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The taste of heat: How humoral qualities act as a cultural filter for chemosensory properties guiding herbal medicine

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A B S T R A C T

Ethnopharmacological relevance: Organoleptic properties, and more specifically chemosensory cues, have been shown to guide therapeutic applications of medicinal plants. Humoral qualities, on the other hand, are widely believed to be an abstract concept, mainly applied *post hoc* to validate therapy. However, the nexus between humoral qualities, chemosensory properties, and medicinal plant uses has never been systematically assessed.

Aim of the study: To systematically analyse the correlations between chemosensory properties, humoral qualities, and medicinal uses of selected botanical drugs.

Methods: The issue was approached experimentally via an organoleptic testing panel, consisting of Zoque healers in Chiapas, Mexico. The healers smelled and tasted 71 selected herbal drugs and subsequently commented on their humoral qualities and therapeutic uses. The resulting dataset is analysed for correlations between these variables using Bayesian statistics. Qualitative data on the characteristics and role of the hot-cold dichotomy complement the quantitative analysis, facilitating meaningful interpretation.

Results and discussion: The results reproduce and extend the findings of previous studies, which established specific correlations between chemosensory cues and nosological units. The key predictors of drugs' therapeutic uses, however, are their humoral qualities, which are themselves conditioned by taste and smell. These findings appear to be valid for drug samples known to the participants as well as for unfamiliar samples. Thus, this study establishes the role of the hot-cold dichotomy as an important cultural filter connecting organoleptic properties and therapeutic uses of herbal drugs.

Conclusions: There is considerable cross-cultural consensus in Mesoamerica for the specific correlations described in this study. Given the continued pervasiveness of the hot-cold dichotomy, humoral qualities and the underlying organoleptic properties ought to be increasingly considered in the design of pharmaceutical products as well as public health strategies. Such culturally appropriate adjustments may considerably improve the perceived quality and effectiveness of healthcare.

Keywords: Mexico Hot and cold Organoleptic properties Medical anthropology Health beliefs Medicinal plants

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1. Introduction

The hot-cold dichotomy is the most widespread explanatory concept in Mesoamerican folk medicine and has received considerable amount of attention in anthropological research (see Anderson, 1987; Foster, 1994; Manderson, 1987; and Messer, 1987 for an overview). According to this concept, illness is the result of a disturbed equilibrium and treatment is based on the principle of opposites. Its basic framework, thus, strikingly resembles the maxims of humoral medicine (cf. Galen, 1561; Jackson, 2001). Indeed, the influence of European humoral concepts on

Mesoamerican medical beliefs and practices is undeniable (Currier, 1966; Foster, 1953, 1987, 1994: 147–164; Madsen, 1955). On the other hand, epistemological evidence (see glossary) implies a pre-Columbian (before CE 1492) foundation, as the principle of binary opposition figured prominently in indigenous medical systems (Lopez Austin, 1980: 285–318; Manderson, 1987; Messer, 1987; Ortiz de Montellano, 1980; Tedlock, 1987). Bye et al. (1995: 76) and Ortiz de Montellano (1990: 205-9) have argued that analogous concepts of polar opposites formed the basis for the rapid syncretic evolution of medical theory and practice in post-conquest Mexico.

A recent ethnopharmacological study (García-Hernández et al., 2015) pointed out the crucial role of humoral qualities (see glossary) in determining therapeutic uses of herbal drugs. Foster (1988, 1994: 134) and Messer (1981), on the contrary, concluded that the hot-cold dichotomy serves only for *post hoc* validation of treatment. That is, remedies are not chosen based on humoral criteria; rather, humoral qualities are assigned, *a posteriori*, according to the drugs' perceived effectiveness in curing particular ailments. Despite its continued pervasiveness, the hot-cold dichotomy has been criticised for being excessively abstract, arbitrary, flexible, and narrow in order to be empirically verified (Ankli et al., 1999; Brett, 1994; Foster, 1994: 138; Logan and Morrill, 1979; Ortiz de Montellano and Browner, 1985). However, recent pharmacological studies indicate that there is a physiological basis for the hot-cold classification of herbal drugs in traditional Chinese and Iranian medicine (Chao et al., 2011; Parvinroo et al., 2014; Zhao et al., 2011).

Among Mesoamerican societies, chemosensory properties (see glossary) play an important role in evaluating the medicinal potential of plants (Ankli et al., 1999; Brett, 1998; Brett and Heinrich, 1998; Frei et al., 1998; Heinrich, 1998; Leonti et al., 2002). Gustatory and olfactory cues are considered when distinguishing medicinal from non-medicinal taxa as well as for guiding specific uses. As sensory cues can be related to plant secondary metabolites, these data have a particular potential to bridge the gap between traditional medicine and modern pharmaceutical sciences (Ankli et al., 1999; Brett and Heinrich, 1998; Johns, 1990: 288; Shepard, 2004). While sensory perception is essentially a physiological process, the interpretation and evaluation of chemical stimuli is to a large degree determined by culture (Brett and Heinrich, 1998; Classen, 1997; Johns, 1990: 3, 14, 163; Leonti, 2011; Purves et al., 2004: 355; Sorokowska et al., 2014).

Several studies discuss the relationship between chemosensory and humoral qualities of medicinal plants (Berlin and Berlin, 1996: 60–67; Brett, 1994; Frei et al., 1998; Leonti et al., 2002; Messer, 1981; Tedlock, 1987). However, the interrelation and its role in determining therapeutic uses have never been systematically assessed. This case study with the Chiapas Zoque therefore aims at:

(i) Contributing to an enhanced scientific understanding of humoral theory in traditional Mesoamerican medicine by describing the hot-cold dichotomy as an ethnomedical concept of the Chiapas Zoque.
(ii) Providing further data describing the role of chemosensory cues for the selection of herbal medicine.
(iii) Assessing whether there is an empirical basis for the hot-cold dichotomy in folk medicine by testing for correlations between humoral qualities, chemosensory properties, and medicinal uses of selected botanical drugs (Fig. 1).

2. Ethnobotanical background

The Zoque belong to the Mixe-Zoque linguistic family (Wichmann, 1995: 8–12), the members of which are considered to have descended from the Olmecs, Mesoamerica's "mother culture" (e.g. Campbell and Kaufman, 1976; Coe and Houston, 2015: 14; Coe and Koontz, 2013: 62; Justeson and Kaufman, 1993). The Chiapas Zoque have established their communities in diverse ecological environments, including both humid and dry tropical lowlands as well as humid temperate highlands (Thomas, 1974: 33–38; Villa Rojas, 1975: 21). Although the national and globalized cultures are increasingly influential in Zoque communities, most still rely on family-based agriculture for their subsistence and traditional med-icine plays and important role in local healthcare. In a recent study we have documented 3633 use-reports on 421 plant species used medicinally by the Zoque of Chiapas (Geck et al., 2016).

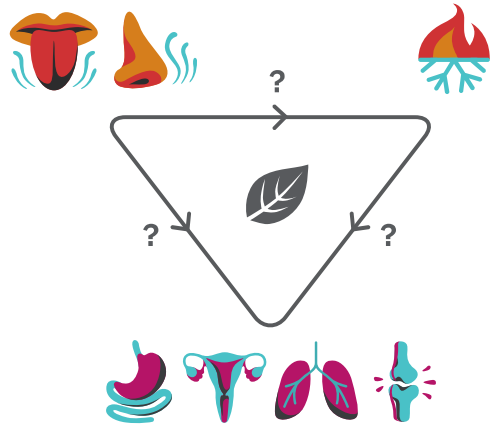

Fig. 1. The epistemological model underlying the principal research question: How are chemosensory cues, humoral concepts and therapeutic uses of medicinal plants correlated?.

3. Methods

Field research was carried out from July 2014 to July 2015 in five municipalities of Chiapas, Mexico. Participant observation and semi-structured interviews were essential for establishing the ethnobotanical background. The former was particularly important in order to achieve a certain degree of embodiment of local flavours and odours. Terms in Zoque language have been transcribed according to the standard established by indigenous academics and the Mexican National Institute of Indigenous Languages (INALI, 2011).

3.1. Focus group sessions

In order to obtain a detailed understanding of the concepts underlying the ethnomedical system, four focus groups were established (Bernard, 2006: 232–239), representing the ecological diversity of the Zoque homeland. Each focus group consisted of four to six healers and in each group at least one midwife, one bonesetter, and one herbalist were present (purposive sampling; cf. Bernard, 2006: 189–191). All informants also participated in the previous ethnobotanical study and were fluent in both Zoque and Spanish. Every group met for three two-day sessions revolving around the following topics:

(i) Disease classification and aetiology (see glossary);
(ii) The hot-cold dichotomy and its function and meaning in traditional worldview and medicine;
(iii) Concepts and terminology of taste and smell and their importance in regard to herbal medicine.

In session one, the participants classified all the illnesses and diseases recorded during fieldwork (Geck et al., 2016) in a modified version of free pile sorts (Bernard, 2006: 311–315). The disease terms were written on pieces of paper, which the participants grouped and regrouped until circumscribable categories, or nosological units (see glossary), emerged. The consensus between the four focus groups yielded 17 emic-defined (see glossary) disease-categories (cf. Staub et al., 2015). In the following, discussions focussed mostly on the aetiology of the different types of illness and disease.

In the second session, the participants were asked to explain their understanding of hot and cold and the applicability of this concept to different aspects of the natural and supernatural world. Subsequently, the emphasis was on the role of the concept in traditional Zoque medicine. Specific questions discussed included:

- What is the humoral state of a healthy human mind, body and soul?
- Are there parts of the body, which are metaphorically warmer or colder than others?
- How does heat or cold enter the body and how is the changed humoral state manifested?
- How can hot and cold illnesses be distinguished from one another and how is this diagnosed?
- How is the humoral quality of medicinal plants established?

Finally, the informants were again presented with the disease terms from session one and asked whether each condition could be classified according to the hot-cold concept and, if so, what their humoral quality was. The complete results of the humoral evaluation of individual health conditions are presented in Appendix A.

Session three began with a general discussion of tastes and smells, followed by a free listing of Zoque and Spanish terms for chemosensory properties. The resulting lists were then discussed in detail, focussing on the relation between these properties, humoral qualities, and medicinal plants. The consensus between the four focus groups yielded the olfactory and gustatory properties used in the subsequent organoleptic (see glossary) testing (Table 1).

