4.1.2 Medicinal Plants in the Tropical Andean Region. Quinoa (*Chenopodium quinoa* Willd.) and Coca (*Erythroxylum* sp.), millenary treasures for medicinal treatment

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Abstract

The traditional knowledge about plants used in ethnomedicine was generated from millenary praxis and transmitted orally between generations. In this review, we summarize the information reported in ethnobotanical studies of the tropical Andes region to recognize the importance of plants in medicinal treatments and their role in the Andean worldview. The broad traditional knowledge in Andean communities is the ancestral, collective and integral knowledge that allows the use and bioprospecting of biodiversity. The Andean region represents a highly diverse area in terms of culture and plant species; subsequently, the use of medicinal plants differs enormously among and within countries. Andean communities found in plants the treatment of some health and spiritual disorders. Interestingly, some plants showed potential properties that could be deeply investigated, e.g. cancer prevention or treatment. Two millenary and sacred Andean plant species are described in detail due to their potential in medicinal treatments, *Chenopodium quinoa* Willd. and *Erythroxylum* sp. The Andes region has a great wealth of knowledge concerning biological and cultural diversity that should be explored, used and conserved.

Keywords: tropical Andes, medicinal plant, ethnomedicine, traditional knowledge, quinoa, coca

Description of the Tropical Andean Region

South American diversity is strongly influenced by the Andes mountain range, which is better known as the Andean region. The Andes extends from Tierra del Fuego and finishes in Leeward Antilles, and is divided into three sections: Southern, Central and Northern Andes (Josse *et al.*, 2009).

This review will focus on the Northern and Central Andes, known as Tropical Andes. This subregion extends from west of Venezuela and finishes on the border between Bolivia, Chile and Argentina, the subregion area spans 1.542.644 km^2. The tropical Andes region has a high wealth in biological and cultural diversity (Brown & Mitchell, 2000); it contains approximately 100 types of ecosystems that hold about 45.000 vascular plants of which 20000 are endemic. Additionally, the Andean region is the main source of water for many communities (Josse *et al.*, 2009).

Different geoformations, along with varying weather, altitude and geographical locations, have generated a high ecosystem diversity, which has been clustered in five regions, Northern Andes, Yungas, Wet Puna, Xerofitic Puna and Bolivian-Tucuman (Josse *et al.*, 2009). These different biogeographic characteristics along the tropical Andes region play an essential role in an ancestral and modern culture of Andean communities and subsequently, in the traditional knowledge and use of plants according to the Andean world-view.

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Indigenous Communities and Traditional Knowledge in the Tropical Andean Region

There is no unique definition of traditional knowledge, however, from indigenous communities it has been established that "the traditional knowledge is all ancestral wisdom and, collective and integral knowledge that are an essential part of indigenous, Afro-American and local communities, they were built from millenary praxis and an interaction process between human beings and nature, transmitted orally among generations (De la Cruz *et al.,* 2005)." According Nagoya's protocol, traditional knowledge is associated with genetic resources used by indigenous and local communities, regarding the traditional and cultural lifestyle (Greiber, 2013).

The broad traditional knowledge in Andean communities regarding medicinal plants becomes a dynamizing tool for the bioprospection of biodiversity. South America has a unique wealth of traditional knowledge, simultaneously shared among five tropical countries of high cultural and biological diversity (Colombia, Ecuador, Peru, Bolivia, Venezuela), with two cultural groups (Amerindian and no Amerindian). From these countries, Colombia has not been sufficiently explored by ethnobotanical studies (Cámara-Leret *et al.,* 2014).

In Colombia, ethnobotanical research showed that traditional knowledge is deeply established in communities by "curanderos" and women in non-Amerindian families (Toscano González, 2006). Traditional knowledge in indigenous communities responds to a worldview that considers the relationship between culture and nature, therefore, this knowledge contributes to maintaining plant diversity by sustainable use and management of agroecosystems (Rosero, 2006). By extension, in the "*Ese Eja*" indigenous community in Peru, traditional knowledge and conservation areas are at risk as a consequence of diversity and forest disappearance due to external activities (Paniagua-Zambrana *et al.,* 2012).

