.4%). National health services are available in the municipality; the SSA offers one health centre with adequated equipment for primary health care (INEGI, 2005).

2.2. Previous ethnobotanical work

While conducting a detailed ethnobotanical study focusing on all medicinal plants (Ankli et al., 1999; Ankli, 2000), the authors had already noticed the importance of diabetes in the community: "Diabetes is now considered an important health problem by the local health authorities, and informants often claim to suffer from this illness".

With respect to the use of plants for treating diabetes the author conclude; "The Yucatec Maya consider plants to be effective in the treatment of the latter illness if the plants act as diuretic". Among the seven plants reported to treat diabetes, the authors conclude that *Mosannona depressa* (Baill.) Chatrou cited as (*Malmea depressa* Baill)[3] is the most popular treatment against kidney problems and diabetes (Ankli, 2000).

3. Methods

3.1. Case detection

With prior ethical approval by our university (UNAM), local authorities were contacted and the relevant permits were obtained. Diabetic patients were traced from the Health Centre (part of the services of the Mexican Department of Health; "SSA"): their names, ages, last glucose measure, treatment and address (initial list or list 1) were recorded. In addition, since not all diabetics attend to the health services, we asked the people from list 1 if they had relatives or knew other sufferers from this illness. Using this snowball approach, we attempted to cover as large a sample of all diabetics as possible (list 2). An exhaustive census of all diabetics in the population was neither the goal of this project nor would it be feasible. Diabetic people were interviewed on the basis of structured questionnaires, during short stays in the community in 2003, 2004 and 2005.

The purpose of the study was clearly explained to the participants to avoid possible misinterpretations. Individuals were advised that their participation was voluntary and had nothing to do with the health care services or the promotion of any medications. The goal was the evaluation of the use of medicinal plants to treat diabetes type 2. All participants were free to withdraw from the interviews at any time.

3.2. Interviews

Interviews were conducted by our group with the first 10 detected patients (list 1); we used a semi-structured questionnaire previously tested by Andrade-Cetto (1995), to get the perception of medicinal plants used to treat the illness among type 2 diabetics. On the basis of Ankli's work (2000) we visited the traditional healers using the same questionnaire. Medicinal species mentioned were collected in situ with the help of the local healers or the diabetic people. Additional relevant data relating to the informants' knowledge about plants like growing location, part used, flavour and mode of preparation, were also elicited. All data were analyzed in our laboratory, plant material were precisely determined and mini-herbaria were made for further

[2] List of abbreviations: (1) F_{IC}: index of informant consensus, (2) DCI: Disease-Consensus Index, (3) *Vxi*: numerical value for one species, over the information proportionate by one informant, (4) $\sum Vxi$: the mathematical sum of *Vxi*, (5) *mVxi*: statistical mean of *mVxi*, (6) Cc: Correlation coefficient, (7) Pm: preparation way factor.

[3] The species name was changed from Malmea depressa (Baill.) R.E. Fr. To Mosannona depressa (Baill.) Chatrou (Chatrou, 1998) and this change was recently confirmed by the Nomenclature Committee of the International Botanical Congress (Vienna, 2005).

field reference. On the basis of the recorded perceptions about the use of medicinal plants to treat diabetes a specific questionnaire to obtain the index was developed and administered to 46 type 2 diabetics (list 2) and 3 healers were interviewed, on the basis of 25 questions, from which 10 were used specifically for calculating the index.

3.3. Questionnaire

The questionnaire contains 25 questions, 15 are about the personal perception of the disease, personal information like, gender, age, address, education level and spoken language which are not direct related to the DCI. The following questions were used to calculate the index: (1) plant name in Maya or Spanish, (2) general plant description, (3) mode of preparation, (4) way of administration during the treatment, (5) "Organoleptic" characteristics, like flavour, odour, texture, (6) main symptoms after the plant consumption, (7) how often must the species (tea) be administered, (8) did the person feel better after consuming the species, (9) general knowledge about the region of gathering or information about how to grow the species, (10) whether the patient has recommended the species to other members of the community.