3.2. Organoleptic testing

For determining the chemosensory properties and humoral qualities of plants used as medicine by the Zoque, a panel was established, consisting of nine particularly knowledgeable and motivated participants of the focus groups (purposive sampling; Bernard, 2006: 189–191). Three of the panellists specialized as herbalists and two each as bonesetters, midwives and ritual healers; two were women, seven men; their age ranged from 44 to 81 (average 58.8 ± 12.7). Each panellist was thoroughly briefed on the purpose and process of the testing and gave oral consent for participation.

The samples for the testing were selected from the 421 medicinal plant species previously documented with the Chiapas Zoque (Geck et al., 2016). From each of the 17 therapeutic categories the most salient drugs were chosen (between two and seven), the number of taxa depending on the number of use-reports in the respective category. Voucher specimens were collected for the resulting 48 drug-samples (a specific plant part of a specific species) and taxonomically identified at the National Herbarium of Mexico (MEXU).

The nine panellists tested all 48 samples in a randomized order, individually in several sessions. Each drug sample was presented fresh and collected from the same plant individual or population throughout the panel. Each panellist first smelled and then tasted a sample and commented on the perceived sensations. The answers on olfactory and gustatory sensations were recorded as one of the pre-defined properties as well as “other” or “none” (Table 1). A maximum of three answers per sample were considered for smell and taste respectively and the panellists were asked to rank those sensations according to intensity from strongest to weakest. After each testing, the panellists were asked to wash their hands and rinse their mouth with water. A 15 min break between each sample was used to inquire about:

(i) The drug's humoral quality;
(ii) The reason for this hot-cold classification;
(iii) The drug's therapeutic uses;
(iv) The reason for each use.

In order to further investigate these interrelations, an additional 23 commercially traded, yet locally unknown, drugs were presented for testing. These herbal remedies were bought from medicinal plant stalls at the *Mercado Público José María Pino Suárez* in Villahermosa, Tabasco. Only drugs derived from taxa listed in the digital library of traditional Mexican medicine (http://www.medicinatradicionalmexicana.unam.mx/index.php; accessed 6 March 2016) were considered. Taxonomic identification was based on common names recorded in the market and verified with voucher specimens. However, given the degree of processing of these samples, an accurate taxonomic identification cannot be guaranteed. The samples were presented in a dried state and the panellists were asked to guess the therapeutic uses of the drug. For the descriptions, including taxonomic details and voucher numbers, of all samples please refer to Appendix B. Complete sets of herbarium specimens are deposited at MEXU and Geneva herbarium (G). The taxa's nomenclature was verified with www.theplantlist.org (accessed 3 March 2016).

3.3. Statistical analysis

Associations or stochastic relations between the different variables recorded for each drug sample during the organoleptic testing were analysed using a Dirichlet process mixture of products of multinomial distributions model (DPMPM). This is a nonparametric Bayesian model for multivariate unordered categorical data (Dunson and Xing, 2009; Si and Reiter, 2013).

The DPMPM uses a prior distribution that reflects the uncertainties on the model that explains the relationship among involved variables. The model is identified by the set of π values, each of which indicates the probability of a specific combination of values for taste, smell, humoral quality, and therapeutic category. This model is needed because the possible number of π values is much larger than that of observations and thus classical regression methods would fail. By using the Bayes theorem, probabilities (π) are then *a posteriori* distributed according to the observed data. *A posteriori* distributions of all π are used to answer the following five inquiries:

(i) Given a certain smell, what is the most probable humoral quality?
(ii) Given a certain taste, what is the most probable humoral quality?
(iii) Given a certain smell, what is the most probable therapeutic category?
(iv) Given a certain taste, what is the most probable therapeutic category?
(v) Given a certain humoral quality, what is the most probable therapeutic category?

Further, for each inquiry the mean value of the Cramer's V statistic is reported, indicating how strong the correlation between the two involved categorical variables is. The Creamer's V is the Chi-Squared statistics normalized to fall between 0 and 1 (0 in case of independence and 1 in case of perfect dependence). All estimations are based on 50′000 Gibbs sampling steps, therefore reported means (of π and Cramer's V statistics) have a standard error of $1/\sqrt{50000}=0.0044$, that is the first two decimals are significant.

While all three intensity levels of taste and smell were included to construct the model, the second and third levels were excluded from the actual analysis due to the large number of blanks (i.e. less than three taste/smell properties were mentioned by the informant for the respective sample). In order to facilitate analysis and interpretation of the data, all tastes and smells that were mentioned in less than five per cent of the records as primary sensations were counted as “other”. Equally, all therapeutic categories mentioned in less than five per cent of the records were combined in “other”, after verifying in a previous model that the limited amount of data on each category yielded no

significant correlations. The complete results of the statistical analysis are presented in Appendix D in the supplementary material.

4. Results and discussion

4.1. The hot-cold dichotomy in Zoque worldview and medicine

Contemporary Zoque principally apply the hot-cold dichotomy in five domains (Fig. 2): (i) topography and ecology; (ii) celestial objects; (iii) colours; (iv) foods and beverages; and (v) health and medicine. As pointed out by Foster (1984, 1994: 115, 120), the neutral humoral state is an ill-defined category for anything with mixed or ambiguous characteristics rather than just the absence of indicators for hot or cold.

In regard to food, the Zoque classification mostly follows the cross-cultural pattern, in which carbohydrate staples are neutral, juicy fruits and leafy vegetables cold, and red meat as well as spicy and greasy foods are hot (cf. Anderson, 1987; Foster, 1994: 12; Logan and Morrill, 1979; Manderson, 1987; Messer, 1981; Messer, 1987; Tedlock, 1987). A noteworthy exception is the starchy *papa voladora* (*Dioscorea bulbifera* L., Dioscoreaceae), which is considered cold as it climbs high in the trees where it is exposed to the winds.

In regard to health and medicine, a humoral imbalance is conceived as the proximate cause for virtually all illnesses. This aetiological association is irrespective of the ultimate causes, which include both naturalistic and personalistic elements (Fig. 3). This contrasts with the claim that the hot-cold dichotomy was by definition limited to naturalistic causation theory (Foster, 1994: 69; Foster and Anderson, 1978: 56).

Once the healthy neutral state is disturbed, the excess heat or cold can manifest itself in a number of ways, and symptoms are often not restricted to specific organs. Typical symptoms of heat include a tangible increase in local or systemic temperature as well as rubor caused by inflammation. Also a general drying of the body, yellow urine, itchy skin and the eruption of furuncles, as well as increased excitability and aggression are characteristic for hot disorders. Excessive cold, on the other hand, is indicated by pale skin and excessive moisture, often accumulated in oedemas, as well as by fatigue, weakness, sadness, and lack of sexual desire. Pain is ambiva-lently classified by the Zoque: toothache, most headaches, and burning or stinging pains are considered hot, whereas dull or pounding pains as well as numbness and cramps are cold. Most of these associations conform to global patterns, reflecting the legacy of European humoral medicine (Anderson, 1987; Foster, 1953, 1987, 1994; Manderson, 1987). These beliefs appear far from moribund and are also held by Mexican migrants living in the USA (Manderson, 1987; Waldstein, 2010).

The general criteria result in a distinctive hot-cold pattern of the different disease categories (Fig. 4). Thus, dental, dermatological, febrile, and ophthalmological conditions but also psychological afflictions and diabetes are mostly perceived as hot, whereas women's and musculoskeletal ailments are mostly cold. Gastrointestinal and soul-related ailments are rather ambiguous, as there are several conditions of which both a hot and a cold version are recognized. For example, the quality of *espanto* (fright), a complex condition related to soul-loss (e.g. Klein, 1978; Ortiz de Montellano, 1990: 153), depends on the place and details of the frightening event. The difference is usually deter-mined by feeling the patient's pulse: cold manifests itself in a low and slow pulse whereas heat causes the pulse to be strong and jumpy. Symptomology, too, is important for diagnosis. Cold diarrhoea, for instance, is light-coloured, mucous, and related to throbbing pain whereas hot diarrhoea is darker, of extremely foul odour, and often accompanied by burning pain (cf. Foster, 1994: 77, 82; García-Hernández et al., 2015). A special case are those conditions caused by a rapid transition from the hot to the cold state (*espasmo* or *espasmazón*; cf. Foster, 1994: 37–38; García-Hernández et al., 2015). Such a "shock" is mostly made responsible for earache and respiratory diseases. The transition is not necessarily of physical nature, it can also occur in the humoral state of the mind or soul. Either way, it results in the manifestation of cold symptoms on the body's exterior while the heat becomes "trapped" inside. These situations are conceived as very delicate and treatment needs to be cautiously balanced in order to avoid exacerbating either extreme.

In order to determine a plant's humoral quality, observation of physiological effects is the most definite approach (cf. Foster, 1994:101). Thus, a cold plant is expected to cause cold symptoms in a healthy person while being beneficial to anyone suffering of a hot ailment. However, before experimenting with new plants, the Zoque healers take sensory cues as well as ecological factors into account. Accordingly, hot plants are mostly found in the lowlands, thrive in full sun, are often deciduous, and appear either dry and pale or of reddish colour. They are coarse to the touch and often spiny, sticky, or rich in resin or latex. Cold plants, on the other hand, are mostly evergreen and grow in the highlands or in shady, moist places. They are smooth-surfaced and soft to the touch, have a vividly green visual appearance, and are often succulent. These characteristics conform to a general pattern in Latin America (Foster, 1994: 103; Leonti et al., 2002; Logan, 1973; Lopez Austin, 1980: 289–303; Madsen, 1955; Mazess, 1968; Messer, 1981; Tedlock, 1987). Finally, all informants agreed that a plant's taste and smell is of considerable importance in predicting its humoral quality as discussed in Section 4.3 (cf. Foster, 1994: 102; Frei et al., 1998; Leonti et al., 2002; Messer, 1981; Tedlock, 1987).