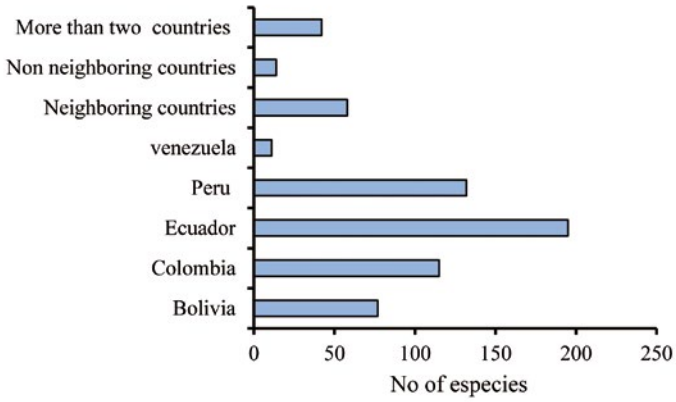
For the Kallawaya culture of the Bolivian Andes, traditional knowledge is constantly revitalized by "curanderos". However, research on medicinal plants is urgent due to their therapeutic potential to improve the quality of life in the communities; it can be done with the integration of a multidisciplinary team including traditional knowledge holders (Vidaurre de la Riva, 2006). In this sense, several ethnobotanical studies have been done in many provinces of Ecuador; however, these reports have not been well diffused, which does not help avoiding loss of traditional knowledge, nor does it help the recognition of Andean resources; their potential and sustainability is at risk. Among the Quechua, Shuar, Oyacachi and Kichwa, many plants are used with a medicinal purpose (De la Torre *et al.,* 2006).

Medicinal Plants Used in Andean Tropical Countries

This review followed several reports about plants used in medical treatments in the Andean region of South-America, as mentioned previously; the Andean region represents a highly diverse area in terms of plant species that are endemically distributed according to microweather created by geographical position. Subsequently, the plant species used in different countries of the Andean region differ enormously and even within the country, the differences not only come from environmental conditions but also are strongly linked to community traditions. We have tried to summarize the results of some studies about ethnomedicine in the Andean region of Colombia, (Angulo *et al.,* 2012; Cadena-González *et al.,* 2013, Rosero, pers. comm.), Peru (De Feo, 1992; Monigatti *et al.,* 2013), Ecuador (Tene *et al.,* 2007), Venezuela (López-Zent, 1993) and Bolivia (Macia *et al.,* 2005). The numbers only correspond to publicly available reports. However, many results were not accessible online and it is important to keep in mind that extensive areas and communities have not yet been registered by ethnobotanical studies.

Around six hundred species were reported from selected ethnobotanical studies which were distributed as follows (Fig. 13), more than one hundred species were reported in several countries and most of them were found in neighboring countries, e.g. Colombia-Ecuador, Ecuador-Peru, etc. This was followed by species that were simultaneously used in more than two countries and finally, by species that were reported in non-neighboring countries,

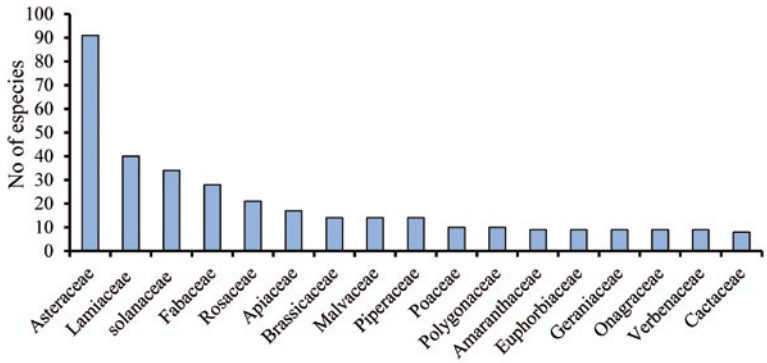
e.g. Colombia-Bolivia, Venezuela-Bolivia, etc. The values observed independently in each country represent medicinal plants registered in the available reports.