The analysis of the data consists of a binary evaluation – (1) or "yes", which indicates the knowledge or (0) or "no" – a lack of such knowledge. In each case this refers to a single question, allowing a mathematical analysis of the results. The potential maximum value for one informant (about one plant, OP) is always 1. In this case we evaluated on the basis of 10 questions, but this methodology provides a method applicable to as many questions as required in the context of the research (Eq. (1)). If all informants have knowledge about all aspects of this medicinal plant's use and biology, a species can score a maximum of 1 (see Section 3.4):

$$\mathrm{OP} = \frac{(\text{answers (yes)} \times 100/\text{number of question})}{100} \quad (1)$$

where OP is the one plant value.

3.4. Index

The Eq. (2) used was specifically developed for this project (see Section 4). The Disease-Consensus Index (DCI) is a comparison based on mathematical aspects (limit theory), the ideal answers of informant reports (Cc) and the ideal answers for each species (Vx).

It is calculated as follows:

$$\mathrm{DCI} = \left(\frac{\sum_{i=1}^{\infty} Vxi}{\mathrm{Cc}} mVx\right) \mathrm{Pm}^{-0.1} \quad (2)$$

where (x) is any species; (ΣVxi) the sum of the individual values obtained for one species within the community. Evaluates: (Knowledge, Mentions); (mVx) the statistical mean of the individual values, for one plant. Evaluates: (Knowledge); Cc the Correlation coefficient, defined as the maximal number of informants whom refer a plant. Evaluates: (Mentions); $\mathrm{Pm}^{-0.1}$ is the compensation factor, and analyses the dispersion for one plant, considering the mode of preparation and parts used.

4. Results and discussion

4.1. Development of the index

Here we propose a new index for evaluating the consensus within a group of people with one illness (in this case diabetes) as it relates to use of various species. Crucial for the index is the inclusion of various types of data about a single species as well as the collective knowledge for the same species in the group of informants and subsequently the comparison of the individual (folk) species.

When conducting an ethnobotanical survey searching for new plants with potential pharmacological effects in the treatment of a disease, a simple free listing of species may not result in a selection of species which are culturally most important or which are the best candidates for further studies. Knowledge/lack of knowledge (1–0) about a plant and its use, does not yield information regarding the relative importance and knowledge about a species by an individual informant and the community as a whole.

The DCI solves this problem based on the following assumptions:

(a) Medicinal plants are not selected and used at random; the use of a plant is a product of a directed selection by the people.
(b) People have different degrees of knowledge and appreciation about one species, which can be analyzed quantitatively.
(c) Different species can be differentiated on the basis of this individual knowledge.

Consequently, with the DCI we evaluate the knowledge about one plant, the plant knowledge as a remedy (for the specific decease) and how much the people appreciate the plant/remedy.

In mathematical terms the *limit theory* is used, evaluating the degree of mentions for a plant and the knowledge about this plant, the index is formed by three simple equations; in the first one the sum of the mentions for one plant in the community between the maximal number of informants who reports a plant, *ideal answer* (Cc); evaluates the degree of mentions for the desired plant. $\sum_{i=1}^{\infty} Vxi/\mathrm{Cc}$.

In the second one the sum of mentions multiplied by the statistical mean of the individual values (that is the proportion between knowledge and occurrence, for the total number of informants whom report a plant) evaluates the knowledge about the desired plant, based on the *ideal answer* the same $mVxi$ for all plants. $\left(\sum_{i=1}^{\infty} Vxi/\mathrm{Cc}\right) mVx$.

In virtual trial runs, choosing random data to evaluate the number of mentions and the knowledge, we confirmed that this index did not favour the species with more mentions, or the one with the highest mean (Knowledge). The aim of our analysis is to select the more consistently used species within a community, for a specific disease. Therefore, the index measures *how many*