4.2. Chemosensory properties of medicinal plants

The Zoque word for smell (*omompa*) is clearly related to taste (*ompa*) and the Chapultenango dialect does not differentiate between the two at all. This notwithstanding, all informants explicitly discriminated olfactory from gustatory sensations. Astringency, pungency, and irritation are included as tastes, as they were classified as such by the informants. Table 1 gives an overview of the taste and smell properties considered for the organoleptic testing, as well as some typical examples mentioned repeatedly during the focus group sessions. In addition to the listed terms, the Zoque distinguish rotten (*jakapä*) and smoky smells (*joko wujpapä*) as well as salty (*kana pa'ajkpä, jene pa'ajkpä*) and oily tastes (*pänpapä*), yet no informant considered them properties of medicinal plants. Interestingly the term for salty relates to sweetness, as it does for the neighbouring Tzeltal Maya, for whom the two terms are identical (Brett, 1994: 143).

In Section 4.3, the results of the organoleptic testing are presented and discussed in relation to the plants' humoral qualities and medicinal uses. The perception of gustatory and olfactory sensations is highly subjective, depending on genetic, physiological, environmental, and cultural variables (e.g. Classen, 1997; Melis et al., 2015; Prutkin et al., 2000; Shepard, 2004; Sorokowska et al., 2014). Hence, the results of the organoleptic testing should be interpreted in its cultural and experimental context. For the complete results of the testing please refer to Appendix C in the supplementary material.

4.3. Correlations between humoral qualities, organoleptic properties, and uses of botanical drugs

While all informants agreed that chemosensory cues alone are rarely sufficient for determining therapeutic uses, they were considered very valuable for distinguishing hot from cold plants and thus guide therapeutic applications. As expressed by an experienced herbalist from the highland community of Tapalapa:

> "Plants cannot talk, but, through their smell and taste, they tell us if they are hot or cold. Thus we can know what they cure."
>
> Field notes, 3 July 2015

This notion is also reflected in the results of the statistical analysis

Table 1
Chemosensory properties used for the organoleptic testing. The properties placed in brackets were counted as other for the statistical analysis. The typical examples are those most commonly mentioned during focus group session three.

English	Spanish	Zoque	Typical examples
Smells	***Olores***	***Omompa***	
[Of animal protein (meat, fish, or eggs)]	*De carne, pescado, huevo*	*Tzanapä, tzananpä*	*Siparuna thecaphora* (*kun tzantzan*)
Bad, malodorous, stinky	*Apestoso*	*Wujpapä*	*Petiveria alliacea* (*hierba de zorrillo*)
Bitter	*Amargo*	*Takay omompapä*	*Artemisia ludoviciana* (*estafiate*), *Tagetes erecta* (Aztec marigold)
[Earthy]	*De tierra*	*Nas omompapä*	Subterranean parts in general
Good, pleasant, aromatic	*Sabroso, bueno*	*Sunhi omompapä*	*Citrus* spp. (citrus flowers and leaves), *Mentha* spp. (mint), *Ocimum* spp. (basil)
Green, herby, grassy	*De verde*	*Tzukspapä*	*Justicia spicigera* (*tzitz*), *Sambucus canadensis* (elder leaves) *Citrus* spp. (citrus fruit skin)
Irritating, tangy	*Irritante*	*Tzisispapä*	
Menthol, camphor	*Mentolado*	*Nezesomompapä*	*Eucalptus* spp. (eucalypt), *Mentha* spp. (mint), *Pimenta dioica* (allspice), *Polygala floribunda* (*kä tzanhga*)
[Penetrating, strong, musky, repugnant]	*Penetrante, fuerte, de almizcle*	*Jukukpapä, jukuj'kpapä*	*Abelmoschus moschatus* (musk mallow), *Tanacetum parthenium* (feverfew)
[Resinous, of incense]	*Resinoso, de incienso*	*Tänä omompapä, pomo ompa*	*Protium copal* and *Bursera* spp. (*copal*), *Pinus* spp. (pine resin)
[Sour]	*Agrio*	*Katzu omompapä/ wujpapä*	*Citrus limon* (lemon juice), *Vitis tiliifolia* (wild grapes)
Sweet	*Dulce*	*Pa'ajk omompapä*	*Foeniculum vulgare* (fennel), *Tagetes lucida* (*pericón*)
Tastes	***Sabores***	***Ompa***	
Astringent	*Estítico, astringente*	*Tänänpa, tänänya, jekopya*	*Byrsonima crassifolia* (*nanche*), *Psidium* spp. (guava leaves) *Artemisia ludoviciana* (*estafiate*), *Tanacetum parthenium* (feverfew), *Tithonia diversifolia* (*árnica*)
Bitter	*Amargo*	*Takay, takpyä*	
[Good, pleasant, savoury]	*Sabroso*	*Sunhi ompa*	*Cymbopogon citratus* (lemongrass), *Dysphania ambrosioides* (*epazote*), *Mentha* spp. (mint)
[Irritating, acid]	*Irritante, pica, da comezón en la boca*	*Tzikspapä*	*Ananas comosus* (pineapple), *Xanthosoma* spp. (*quequeste*)
Menthol, numbing	*Mentolado, anestésico, entumbante*	*Nezespa, nezesya, jelongya*	*Eucalyptus* spp. (eucalypt), *Mentha* spp. (mint), *Pimenta dioica* (allspice), *Polygala floribunda* (*kä tzanhga*)
Pungent, spicy hot	*Picante*	*Topyapä*	*Capsicum* spp. (chilli), *Pimenta dioica* (allspice leaves) *Arthrostemma ciliatum* (*caña agria*), *Citrus limon* (lemon juice), *Vitis tiliifolia* (wild grapes)
Sour	*Agrio*	*Katzu ompa*	
Sweet	*Dulce*	*Pa'ajkpä*	*Phyla scaberrima* (*hierba dulce*), *Tagetes lucida* (*pericón*)
[Sweet-sour]	*Agridulce*	*Katzupa'ajkpä, paktzukya*	*Ananas comosus* (pineapple), *Citrus sinensis* (orange juice) *Equisetum* spp (horsetail)
Weak, simple, mild	*Suave, simplete*	*Mamsämpa, sekepä*	

of the organoleptic testing data. The Cramer's V – which indicates the variables' power to predict therapeutic uses – for humoral qualities, at 0.23, is over four times higher than that of smell, at 0.05. A plant's taste is 40% more important for predicting its usage, with a Cramer's V of 0.07, which is in accordance with the general assumption that smell is the least acute of the human senses (Purves et al., 2004: 339).

4.3.1. Correlations between chemosensory cues and therapeutic uses

Notwithstanding the above, specific tastes and smells are directly correlated with certain therapeutic uses [Fig. 5(a) and (b)]. For example, astringent, bitter, and aromatic plants are particularly indicated for digestive system disorders. There is a strong cross-cultural consensus for this correlation in Mesoamerica as it has also been documented among the Maya (Ankli et al., 1999; Brett, 1998), Mixe (Heinrich, 1998), Popoluca (Leonti et al., 2002), and Zapotecs (Frei et al., 1998). Musculoskeletal ailments, too, are preferentially treated with plants that induce bitter, yet also pungent and sour, sensations. Healers from different cultural groups agree that respiratory diseases require sweet plants (cf. Ankli et al., 1999; Heinrich, 198, Leonti et al., 2002). In addition, the Zoque also commonly use plants with pungent, irritating, pleasant, and menthol-like aromas and tastes to treat diseases of the respiratory tract. The Yucatec Maya apply bitter and astringent remedies topically for skin problems (Ankli et al., 1999), whereas the Zoque prefer sour herbs as well as taxa, which induce very weak sensations or have a particularly herby ("green") smell. Drugs with weak chemosensory properties are also commonly ingested to treat urological complaints. Soul-related illnesses are often thought to involve harmful spiritual forces, which need to be expelled through fumigation with irritating plant material. Fever, paediatric illnesses, as well as mental and psychosomatic conditions are mostly treated with ritual washings and cleansings (*limpias*), which call for plants with a menthol-fresh taste and particularly strong aromas. Interestingly, strong-smelling plants are used for ritual purposes irrespective of the hedonic evaluation (good or bad) of the olfactory sensation. While, due to limited data, no significant correlations were identified for the smaller disease categories, it is noteworthy that the Zoque consider most bitter plants potential remedies for diabetes (Geck et al., 2016). There is limited evidence for correlations between both gynaecological uses and headache remedies and specific chemosensory properties, indicating that other factors – such as humoral qualities – are predominant in guiding herbal treatments.

4.3.2. Correlations between organoleptic properties and humoral qualities

Chemosensory cues also guide uses indirectly, acting via humoral qualities as an intermediary [Fig. 5(c) and (d)]. Hence, while the evidence for sour and malodorous plants being preferred for relieving headaches is limited, these are the stereotypical chemosensory properties of cold plants. Hot remedies, on the other hand, are mostly bitter, pungent or irritating. Astringent and sweet plants are usually considered neutral, as are plants with weak or ambiguous properties. With a Cramér's V of 0.19, taste is again a stronger predictor than smell (Cramér's V of 0.15).

The correlations between the cold humoral quality and specific chemosensory properties are generally rather weak, indicating that other factors may be more important for classifying plants as cold. Organoleptic properties other than taste and smell, mainly visual and tactile cues, may be evaluated when judging the therapeutic potential of plants and are important mnemonic aids (Bennet, 2007; Browner, 1985; Etkin, 1988; Leonti et al., 2002; Shepard, 2004). Thus, irrespective of taste and smell, plants that grow in or near the water or are succulent are almost automatically considered cold.