13: *Number of species used in ethnomedicine in the Andean region of Venezuela, Peru, Ecuador, Colombia and Bolivia*
Source: Authors' Archive

With respect to species used in several countries, most of them are introduced species, such as *Apium graveolens* L., *Foeniculum vulgare* Mill., *Taraxacum officinale* F. H. Wigg., *Melissa officinalis* L., *Mentha piperita* L., *Rosmarinus officinalis* L., *Linum usitatissimum* L., *Cymbopogon citratus* (DC.) Stapf., *Ruta graveolens* L. and *Urtica urens* L. These species are recognized for their content of chemical compounds that are useful for medical treatments. *Equisetum bogotense* Kunth, *Equisetum giganteum* L. and *Chenopodium ambrosioides* L. are native species that are used in several countries. *Equisetum* species are used to treat disorders in the renal-urinary system and skin infections, and in Bolivia, they are used as part of Andean offerings. *Chenopodium ambrosioides* L. is mainly used for gastrointestinal problems and against intestinal parasites.

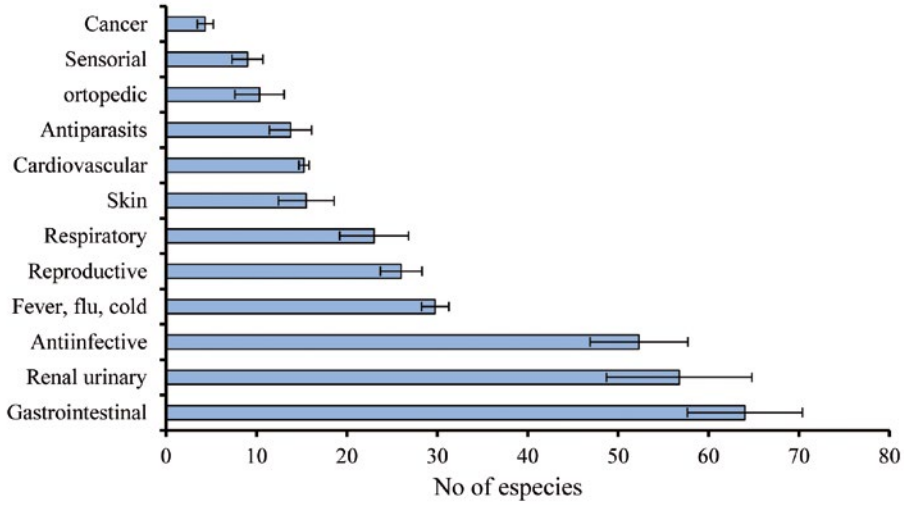
Reported species were identified as members of 116 botanical families, and the most representative was the *Asteraceae* family with nearly one hundred species, followed by *Lamiaceae*, *Solanaceae*, *Fabaceae* and *Rosaceae,* which have more than 20 species (Fig. 14). The members of *Asteracea* family are abundant due to their cosmopolitan character and herbaceous habit. Their phytochemical components make them more used than others (Rosero, pers. comm.).



14: *Number of species according to the botanical family used in ethnomedicine in the Andean region of Venezuela, Peru, Colombia and Bolivia*

Source: Authors' Archive

Andean communities find in plants the treatment of many health and spiritual disorders; this knowledge is strongly linked to traditions, ancestral legacy and to social conditions. Because some families live far from cities and towns, the access to hospitals or health centers is limited. Plants are used as a preventive treatment, during the symptomatic phase of the disease as a first treatment or as a treatment for ailments or minor infections. This is visible according in the number of species used to treat gastrointestinal and renal-urinary disorders, infected tissue (or to protect), fever, flu and cold (Fig. 15).



15: *Number of species used to treat health disorders and in Andean offerings in the Andean region of Bolivia, Peru, Colombia and Ecuador.*