Table 1
Used species used in the treatment of type 2 diabetes

Common name	Scientific name	Family	Plant part used	Form of preparation and use (Pm)	$\sum Vx$	m*Vx*	DCI values
GUARUMBO X'koochle	*Cecropia peltata* L.	Cecropiaceae	Leaves and root	Three forms: up to three leaves boiled in 1 l of water, AU.; same as above, just adding some salt; the decoction of the root as AU	15.8	0.93	0.78
ELEMUY	*Malmea depressa* (Baill.) *R.E.* Fr.	Annonaceae	Root	Two forms: root decoction with or without salt; root left in cold water for some days, AU	12.7	0.82	0.56
GUACO Wahk'oh	*Aristolochia littoralis* D. Parodi	Aristolochiaceae	Root	One form: root decoction in 1 l of water, AU	2.4	0.8	0.12
NONI Piña ak' Piña kam	*Morinda yucatanensis* Greenm.	Rubiaceae	Fruit	One form: mature fruit liquified in 1 l of water, AU	2.4	0.8	0.12
VIPEROL AK Viperol negro	*Crossopetalum gaumeri* (Loes) Lundell	Celastraceae	Leaves	One form: leaves decoction in 1 l of water, AU	1.9	0.95	0.11
TRONADORA K'anlol	*Tecoma stans* (L.) Juss. ex Kunth	Bignoniaceae	Flowers and leaves	One form: decoction of flowers and young leaves in 1 l of water, AU	1.9	0.95	0.11
Morax	*Momordica charantia* L.	Cucurbitaceae	Leaves	One form: leaves decoction in 1 l of water, AU	1.5	0.75	0.07
NOPAL	*Opuntia* sp.	Cactaceae	Cladode	One form: half a cladode liquefied without water. Drunk during the morning	1	1	0.06
Xpasmar xiw	*Ageratum houstonianum* Mill	Astearaceae	Leaves	One form: decoction of leaves in 1 l of water. AU for 3 days	1	1	0.06
AGUACATE	*Persea americana* Mill	Lauraceae	Leaves	One form: large leaves chopped and decocted in 1 l of water, AU	1	1	0.06
COCO CHICO	*Cocos nucifera* L	Arecaceae	Fruit	One form: six coconuts (average size) decocted in half a liter of water, AU	1	1	0.06
HIGUERA CHICA Higuerilla Xk'ooch	*Ricinus communis* L.	Euphorbiaceae	Leaves	One form: one decoction of leaves in 1 l of water, AU (drunk cold)	1	1	0.06
PELO DE ELOTE Maíz	*Zea mays* L.	Poaceae	Elote hair (pistils)	1 form: decoction of 'hair' in 1 l of water, AU	1	1	0.06
RESINA DE PLATANO Ha'as	*Musa sapientum* L.	Musaceae	Resin	One form: banana tree resin added to 250 ml of fresh water, AU	1	1	0.06
SAK-AK'	*Arrabidaea floribunda* Loes	Bignoniaceae	Steam	One form: an small steam chopped and decocted in 1 l of water, AU	1	1	0.06
PEPINO KAT	*Parmentiera aculeata* (Kunth) Seem	Bignoniaceae	Fruit	One form: fruit decoction in 1 l of water, AU	1	1	0.06
CHAYA Chay	*Cnidoscolus aconitifolius* subsp. *aconitifolius*	Euphorbiaceae	Leaves	Two forms: leaves decoction in 1 l of water and AU. Leaves liquefied in 1 l of water, AU	0.4	0.4	0.009
COCOYOL	*Acrocomia mexicana* Karw. ex Mart	Arecaceae	Root	One form: root decoction in 1 l of water., AU	0.2	0.2	0.003

AU, drunk as 'aqua de uso' (daily water), CC value is 16.

people know a single species and as a derivation, how much does each one know about the species.

In the third part of the equation we introduce a comparison of the *dispersion* in the way the people use the plant; in example for one species the part used may be the leaves (1), or the leaves and the stem (2), the mode of preparation (Pm) evaluates the dispersion and it is elevated to 0.1 as a logarithmic factor, and is then – for mathematical reasons – converted to a negative value.

4.2. Use of the index with diabetic patients in Chikindzonot

We confirmed Type 2 diabetes is an important health problem among the Yucatec-Maya in the community of Chikindzonot. Informants share similar concepts and ways of perceiving the disease. In terms of how people call the illness, 91% label it as diabetes and only 9% as "Orina dulce" (sweet urine) and the Mayan equivalent "Chu-juk'uis". Many of the informants associate the onset of their problem (diabetes) with different psychological problems they faced at a certain point in the past. In most of the cases, it had something to do with fear, anger, worry, sadness and stress. After a shocking event, people started feeling ill, facing symptoms like tiredness, dry mouth, polyuria, blurred sight, lose of weight, etc. In the end, people had to attend to the physician for checking (cf. Daniulaityte, 2004 in Guadalajara, México).

Diabetes generally requires modern methods of diagnosis. For a basic diagnosis blood sugar values have to be determined. In Chikindzonot 80% of the patients receiving synthetic drugs and learned about their sickness after being diagnosed in the municipal health centre. As a result of attending the municipal health centre for purposes different to type 2 diabetes (e.g. broken bones, stomach pain, knife cuts), 14% were diagnosed with this condition. In sum 94% had a medical diagnosis and only 6% a local healer or other specialist diagnostic.