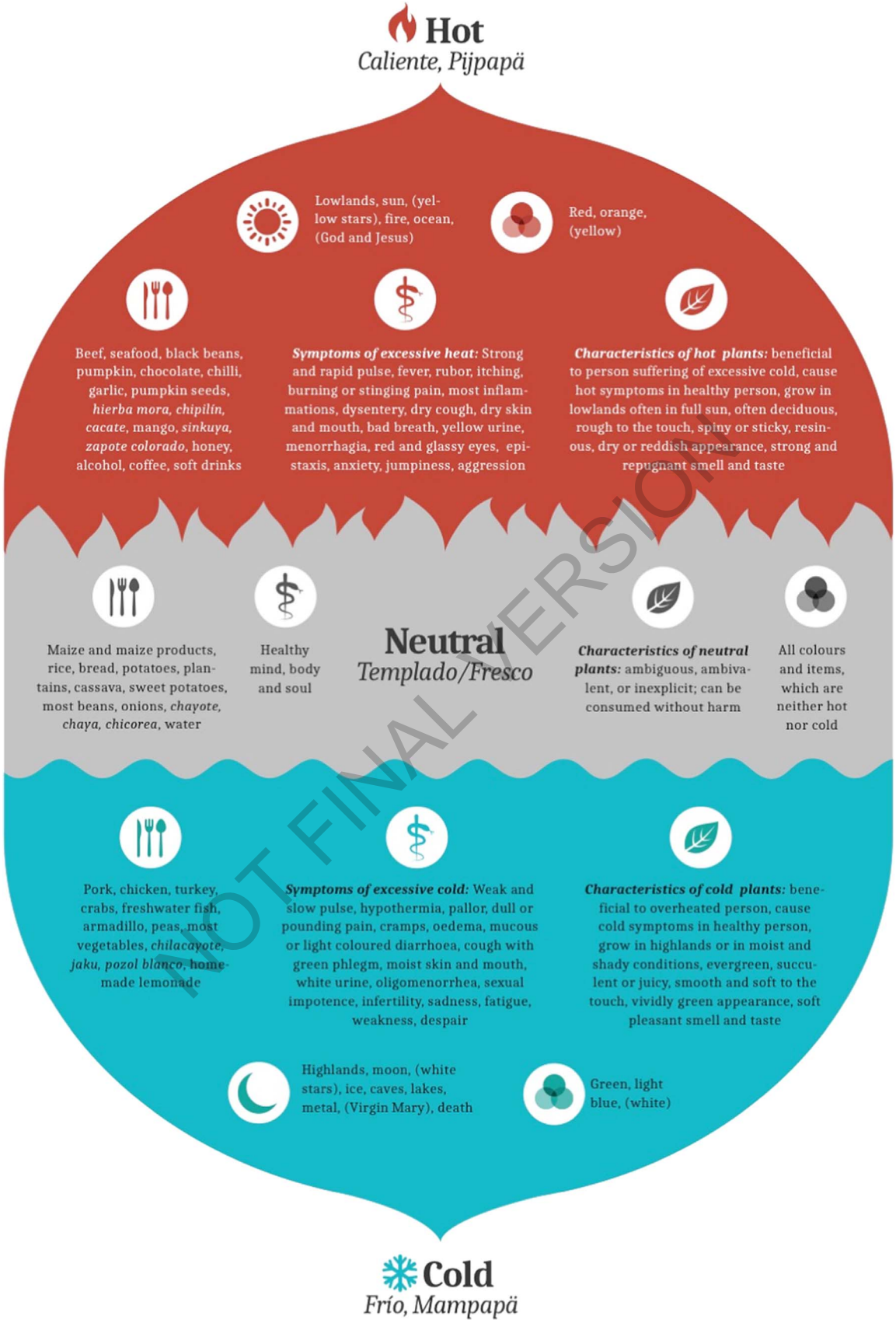

Fig. 2. The hot-cold dichotomy in Zoque worldview and medicine. The results of four focus group discussions on humoral qualities, their applicability and meaning are summarized. The terms placed in parentheses are characterized by a low consensus within and between the different groups.

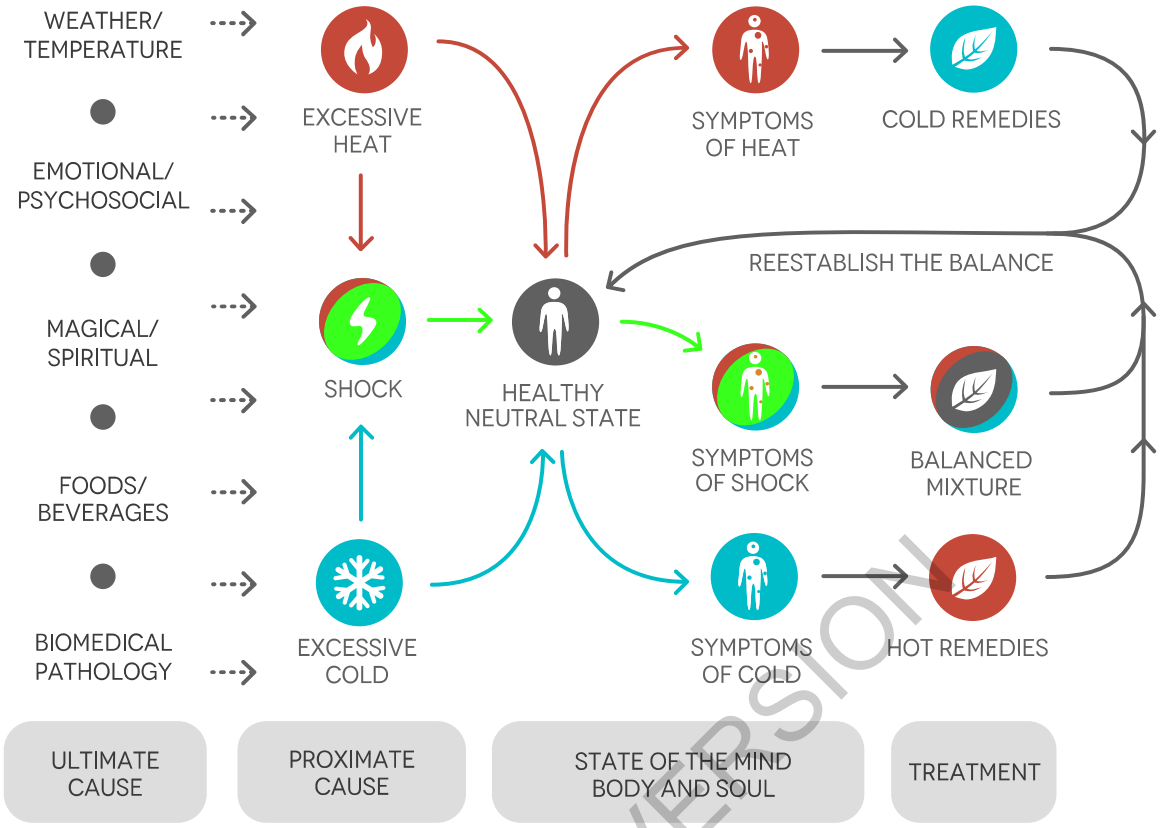

Fig. 3. Aetiological model of the Zoque medical system. Diverse ultimate causes result in an accumulation of heat or cold. This in turn transforms the healthy neutral state into one of illness, where hot or cold symptoms prevail. By applying remedies according to the principle of opposites, the balance, and thus health, is re-established. A rapid transition from a heated to a cold state results in ambiguous symptoms of shock, which require treatment with a balanced mixture.

There appears to be a broad cross-cultural consensus for these correlations between humoral qualities and organoleptic properties in Mesoamerica (cf. Browner, 1985; Foster, 1994: 102; Frei et al., 1998; Leonti et al., 2002; Messer, 1987; Tedlock, 1987). However, the ambiguous classification of bitter items by the Zapotecs (Frei et al., 1998; Messer, 1987, 1981) demonstrates the flexible nature of the hot-cold dichotomy.

4.3.3. Correlations between humoral qualities and therapeutic uses

Cold plants are mainly used externally to treat fevers, headaches, psychological and paediatric illnesses, and dermatological conditions [Fig. 5(e)]. This is in full accordance with the principle of opposites, as these categories include predominantly hot conditions (cf. Fig. 4). In a logically consistent manner, the cold gynaecological and musculoskeletal ailments are mostly treated with hot plants. Hot remedies also prevail for respiratory diseases. Yet, as they are associated with *espasmo*, thought to result from a rapid transition from a hot to a cold state, the hot remedies are usually balanced with neutral ingredients in order to avoid further harm. Similarly, cold-neutral treatments are elaborated for paediatric illnesses, as children are considered particularly vulnerable to humoral shocks. Neutral, often astringent, drugs are also the treatment of choice for most gastrointestinal disorders. These are commonly combined with either hot or cold ingredients depending on the humoral evaluation of the specific condition diagnosed. Foster (1984, 1994:) argues that neutral remedies would be essentially useless in a humoral medical system, as they could not counteract an imbalance caused by either heat or cold. Our results contradict this argument as the Zoque healers very consciously apply neutral medicinal plants under a hot-cold paradigm in order to re-establish the balance without risking an excessive shock to the patient's system.

4.3.4. Correlation patterns for unknown drugs

Humoral qualities and organoleptic properties, including the doctrine of signatures, are often considered mnemonic aids (see glossary) or validators assigned *post hoc* in order to match ethnomedical theory, rather than selection criteria for medicinal plants (e.g. Bennet, 2007; Etkin, 1988; Foster, 1988; Tedlock, 1987). As it is virtually impossible to observe the actual process of plant selection, simulating this process through the testing of drug samples unknown to the informants might shed some light on the issue. In contrast to the previous testings, the plant material was presented in a dried state and did not allow for the inclusion of ecological factors in the evaluation by the informants. This experimental design had two major consequences:

(i) The predictive power of smell pales into insignificance in comparison to taste.
(ii) The cold humoral quality almost ceases to exist.

This latter point reaffirms the notion that texture (succulence) and ecological habitat (shade, moisture) are more important than chemosensory cues for classifying a given plant as cold. This notwithstanding, the general correlation patterns between specific tastes, smells, humoral qualities, and therapeutic uses proved reproducible (please refer to Appendix D in the supplementary material for the full results). Further, the dominance of humoral qualities (Cramér's V of 0.15) over chemosensory properties (Cramér's V of 0.05 and 0.03 respectively) as predictors of medicinal uses was similarly pronounced as with the remedies previously known to the informants. Thus, it seems that the role of the hot-cold dichotomy is not limited to *post hoc* validation but indeed plays an important intermediary role in the selection of herbal remedies.