Source: Authors' Archive

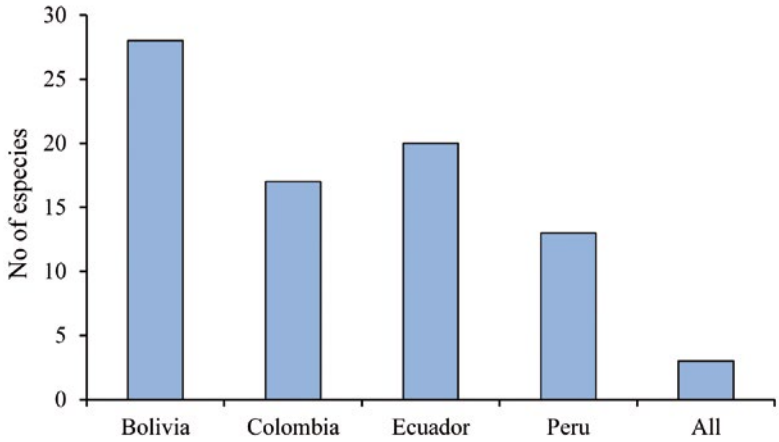
These disorders are mainly treated or prevented using different preparations and include several modes of use. Some examples of gastrointestinal disorders treated by plants are digestive problems, diarrhea, stomach complaints. Plant preparations are also used as preventive treatments for stomach ulcers, amongst others. With respect to the renal-urinary system, plants are used to treat kidney/urinary inflammations, some of them have diuretic properties, etc. Some plants are used as disinfectants of wounds, and of internal and external infections. Fever, flu and cold are commonly treated by plants.

A smaller number of species is used to treat reproductive and respiratory disorders. However, these plants are strongly appreciated because they are used to treat frequent ailments (during the menstrual period) or minor affections.

Few species have been registered to treat cardiovascular, orthopedic, sensorial disorders and cancer; plants are mainly used to prevent these diseases or as simultaneous treatment. Interestingly, the reported species to treat or prevent cancer show potential properties that could be explored and used in cancer treatments. Some of these species have been the subject of cancer research; it is the case of *Aloe vera* L. (El-Shemy *et al.,* 2010), *Annona muricata* L. (Hamizah *et al.,* 2012), *Petiveria alliacea* L. (Urueña *et al.,* 2008), *Bryophyllum pinnata* (Lam.) Oken. (Mahata *et al.,* 2012), *Crotalaria* sp. (Govindappa *et al.,* 2011), *Foeniculum vulgare* Mill. (Devika & Mohandass, 2014), *Marsdenia condurango* Rchb. (Sikdar & Khuda-Bukhsh, 2013), *Uncaria tomentosa* Wild. ex Roem.& Schult. (Rinner *et al.,* 2009) and *Myroxylon balsamum* L. (Barberena *et al.,* 2004), all of which contained compounds against tumour cells. Three species were reported in the ethnobotanical studies for which, however, there were no research

reports regarding their anti-cancer properties: *Echeveria quitensis* Kunth-Lindl., *Prestonia mollis* Kunth and *Althernanthera lanceolata* Benth-Schinz.

Finally, most of the plants used to treat spiritual disorders "espanto" or "susto" and in Andean offerings were identified as native species and were different according to the country (Fig. 16). Thus, endemic plants of specific Andean regions are used for this purpose. Only three species were used in all countries, *Brugmansia sanguinea* (Ruiz & Pav.),*Rosmarinus officinalis* L. and *Ruta graveolens* L. *Rosmarinus officinalis* L. and *Ruta graveolens* L. are burned as incense. *Rosmarinus officinalis* L. is specie introduced from Península Ibérica-Western Mediterranean, *Ruta graveolens* L. is an introduced species from the Canary Islands in Mediterranean Europe and *Brugmansia sanguinea* (Ruiz & Pav.) is an important native South American species.



16: *Number of species used to treat spiritual diseases and Andean offerings in the Andean region of Bolivia, Peru, Colombia and Ecuador.*

Source: Authors' Archive

Quinoa (*Chenopodium quinoa* Willd.), the Mother of Grains and its Potential as Medicinal Plant

Quinua or Quinoa is the seed of the plant *Chenopodium quinoa* Wild. It is called "the Mother Grain" (*La Madre de los Granos*) by the natives of the Andean region (Cusak, 1984). *Chenopodium quinoa* is a dicotyledonous plant and is botanically classified in the family *Chenopodiaceae,* genus *Chenopodium* (Giusti, 1970). The diversity in the uses of the quinoa plant and its wild relatives (*C. carnosolum, C. petiolare, C. pallidicaule, C. hircinum, C. quinoa* subsp. *melanospermum, C. incisum*) are well known to Andean farmers. The farmers distinguish between species and ecotypes, and give them specific uses in food preparation, medicine, ritual events and processing (Mujica & Jacobsen, 2006). Today, thanks to Andean communities, quinoa is known, used and cultivated in different parts of the world due its great potential in human diet, in disease treatment as well and alternative to contributing to the global food security.