In 2005, 48 patients (83%) attended the health centre once a month, but 10 (17%) did not, and, therefore, these cases remain statistically undetected by the Mexican health service. If we compare these 58 detected patients (2005) with the 10 detected at the health centre in 2003 (at the start of our study), in 3 years there has been an increase of 580% of detected patients.

Seventeen species were detected as being used in the treatment of the illness, many more than Ankli (2000) reported (Table 1). According to the results obtained using the Disease-Consensus Index (Table 1), the main species used are *Cecropia peltata* L. (score: 0.74) and *Mosannona depressa* (Baill.) Chatrou (0.59), (already highlighted by Ankli, 2000) both genera are relatively well known for their hypoglycaemic effect. If we compare this with the previous report by Ankli et al. (1999), *Mosannona depressa* is mentioned by the authors as the most important species with eight use reports and *Cecropia peltata* was mentioned by only four. Of note, *Chromolaena odorata* (L.) R.M. King and H. Rob was recorded by Ankli et al. (1999) as an important species, but remained undetected in our study.

The hypoglycemic effect of *Cecropia obtusifolia* Bertol has already been demonstrated in streptozotocin diabetic rats (Andrade-Cetto and Wiedenfeld, 2001) and a possible mechanism of action is under discussion (simultaneous targeting of gluconeogenesis and glycogenolysis; Andrade-Cetto and Heinrich, 2005), while the hypoglycemic effect of *Mosannona depressa* was demonstrated using streptozotocin diabetic rats (Andrade-Cetto et al., 2005).

In general terms, plants with a lower DCI have been studied in less detail pharmacologically or phytochemicaly: *Parmentiera aculeata* (Kunth) Seem (0.06) was assessed by Pérez-Gutíerrez et al., (1998, 2000, cited as *Parmentiera edulis*) and *Acrocomia mexicana* Karw. ex Mart. (0.003) was at the centre of the study by Pérez et al. (1997).

5. Conclusions

We noted an alarming increase in the number of diabetic people in the period 2003–2005. In part this may well be due to a more systematic detection of diabetics by physicians (esp. in the Health Centre). Furthermore is the possibility that several people with Insulin resistance or initial phases of type 2 diabetes were not previously detected. During our field work directed exclusively to detect diabetic people and the species used in its treatment in Chikindzonot, we identified a larger number of plant species used locally as hypoglycemic medicines as compared to previous work performed in the mid-1990s in Chikinzonot and Ekpedz. This clearly depicts ongoing changes in Mexico.

The importance of the methodology proposed here is primarily to understand the ethnomedical importance of plants used in the treatment of a specific disease, i.e. *to contribute to an understanding of the role of these plants in a culture* (Heinrich et al., 1998). In addition as part of ongoing phytopharmacological and phytochemical studies, the first author has worked with *Mosannona depressa* and *Cecropia peltata*, For the first species hypoglycemic effect have been demonstrated (Andrade-Cetto and Wiedenfeld, 2001), but the possible mechanism of action is not yet understood. *Cecropia peltata* must be studied as has been done with *Cecropia obtusifolia*.

In the context of the discussion here it is important that these species were selected prior to the development of the index proposed here. Thus the two examples provide some initial evidence that plants with high score are better candidates for further phytopharmacological investigation and after good laboratory results for potentially developing them into phytomedicines especially ones for local use in rural regions of Mexico.

In conclusion, here we propose a novel tool for assessing the relative cultural importance of medicinal plants for a specific illness and explore its usefulness in the context of diabetes. An approach like this one needs to be tested in different communities and with a larger sample, it contributes to more rigorous and at the same time culturally acceptable tools for ethnobotanical research (cf. Edwards et al., 2005). This effort is part of broader and crucially important processes in a country like Mexico where diabetes is a serious health problem and where medicinal plants are used widely. Such local uses must be investigated and scientifically evaluated by researchers and physicians. Clearly, this also requires appropriate initiatives by the (Mexican) government and its dependencies. In the near future, some species will hopefully be developed into more widely available phytomedicines. Lastly we will need to develop methods to allow for a better way to return the results of such research to the original keepers of knowledge (Jaeger, 2005).

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