4.4. Implications and potential applicability of our findings

Our results support previous claims for specific correlations between chemosensory properties and therapeutic uses of medicinal plants, while

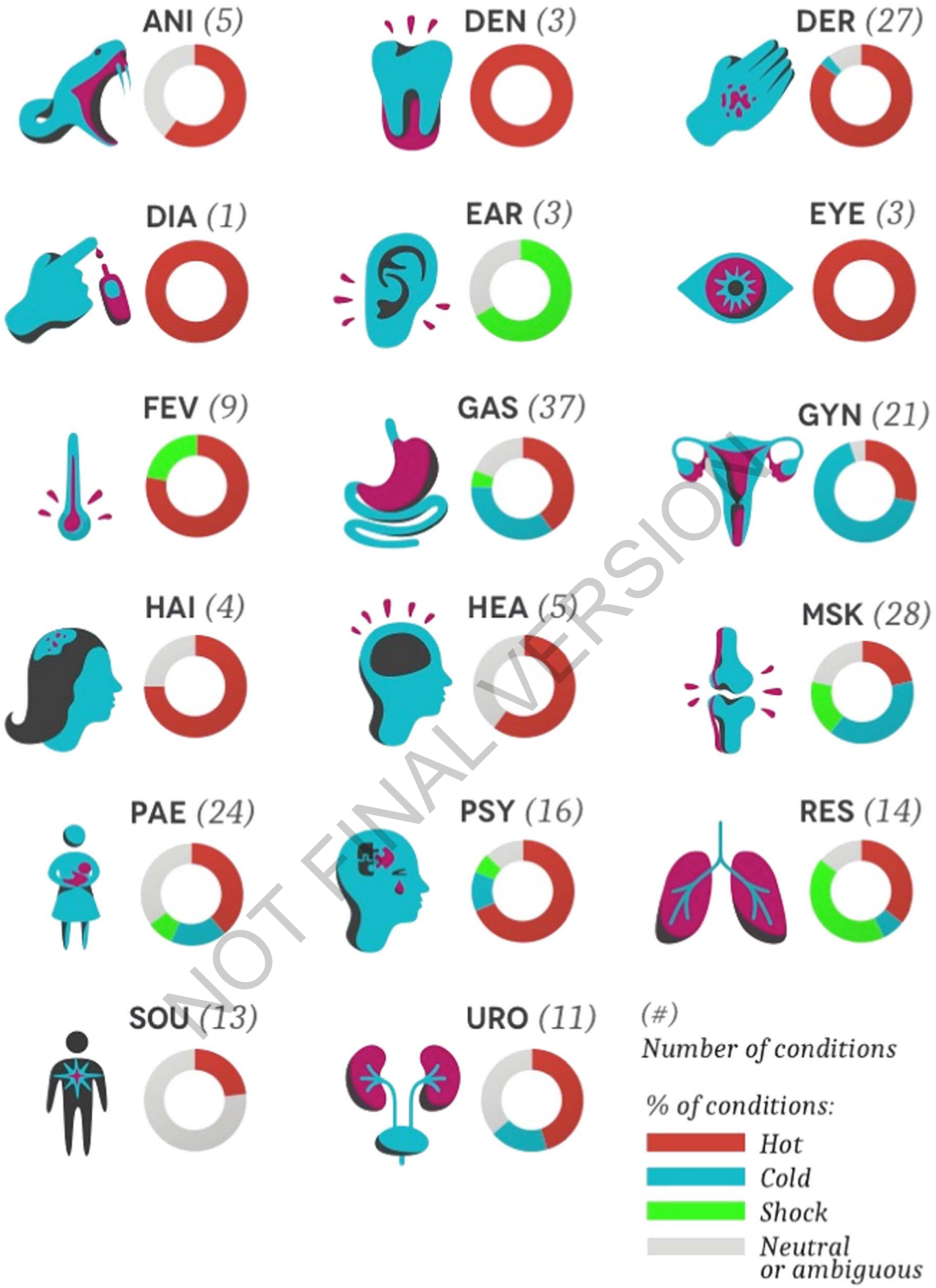

Fig. 4. The 17 emic-defined disease categories and their humoral qualities. For each category the number of distinct conditions is indicated in parentheses. The charts show the humoral qualities of individual conditions in percentages of the total number of conditions. Abbreviations are as follows: Animal bites and stings (ANI), Dental problems (DEN), Dermatological conditions (DER), Diabetes (DIA), Ear complaints (EAR), Ophthalmological diseases (EYE), Fever (FEV), Gastrointestinal disorders (GAS), Gynaecological complaints (GYN), Problems of the hair and scalp (HAI), Headache (HEA), Musculoskeletal ailments (MSK), Paediatric illnesses (PAE), Psychosomatic and mental afflictions (PSY), Respiratory diseases (RES), Illnesses related to the soul (SOU), and Urological complaints (URO). (For interpretation of the references to color in this figure, the reader is referred to the web version of this article.).

adding additional and more precise data. Above all, however, this systematic approach reaffirms the opinion of the healers that humoral qualities are key predictors of therapeutic uses, while being themselves conditioned by chemosensory cues and, ultimately, by plant secondary metabolites. Thus, the hot-cold dichotomy is shown to be an important cultural filter linking the empirically perceived chemical properties of plants

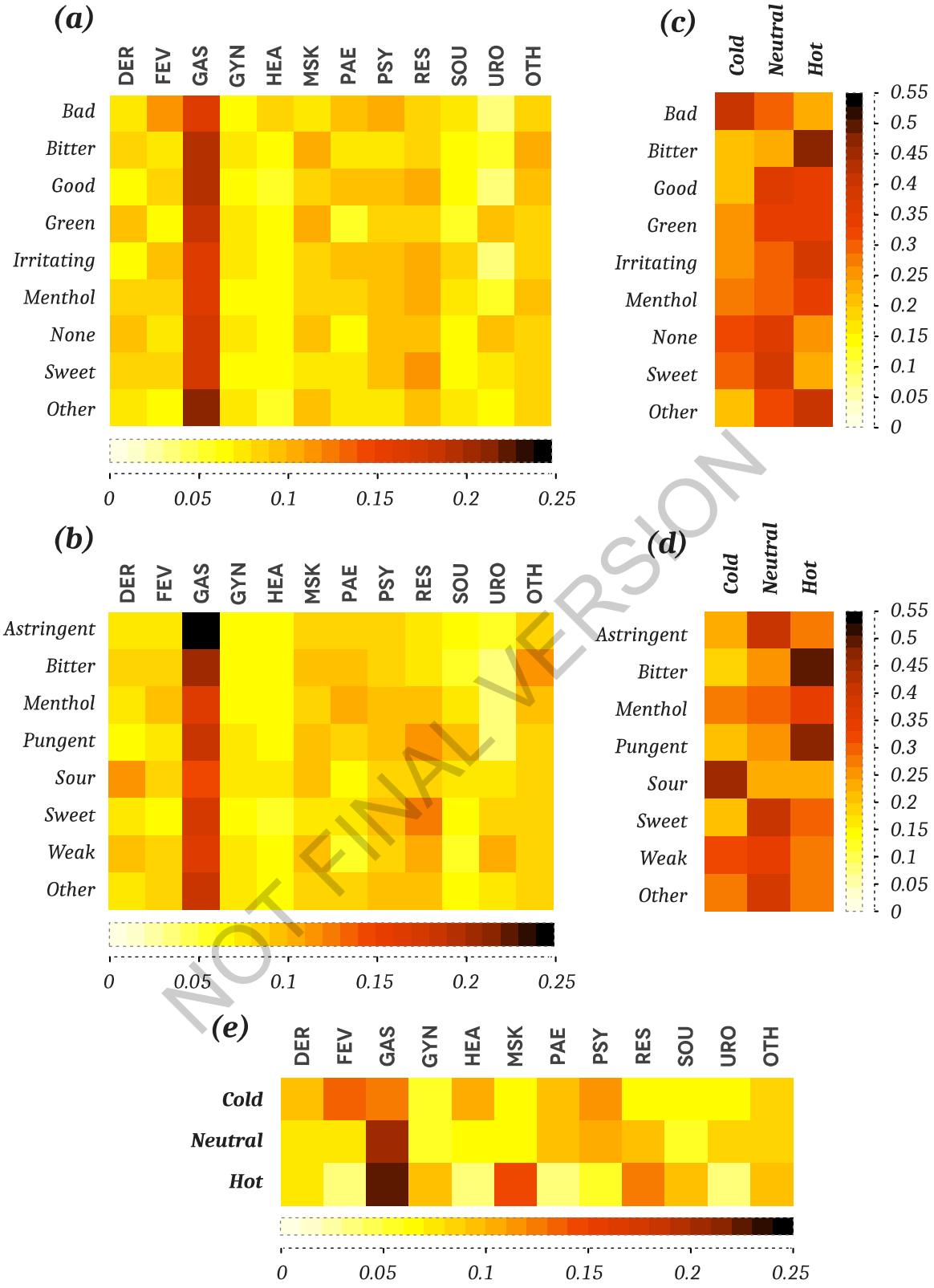

Fig. 5. Graphical display of the results for the statistical inquiries: (a) Given a certain smell, what is the most probable therapeutic category? (b) Given a certain taste what is the most probable therapeutic category? (c) Given a certain smell, what is the most probable humoral quality? (d) Given a certain taste, what is the most probable humoral quality? (e) Given a certain humoral quality, what is the most probable therapeutic category? The darker the colour the higher the prediction probability of the respective correlation. See Fig. 4 for abbreviations of therapeutic categories. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.).

to defined categories of use. Hence, the concept may not be as fully incompatible with bioscientific paradigms as previously criticized (Ankli, 1999; Brett, 1994; Foster, 1994: 138; Logan and Morrill, 1979; Ortiz de Montellano and Browner, 1985).

In conjunction, organoleptic cues and humoral qualities shape cultural expectations in regard to remedies. These expectations, in turn are mediated via neurotransmitters resulting in considerable physiological and therapeutic consequences (Benedetti and Amanzio, 1997; Finnis

et al., 2010; Moermann and Jonas, 2002). Colours, for example, have been shown to significantly influence therapeutic effects (de Craen et al., 1996; Moermann and Jonas, 2002; Schapira et al., 1970). The findings from North America and Europe that red pills induced a stimulatory response while green and blue pills were perceived as tranquilizers are particularly interesting as this coincides with cultural expectations according to the hot-cold dichotomy in Mesoamerica (see Section 4.1).