Incas and previous cultures considered quinoa as a sacred food and also used it for medicinal purposes. Thus, the use of quinoa in traditional medicine has been known since ancient times. In the communities of the Altiplano and valleys, "Kallawaya" (which in Aymara means carriers of medicinal herbs) healers make multiple uses of the quinoa grain, stems, and leaves for healing and even magical purposes. The modes of preparation and application vary for internal and external use. According to traditional medicine, quinoa stems

and leaves increase the quality of blood. The leaf is used as a poultice to heal sore throats and anginas, another leaf preparation is used to purify the stomach, dislodge phlegm and bile and remove nausea and heartburn. An infusion of the leaves is used to treat urinary tract infections as a laxative. The fresh leaf of quinoa "chiwa", consumed either as a soup or a dessert, is a remedy against scurvy and other illnesses or diseases caused by vitamin deficiency. It is a proven remedy against anthrax, herpes, urticaria, and other skin conditions (Zalles & De Lucca, 2006). The quinoa grain can be used to combat liver disease and is applied to sprains, fractures and dislocations due to its composition that includes a lot of alkaline substances, and it is used as a paste by mixing it with alcohol or brandy. It is also recommended as a refrigerant, a diuretic and to prevent colics. It is an anti-blennorrhoeal remedy and is also used in the treatment of tuberculosis and pneumonia (Pinto *et al.,* 2010; Zalles & de Lucca, 2006). A decoction or poultice made from the fruits is applied to wounds and bruises. Water from a cooked grain cures liver abscesses, internal secretions, and catarrhal afflictions. In addition, the water is also used in washing ears when one is experiencing pain, noise and deafness. According to Kallawaya healers, it is a mild laxative, it is good for insomnia, it combats dandruff and is a good hair tonic (Pinto *et al.,* 2010). A good sudorific is produced by cooking five tablespoons of quinoa seeds in two bottles of water that is sweetened with honey or molasses; this is used against bronchial disorders, colds, cough and inflammation of the tonsils. Quinoa soup with ullucu (*Ullucus tuberosus*), chopped quinoa or quinoa chicha, immediately increase the milk supply of lactating women (Zalles & De Lucca, 2006).

Additionally, particular benefits of quinoa are given by their high nutritional value. The key feature of quinoa is that its grain, leaves and inflorescences are all sources of high quality protein (12.9–21.9%, depending on the variety), balanced amino acid spectrum which include a high lysine and methionine content, carbohydrates (77.6%), lipids (6.5%), a wide range of vitamins antioxidants (Vega, 2010); it is also rich in dietary fibre (Ando *et al.* 2002) and its mineral nutrient contents (K, Ca, Mg, P, and Fe) are much higher than those of conventional cereals (Konishi, 2004). This composition gives quinoa a medical and nutraceutical potential, the dietary fiber (6% of the grain's total weight) promotes intestinal transit, regulates cholesterol, stimulates the development of beneficial bacterial flora and helps prevent colon cancer; it is ideal for helping to eliminate toxins and waste products that can damage the body. Quinoa does not contain gluten, meaning that it can be used for coeliacs; so far studies have found that regular consumption of quinoa improves the small intestine of the coeliacs and returns their intestinal villi to normal, much faster than with a simple gluten-free diet. Finally, two important phytoestrogens – daidzein and cenisteina – can help prevent osteoporosis as well as favor adequate metabolic activity and proper blood circulation (FAO, 2011).

Coca (*Erythroxylum* sp.), Sacred and Medicinal Plant

Coca in the broadest sense refers to two closely-related plant species: *Erythroxylum coca* Lam. and *Erythroxylum novogranatense* (Morris) Hieron, which are botanically classified in the family *of Erythroxylaceae* and genus *Erythroxylum*. Each of them has two varieties. *Erythroxylum coca* var. *coca* "Bolivian" or "Huánuco coca" and var. *ipadu* "Amazonian coca", *Erythroxylum novogranatense* var. *novogranatense* "Colombian coca" and var. *truxillense* "Trujillo coca". Among these varieties are important differences in their stem and leaf anatomy, ecology, geographical distribution, and breeding relationships, as well as in the methods of their cultivation and utilization (Hegnauer, 1981; Plowman, 1984).

Cultivated coca was domesticated in pre-Columbian times. It has played an integral and cultural role in different communities of South American for thousands of years, where it serves as a crucial symbol of cultural identity (Allen, 1986). In addition, its use persists today in several parts of the Andes, in Colombia, Ecuador, Peru, Bolivia, Argentina, and in the western part of the Amazon Basin (Plowman, 1986).

Coca is used mainly by chewing the leaves. However, among communities, this mode of use has some minor variations. Coca is always dried before use; this facilitates the rapid release of the chemical constituents from the leaves while chewing. The dried leaves are placed in the mouth one, or a few, at a time and slowly moistened with saliva; coca is never chewed, but rather the moistened quid of leaves is sucked upon to extract the juices, which slowly trickle into the stomach. Traditional rituals frequently accompany this act (Plowman 1986; Allen 1981). In South America, a number of words are used specifically to denote coca chewing: *mambear* (Colombia); *chacchar*, *acullicar*, *pijchear* (Peru, Bolivia); *coquear* and *mascara* (general) (Powman & River, 1983).

The coca plant shares its name with the chemical compound cocaine; all the cultivated cocas contain the alkaloid cocaine and differ appreciably in the content of minor alkaloids and other chemical constituents (Bohm *et al.*, 1982). The leaves contain protein (20.28 g/all values in 100g of dry matter), with lysine as the limiting amino acid; β-carotene (3.51mg); vitamin E (16.72 mg); trace amounts of vitamin D; calcium, (990.18–1033.17 mg) at two different laboratories; iron, (29.16–29.16 mg); zinc, (2.71–2.63 mg); and magnesium, (225.19–196.69 mg). Cocaine is the principal alkaloid, with a concentration of (0.56 g); other alkaloids have also been identified. Coca leaves do not provide nutritional benefits when eaten in the recommended quantities, and the presence of absorbable cocaine and other alkaloids may be potentially harmful; hence leaves cannot be recommended as a food (Penny *et al.*, 2009).

Coca is a powerful plant in medicinal treatments, especially to protect and ensure health. In internal medicine, coca is taken as an infusion and chewed as a quid. Probably, the most important medicinal use of coca is for gastrointestinal disorders, mainly dysentery, stomachaches, indigestion, cramps, diarrhea, stomach ulcers and other painful conditions. Coca is used for treating symptoms of altitude sickness or *soroche*, which include nausea, dizziness, cramps and severe headaches. It is also commonly used for toothaches, rheumatism, hangovers and numerous other ailments, taken cither internally or applied as a plaster or poultice (Plowman, 1986).

Recently, coca has been studied for possible applications in modern medicine. The therapeutic applications include treating painful and spasmodic conditions of the entire gastrointestinal tract; as a substitute stimulant for coffee in persons who suffer gastrointestinal problems from its use or who are overly dependent on caffeine; as a fast-acting antidepressant and mood elevator without toxic side effects; as a treatment for acute motion sickness; as adjunctive therapy in programs of weight reduction and physical fitness; as a symptomatic treatment of toothache and sores in the mouth; as a substitute stimulant to wean addicted users of amphetamines and cocaine, which are more dangerous and have higher abuse potential; and as a tonic and normalizer of body functions (Weil, 1981; Plowman, 1979). However, the importance of coca in medicinal treatments has to be elucidated, especially due cocaine production and consumption, which give a negative view of the coca plant. In the light of this situation, a better understanding of the cultural and biological aspects of traditional coca consumption is urgent.

Summary

In this review, we summarize the information reported in the ethnobotanical studies of the tropical Andes region in order to recognize the importance of plants in medicinal treatments and in the Andean worldview. The tropical Andean region formed by Andes of Colombia, Venezuela, Ecuador, Peru and Bolivia, represents a culturally and biologically diverse area, thus, the use of medicinal plants differs among and within countries. Andean communities use plants in the treatment of many health and spiritual disorders. Among reported medicinal plants, *Chenopodium quinoa* Willd. and *Erythroxylum* sp. are millenary and sacred Andean species that have a high potential in medicinal treatments and they are also used in rituals. This review shows that the Andean region has a great wealth of traditional knowledge and biological diversity that should be explored, used and conserved.

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