There seems to be considerable cross-cultural consensus in Mesoamerica on the colour red as well as bitter, pungent, and irritating tastes being associated with the hot humoral quality. The use of hot treatments for post-partum ailments and musculoskeletal pain is equally widespread. Likewise, the sour taste is commonly associated with cold drugs, which in turn are particularly indicated for fevers and inflammatory skin conditions. In indigenous and Mexican American communities, herbal and synthetic drugs increasingly coexist and concepts of the hot-cold dichotomy are also being applied to biomedical products (Giovannini et al., 2011; Juckett, 2005; Waldstein, 2006). Thus, taking these findings into account during drug development and design may significantly increase the meaning response and hence the effectiveness of drugs. In regard to herbal medicine, ethnopharmacological studies repeatedly point out the need to discourage the use of toxic remedies such as *Aristolochia* species (e.g. Michl et al., 2014). These efforts, however, are bound to be rather fruitless as long as culturally viable alternatives are not offered. Such substitutions ought to be guided by the local rationale for plant use, i.e. by humoral and organoleptic criteria. Finally, raising awareness among health workers on the theory and practical implications of the hot-cold dichotomy may considerably increase the quality of care for local and indigenous commu-nities and ultimately the effectiveness of public health strategies in Mesoamerica. Such cultural competency is also crucial for North American physicians working with Latin American patients (Juckett, 2005).

5. Conclusions

This systematic investigation reinforces the presumption that organoleptic properties, particularly taste and smell, are essential for guiding therapeutic uses of herbal remedies. The results support and extend the claims for correlations between specific chemosensory cues and particular nosological units. Further, we provide evidence that the function of the hot-cold dichotomy is not limited to validating effective uses of herbal remedies *post hoc*. Humoral qualities much rather act as a cultural filter, linking empirically perceived properties and therapeutic uses of medicinal plants, essentially resulting in more meaningful therapy.

Given the continued importance of the hot-cold dichotomy in folk medicine, more interdisciplinary research is needed in order to enhance our understanding of the complex nature of this system. In Mesoamerica, there is considerable cross-cultural consensus regarding certain correlations between organoleptic properties, humoral qualities, and therapeutic uses of drugs. These aspects ought to be taken into account in the design of public health programs and pharmaceuticals, in order to fulfil cultural expectations and thus increase the perceived quality and effectiveness of healthcare.

Acknowledgements

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Appendix A. Classification and humoral qualities of diseases and illnesses

see Table A1.

Table A1
Classification and humoral qualities of diseases and illnesses. The Spanish terms were translated into English as literally as possible in order not to falsify the original data. Only when there is no direct translation are English explanations provided. Zoque names for the diseases are not listed, due to the diversity of Zoque dialects. The humoral qualities reflect the consensus among the 4 focus groups. This table represents a modified version of Table S3 in Geck et al. (2016).

Local name	English translation or description	Humoral quality
Gastrointestinal disorders (GAS)		
Dolor de barriga	Abdominal pain	Cold
Amebas	Amoebas	Both
Bilis	Bile	Both
Abultazón	Bloated stomach	Cold
Diarrea fría	Cold diarrhoea	Cold
Disentería blanca/fría	Cold dysentery	Cold
Colitis	Colitis	Hot
Estreñimiento	Constipation	Hot
Calambres	Cramps	Shock
Torzejón	Cramps accompanied by white diarrhoea	Cold
Diarrea	Diarrhoea	Both
Disentería	Dysentery	Hot
Aventazón, aires	Flatulence	Cold
Gastritis	Gastritis	Hot
Cólico	Gastrointestinal disorder related to emotional distress	Hot

(continued on next page)

Table A1 *(continued)*

Local name	English translation or description	Humoral quality
Inflamación de barriga, inflamación gastrointestinal por frialdad	Gastrointestinal inflammation caused by cold	Cold
Inflamación gastrointestinal por calentura	Gastrointestinal inflammation caused by heat	Hot
Inflamación del ombligo	Gastrointestinal inflammation underneath the navel	Cold
Hemorroides	Haemorrhoids	
Quemazón de corazón	Heartburn	Hot
Hipo	Hiccups	Hot
Empacho	Illness due to eating too much and too quickly	Cold
Indigestión	Indigestion	None
Calor de estomago, calentura de adentro, calor encerrado, calor del corazón	Internal or trapped heat	Cold Hot
Inflamación del intestino	Intestinal inflammation	
Heridas en el intestino	Intestinal wounds	Hot
Falta de apetito	Lack of appetite	Hot
Vasca	Nausea	Hot
Obesidad	Obesity	Both
Dolor del ombligo, pulsación del ombligo	Pain and pulsation around the navel	Hot
Parásitos	Parasites	Cold
Dolor de estomago, dolor de corazón	Stomach ache	Cold
Tapeación, tapeadura	Urinary retention combined with constipation	Both
Mal aire negro y blanco	Very strong gastrointestinal pain and diarrhoea caused by spiritual forces	Hot
Vómitos	Vomiting	Shock
Diarrea caliente	Warm diarrhoea	Both
Lombrices	Worms	Hot
Musculoskeletal ailments (MSK)		Cold
Aire	A "wind" that enters the body and causes cramps and pains, similar to shooting pains	Shock
Dolor de huesos	Aching bones	
Dolor de los pies	Aching feet	Cold
Aire en el pie	*Aire* (see above) in the foot	Cold
Artritis	Arthritis	Shock
Dolor de espalda y de cintura	Back and waist pain	Hot
Dolor de cuerpo	Body pain	Shock
Quebradura/ fractura	Bone fracture	Both
Ardor en la planta de los pies	Burning pain in the palm of the feet	Both
Pies fríos	Cold feet	Hot
Frialdad en las coyunturas	Cold in the joints	Cold
Calambres	Cramps	Cold
La mano queda cerrado por calambres	Cramps causing the hand to stay closed	Shock
Desbrinzadura, zafadura	Dislocation	Cold
Sangre acumulada por golpe	Haematoma	Hot
Inflamación de coyunturas	Inflamed joints	Cold
Inflamación por golpe	Inflammation after a traumatic injury	Both
Pie ablandado	Lack of tension in muscles of the feet	Cold
Osteoporosis	Osteoporosis	Hot
Contracción de huesos con escalofríos	Painful contracting feeling of the bones accompanied by chills	Cold Shock
Reuma	Rheumatism	
Dobladura/ torcedura	Sprain	Both
Retorcido el pie	Sprained ankle	Cold
Estirón	Strain	Hot
Hinchazon por golpe	Swellings after a traumatic injury	Cold
Hinchazon de pie	Swollen feet	Cold
Golpe	Traumatic injury	Both
Acido urico	Uric acid	Hot
		Neutral

(continued on next page)

Table A1 *(continued)*

Local name	English translation or description	Humoral quality
Dermatological conditions (DER)		
Granos	Any sort of bump or pimple, often infected or inflamed	Hot
Hongos de los pies	Athlete's foot	Hot
Quemadura	Burn	Hot
Quemadura de rayo	Burn due to lightning strike	Hot
Cortada	Cut, laceration	Cold
Hongos de la piel	Dermal mycosis	Hot
Disípela	Erysipelas	Hot
Nacidos	Furuncle	Hot
Nacidos del pie	Furuncle on the foot Gangrene	Hot
Yaga	Itching	Hot
Comezón	Itchy skin, not locally restricted	Hot
Felicidad	Measles	Hot
Sarampión	Melasma	Hot
Manchas negras	Rash	Neutral
Sarpullido	Circular inflammatory skin	Hot
Caracolillo	condition, accompanied by intense itching	Hot
	Scabies	
Sarna	Scald	Hot
Quemadura de agua	Skin cancer	Hot
Cáncer/ tumores de la piel Inflamación	Skin inflammation	Hot
de la piel	Spine in the skin	Hot
Espina	Varicella	Hot
Varicela	Variola	Hot
Viruela	Vitiligo	Hot
Manchas blancas	Warts	Neutral
Mezquino/ verrugas	Wheals	Neutral
Ronchas en la piel	Wounds	Hot
Heridas		Hot
Paediatric illnesses (PAE)	A child's body does not develop	
Täpsi	properly	Hot
	Candidiasis	
Saro	*Carga* (see below) in advanced	Hot
Alperezia	stages	Neutral
	Child cries a lot	
Niño llora mucho	Child cries a lot at night Child	Both
Niño llora mucho en la noche	does not speak Children's	Cold
Niño que no habla	disease with numerous well-	Neutral
Carga	defined symptoms	Hot
	Cold in infants	
	Cold sore	
Frialdad del bebe	Diarrhoea accompanied by	Cold
Fuego de la boca	fever in infants	Shock
Diarrea con calentura en bebes	Diarrhoea in infants Diarrhoea	Hot
	when the first teeth appear	
Diarrea de niños	Enuresis	Both
Diarrea cuando salen los primeros dientes	Evil eye	Neutral
	Fever in infants	
Niño orina en la noche	*Granos* (see above under	Cold
Ojeadura, mal de ojo	dermatological conditions) in	Hot
Calentura de niños	infants	Hot
Granos de bebes	*Granos* (see above under dermatological conditions) in or around the mouth	Hot
Granos de la boca	Infant still requires breastfeeding at an advanced age	Shock
Bebe no deja de mamar	Open head, similar to *muñera* (see below)	Neutral
	Skin infection in infants	
Cabeza abierta	Stomach ache in infants Fallen	Neutral
	fontanel	
Infección de la piel de bebes	After cutting the umbilical cord	Hot
Dolor de estomago de bebes Muñera	does not heal well or “grows	Both
Ombligo no sana, crece por	upwards”	Hot
	Vomiting in infants	Cold
arriba		
	Abdominal pain	
Vómitos de niños	Breast cancer	Both
Gynaecological complaints (GYN)		
Dolor de vientre		Cold
Cáncer de mama		Hot

(continued on next page)

Table A1 *(continued)*

Local name	English translation or description	Humoral quality
Cáncer de matriz	Cervical cancer	Cold
Frialdad después del parto	Cold after childbirth	Cold
Detención de menstruación	Amenorrhea	Cold
Menstruación excesiva/ hemorragia vaginal	Excessive menstrual bleeding	Hot
Expulsar la placenta	Expel the placenta	Cold
Infertilidad	Infertility	Cold
Inflamación de ovarios	Inflamed ovaries Inflammation	Hot
Inflamación después del parto	after childbirth	Cold
Menstruación irregular	Menstruation irregularities	Cold
No baja la leche	Breast milk will not flow	Cold
Menstruación dolorosa	Painful menstruation Painful/	Hot
Parto doloroso/difícil	difficult childbirth Swollen feet	Cold
Hinchazón de los pies	Inflammation of the uterus	Cold
Inflamación de matriz	Vaginal discharge	Cold
Flujo vaginal	Vaginal haemorrhage after an	Both
Hemorragia después de un aborto	abortion	Cold
Hemorragia durante el parto	Vaginal haemorrhage during childbirth	Hot
Hemorragia durante el embarazo	Vaginal haemorrhage during pregnancy	Cold
Infección vaginal	Vaginal infection	Hot
Psychosomatic and mental afflictions (PSY)	Anaemia	
Anemia	Apoplexy	Neutral
Embolio	Emotional distress causing a	Hot
Cólico	number of physical symptoms, mainly of the digestive system	Hot
	Epilepsy	
Epilepsia	Evil spirits	Shock
Espíritus malos	Fatigue	Both
Cansancio	Nervous agitation Hypertension	Hot
Nervios	Hypotension	Hot
Presión alta	Insomnia	Hot
Presión baja	Lunacy, insanity	Cold
Insomnio	Nervous and emotional	Hot
Delirio, trastornada, locura	afflictions	Hot
Aflicciones	Shame, a complex folk illness with diverse psychological and	Hot
Azar, vergüenza	physical symptoms	Hot
	Stress	
Estrés	Weakness and nervous afflictions due to the death of a	Hot
Debilidad y aflicciones por muerte de querida persona	beloved person	Hot
Debilidad	Weakness, debility	
Respiratory diseases (RES)	Asthma	Cold
Asma	Bronchitis	
Bronquitis	Cigarette/nicotine addiction	Neutral
Adicción a cigarros	Cold cough	Shock
Tos fría	Common cold	Hot
Resfriado, lagrimeo	Cough	Cold
Tos	Dry cough	Shock
Tos seco	Flu	Both
Gripa	Inflammation of the throat	Hot
Inflamación de la garganta Tos	Pertussis	Shock
ferina/ chichimeca	Sore throat	Hot
Dolor de garganta Garraspara	Sore, itchy throat; hoarseness	Hot
Angina	Tonsillitis	Shock
Tos caliente	Warm cough	Shock
		Shock
		Hot
Illnesses related to the soul or spiritual illnesses (SOU)		
Ataque de salvajes/ demonios	Attack by demonic creatures	Both
Encanto	Enchantment	Both
Espíritus malos	Evil spirits	Both
Espanto	Fright, a complex folk illness with diverse psychological and physical symptoms	Both
Espanto de fuego	Fright of fire	Hot
Espanto de rayo	Fright of lightning	Hot
Hinchazón	General swelling of the body,	Both

(continued on next page)

Table A1 *(continued)*

Local name	English translation or description	Humoral quality
	oedema	
Daño de espíritu	*Harm caused by spiritual forces*	*Both*
Daño de sueño	*Harm during the dream*	*Both*
Suciedad de la sangre	*Impurity of the blood*	*Neutral*
Espanto de noche	*Nocturnal fright*	*Both*
Sudor de noche	*Nocturnal sweating Witchcraft*	*Hot*
Brujería, hechicería, mal de brujo, magia negra		*Neutral*
Urological complaints (URO)	*Combination of urinary*	
Tapeación, tapeadura	*retention and intestinal constipation Incontinence*	*Hot*
Incontinencia	*Inflamed testicles*	*Cold*
Inflamación de testículos	*Inflammation of the kidneys*	*Hot*
Inflamación de los riñones	*Kidney disorders*	*Hot*
Riñones	*Kidney stones*	*Neutral*
Piedras de riñones	*Pain while urinating*	*Neutral*
Mal de orín	*Prostate cancer*	*Both*
Cáncer de próstata	*Prostate gland disorders*	*Hot*
Próstata	*Urinary retention*	*Hot*
Tapeación, estapón de orín, tapeadura de orín	*Waist pain*	*Both*
Dolor de cintura		*Cold*
Febrile illnesses (FEV)	*Dry fever*	
Calentura seca	*Fever*	*Hot*
Fiebre, calentura	*Fever accompanied by sweating*	*Hot*
Fiebre con sudor	*Fever with shivering chills*	*Hot*
Fiebre con escalofríos	*Herpes zoster, shingles*	*Shock*
Herpes	*Nocturnal sweating*	*Shock*
Sudor de noche	*Typhoid fever*	*Hot*
Fiebre tifoidea	*Yellow and strongly smelling*	*Hot*
Sudor amarillo apestoso	*sweat Yellow fever*	*Hot*
Fiebre amarilla		*Hot*
Animal bites and stings (ANI) *Piquete de ciempiés*	*Centipede bite Subcutaneous filariasis*	*Hot*
Colmoyote, gusano barrenador	*Insect bites and stings*	*Neutral*
Piquete de insectos	*Scorpion sting*	*Hot*
Piquete de alacrán	*Snakebite*	*Hot*
Piquete de víbora		*Both*
Headache (HEA)	*Epistaxis*	
Hemorragia nasal	*Headache*	*Hot*
Dolor de cabeza	*Headache and epistaxis*	*Both*
Dolor de cabeza con hemorragia nasal Dolor de cabeza con calentura	*Headache with fever*	*Hot*
Jaqueca	*Migraine*	*Hot*
Problems of the hair and scalp (HAI)		*Both*
Caspa	*Dandruff*	
El cabello se pone blanco	*Greying of the hair*	*Hot*
Caída de cabello	*Hair loss*	*Hot*
Piojos	*Head lice*	*Hot*
Dental problems (DEN)		*Neutral*
Inflamación de encías		
Dolor de muelas	*Gingivitis*	*Hot*
Dolor de muelas con calentura	*Toothache Toothache accompanied by fever*	*Hot* *Hot*
Ear complaints (EAR)		
Sordera		
Dolor de oído	*Deafness*	*Shock*
Infección del oído	*Earache*	*Shock*
Ophthalmological diseases (EYE)	*Ear infection*	*Both*
Conjuntivitis		
Infección del ojo	*Conjunctivitis*	*Hot*
Mala vista	*Eye infection*	*Hot*
	Weak eyesight, may often refer to a cataract	*Hot*
Diabetes (DIA)		
Diabetes, azúcar	*Diabetes*	*Hot*

Appendix B. Drug samples used for the organoleptic testing

see Table B1 and B2.

Table B1
Drug samples selected from the 17 disease-categories. For more details on the use of each sample please refer to Geck et al. (2016). For the meaning of the abbreviations please refer to Appendix A.

Sample No.	Species / Collection codes	Vernacular names[a]	Plant part	Chosen for categories[b]
1	*Nicotiana tabacum* L. (Solanaceae) / MSG263	*Tabaco verde, tzuj ozi*	Leaf	ANI, MSK
2	*Tithonia diversifolia* (Hemsl.) A.Gray (Asteraceae) / MSG420	*Arnica, girasol, tapungäsy jäyä, tapkuy, tatkuy, tan tzitzi, tabkuy, tam tzitzi*	Leaf	DER, DIA, MSK
3	*Myriocarpa heterospicata* Donn. Sm. (Urticaceae) / MSG450, MSG695	*Pegasoso, palo de barba, caracolillo, la barbosa, tzoki 'an panatz, tzokyan panats*	Bark	DER
4	*Brugmansia × candida* Pers. (Solanaceae) / MSG259	*Flor de campana, lokitsy, kampandu jäyä*	Leaf	FEV, HEA
5	*Psidium guineense* Sw. (Myrtaceae) / MSG442, MSG674	*Guayaba agria, katzu patan, katzu paran, katsu 'ätz, katsy patan, katzu wos*	Leaf	GAS
6	*Byrsonima crassifolia* (L.) Kunth (Malpighiaceae) / MSG274	*Nanche, nance, nansin*	Bark	DEN, GAS
7	*Polygala floribunda* Benth. (Polygalaceae) / MSG554	*Lavapie, flor de esquipulas, hierba de seiscientos, kä tzanhga*	Root	HAI
8	*Bougainvillea glabra* Choisy (Nyctaginaceae) / MSG411	*Bugambilia, apit jäyä*	Inflorescence	RES
9	*Bryophyllum pinnatum* (Lam.) Oken (Crassulaceae) / MSG362	*Sanalotodo, beladona, malva, hoja de paperón, lakanyo, malva tane, tini rana, tok tzäksy, siwe tana, tukun jäyä*	Leaf	DER
10	*Sambucus canadensis* L. (Adoxaceae) / MSG292, MSG662	*Sauco, okok yui, ok yui, ä'ju rane*	Inflorescence	RES
11	*Sambucus canadensis* L. (Adoxaceae) / MSG292, MSG662	*Sauco, okok yui, ok yui, ä'ju rane*	Aerial parts	SOU
12	*Solanum torvum* Sw. (Solanaceae) / MSG320, MSG475	*Sosa, täptäp kuy awit, tawis tane, awin täptäp kuy, täm tujkuy, awit kuy, täptäjkuy awit, tätsy koya awit, täktäk kuy awit*	Leaf	MSK, DER
13	*Equisetum myriochaetum* Schltdl. & Cham. (Equisetaceae) / MSG280, MSG666	*Cola de caballo, cola de macho, cayo tuts, sus tokdong, tu tane, caballo tutz muk*	Aerial parts	URO
14	*Pimenta dioica* (L.) Merr. (Myrtaceae) / MSG307	*Pimienta, moki*	Leaf	DEN, GYN, MSK
15	*Litsea glaucescens* Kunth (Lauraceae) / MSG443	*Laurel, toka tsajtza, toka tzasa, toka' ay*	Leaf	GYN
16	*Phyla scaberrima* (Juss. ex Pers.) Moldenke (Verbenaceae) / MSG408	*Orozus, Santa Lucia, verbena, kanak pa'ak*	Leaf	RES
17	*Eucalyptus camaldulensis* Dehnh. (Myrtaceae) / MSG410, MSG673	*Eukalypto*	Leaf	RES
18	*Verbena carolina* L. (Verbenaceae) / MSG438	*Verbena, tung'an petkuy, kan petkuy, tak'an petkuy, tzitzirane, takak rane, tuk tane*	Aerial parts	DIA
19	*Cecropia peltata* L. (Urticaceae) / MSG251	*Guarrumbo, ma'atz kuy, ma'atza, maatsy kuy*	Leaf	DIA, MSK
20	*Artemisia ludoviciana* Nutt. (Asteraceae) / MSG315	*Estafiate, uksuk*	Aerial parts	GAS
21	*Protium copal* (Schltdl. & Cham.) Engl. (Burseraceae) / MSG421	*Copal de chichi, tzyutzyin bono, kutzyin bono, cotsyinbomo, tzyitzyin bomo*	Fruit	GAS
22	*Ocimum × africanum* Lour. (Lamiaceae) / MSG29	*Albahaca, tzukspa' tane*	Aerial parts	EAR, FEV, PAE, PSY, SOU
23	*Rosmarinus officinalis* L. (Lamiaceae) / MSG346	*Romero*	Aerial parts	SOU
24	*Foeniculum vulgare* Mill. (Apiaceae) / MSG316	*Hinojo*	Leaf	PSY
25	*Ocimum carnosum* (Spreng.) Link & Otto ex Benth. (Lamiaceae) / MSG377	*Hoja de cólico, hierba Santa Marta, hierba de cólico, tung an petkuy, tzukspa' tane, näk tane, tzukin jäyä, yäjkuy tane*	Aerial parts	PSY
26	*Ternstroemia tepezapote* Cham. & Schltdl. (Pentaphylaceae) / MSG433	*Trompito, flor de tila*	Flower	PSY
27	*Clinopodium brownei* (Sw.) Kuntze (Lamiaceae) / MSG267	*Tripa de rata, jupitane, tzämi tane, jupirane, tzuk'u pu'*	Whole plant	EYE
28	*Ruta chalepensis* L. (Rutaceae) / MSG255	*Ruda, luta*	Aerial parts	EAR, FEV, PAE, PSY
29	*Allium cepa* L. (Amaryllidaceae) / MSG271	*Cebolla, tzapaas ceullas, tzepolas*	Bulb	PAE
30	*Mentha × piperita* L. (Lamiaceae) / MSG94	*Hierbabuena, yepena*	Aerial parts	PAE, PSY
31	*Abelmoschus moschatus* Medik. (Malvaceae) / MSG431	*Arcalia, doña alpite, curalina, almiz, almisy*	Seeds	ANI GAS,
32	*Citrus aurantiifolia* (Christm.) Swingle (Rutaceae) / MSG252	*Limón, limones, katzu*	Leaf	PSY PSY,
33	*Citrus aurantiifolia* (Christm.) Swingle (Rutaceae) / MSG252	*Limón, limones, katzu*	Fruit	FEV GAS
34	*Psidium guajava* L. (Myrtaceae) / MSG264	*Guayaba, po'os, padan, paran, pataya*	Leaf	HEA MSK
35	*Calliandra houstoniana* (Mill.) Standl. (Fabaceae) / MSG583	*Kine nhäpin*	Leaf	
36	*Phlebodium areolatum* (Humb. & Bonpl. Ex Willd.) J. Sm. (Polypodiaceae) / MSG522	*Calaguala, hierba de golpe, misyu mätzyik*	Rhizome	
37	*Zea mays* L. (Poaceae) / MSG283	*Pelo de elote, cabello de maíz, mok owai*	Pistils	URO
38	*Lantana camara* L. (Verbenaceae) / MSG281	*Riñonia, riñosan, pajk jäyä*	Leaf	URO
39	*Eysenhardtia polystachya* (Ortega) Sarg. (Fabaceae) / MSG298	*Taray, oku'ku piake*	Wood	URO
40	*Tanacetum parthenium* (L.) Sch.Bip. (Asteraceae) / MSG260	*Hierba santa, artamiza, artamisy, altamiza*	Aerial parts	GYN
41	*Cnidoscolus aconitifolius* (Mill.) I.M.Johnst. (Euphorbiaceae) / MSG357	*Chaya, ata tsäpe, ata, kenuk tsäpe*	Leaf	GYN
42	*Oecopetalum mexicanum* Greenm. & C.H. Thomps. (Icanicaceae) / MSG405	*Cacate, kuk yaka, kukyak kawak, kokya kawa*	Seeds	DIA
43	*Asclepias curassavica* L. (Apocynaceae) / MSG383	*Quebra muelas, flor de serrillo, tusy put, witäm toya remedio, tusy kuy, wenguy tätz Aguacate,*	Sap	DEN
44	*Persea americana* Mill. (Lauraceae) / MSG262, MSG282	*owi, kuytäm, kuytäp*	Leaf	GAS, MSK, URO
45	*Persea americana* Mill. (Lauraceae) / MSG262, MSG282	*Aguacate, owi, kuytäm, kuytäp*	Bark	GAS
46	*Cymbopogon citratus* (DC.) Stapf (Poaceae) / MSG256	*Telimón, te de zacate*	Leaf	RES
47	*Matricaria discoidea* DC. (Asteraceae) /MSG314	*Manzanilla*	Aerial parts	EYE, GYN
48	*Allium sativum* L. (Amaryllidaceae) / MSG15	*Ajo, assyus*	Bulb	SOU

[a] Spanish names are in italic, names in Zoque are in italic and underlined.
[b] Each species was selected based on the quantitative salience (most commonly mentioned taxa) in one or more of the 17 disease-categories.

Table B2
Drug samples bought at the *Mercado Público José María Pino Suárez* in Villahermosa, Tabasco. For the meaning of the abbreviations please refer to Appendix A.

Sample No.	Species / Collection codes	Vernacular names	Plant part	Sold for categories
49	*Capraria biflora* L. (Scrophulariaceae) / MSG689	*Esclaviosa Tabaquillo*	Aerial parts	URO
50	*Epaltes mexicana* Less. (Asteraceae) / MSG690	*Quassia*	Aerial parts	RES
51	*Quassia amara* L. (Simaroubaceae) / MSG497	*Zopacle*	Wood	GAS
52	*Montanoa tomentosa* Cerv. (Asteraceae) / MSG688	*Flor de manito*	Leaves	GYN
53	*Chiranthodendron pentadactylon* Larreat (Malvaceae) / MSG687	*Marubio*	Flower	PSY
54	*Marrubium vulgare* L. (Lamiaceae) / MSG686	*Anacahuite*	Aerial parts	GAS, DIA
55	*Cordia sebestena* L. (Boraginaceae) / MSG685	*Flor de magnolia*	Leaves	RES
56	*Magnolia* sp. (Magnoliaceae) / MSG684	*Damiana de california*	Flower	PSY
57	*Turnera diffusa* Willd. ex Schult. (Passifloraceae) / MSG683	*Mirto*	Aerial parts	GAS, URO
58	*Salvia coccinea* Buc'hoz ex Etl. (Lamiaceae) / MSG682	*Wereque*	Aerial parts	MSK
59	*Ibervillea sonorae* (S. Watson) Greene (Cucurbitaceae) / MSG681 *Cyperus*	*Chintul*	Root	DIA
60	*articulatus* L. (Cyperaceae) / MSG694		Rhizome	PAE, FEV
61	*Arctostaphylos pungens* Kunth (Ericaceae) / MSG491	*Pinguica*	Fruits	URO
62	*Senna* sp. (Fabaceae) / MSG471	*Hoja sen*	Leaves	GAS
63	*Buddleja sessiliflora* Kunth (Scrophulariaceae) / MSG680	*Tepozan*	Leaves	MSK
64	*Lobaria* sp. (Lobariaceae) / MSG698	*Pulmonaria*	Whole plant	RES
65	*Sapindus saponaria* L. (Sapindaceae) / MSG679	*Jojoba*	Fruits	HAI
66	*Juglans regia* L. (Juglandaceae) / MSG678	*Nuez de castilla*	Fruit skin	GYN
67	*Semialarium mexicanum* (Miers) Mennega (Celastraceae) / MSG677	*Cancerina*	Root	DER
68	*Amphipterygium adstringens* (Schltdl.) Standl. (Anarcadiaceae) / MSG676	*Guachalalate*	Bark	GAS
69	*Ambrosia peruviana* Willd. (Asteraceae) / MSG692	*Altamiza*	Aerial parts	GAS
70	*Prunella vulgaris* L. (Lamiaceae) / MSG693	*Prunela Toronjil*	Aerial parts	GAS
71	*Agastache mexicana* (Kunth) Lint & Epling (Lamiaceae) / MSG675		Aerial parts	PSY

Appendix C. Results of organoleptic testing

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.jep.XXXX.XX.XXX.

Appendix D. Statistical results

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.jep.XXXX.XX.XXX.

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Glossary

Aetiology: The believed causes or manner of causation of a disease or illness.
Chemosensory: Referring to the perception of chemical stimuli by the olfactory, gustatory, and trigeminal system.
Doctrine of signatures: Belief found in many cultures that form recapitulates function; thus it is believed that certain plants are effective in treating certain diseases based on analogies in physical and chemical characteristics, such as shape, colour, texture, or taste to the respective part of the body or symptoms of disease. (e.g. Bennet, 2007)
Emic: Used in anthropology when describing cultural concepts or domains as viewed from within the respective culture rather than from an external (etic) viewpoint.
Epistemological: Relating to the theory of knowledge, particularly in regard to the distinction between justified argument and opinion.
Humoral qualities: According to humoral theory illness results from an imbalance of four body fluids (humours). Qualities (cold, hot, wet, and dry) are ascribed to each of the humours as well as to food and medicine. Despite their names, these qualities are not necessarily related to physical temperature or humidity. In order to reinstate health, substances with certain humoral qualities are prescribed based on the principle of opposites; i.e. if a predominance of cold humours is believed to be responsible for an illness hot remedies are prescribed and vice versa. The humoral system has its origin in ancient Greece and Rome. While it is now considered obsolete by Western medicine, its principles remain influential in traditional medical systems around the world. (e.g. Jackson, 2001)
Mnemonic: An item or concept assisting in remembering something.
Nosology: The branch of medicine dealing with the classification of diseases and illnesses.
Organoleptic: Referring to the perception of stimuli by the sense organs, including yet not limited to the chemical senses.