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Review

Plant-based remedies for wolf bites and rituals against wolves in the Iberian Peninsula: Therapeutic opportunities and cultural values for the conservation of biocultural diversity

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ABSTRACT

Ethnopharmacological relevance: Combined approaches to local knowledge and folk plant use improve awareness and promote effective strategies for the conservation of significant biocultural patrimony. Moreover, the information reported might be the basis for further appropriate phytochemical and pharmacological research. Therefore we provide an insight into traditional herbal remedies and practices for healing bite injuries in humans and domestic animals caused by the Iberian wolf. Wolf bites are associated with inflammatory processes and rabies is a potential complication

Aims: This paper describes and summarises the medicinal-veterinary empirical and ritual uses of the Iberian flora for wolf injuries and reviews the ethnopharmacological data of specific plants that are already published. The Iberian wolf is a critically endangered subspecies of the grey wolf. Livestock attacks attributed to wolves are increasingly frequent in the Iberian Peninsula, resulting in serious social problems. Interesting strategies for Iberian wolf conservation might be related to traditional grazing practices that are deeply linked with empirical knowledge and local practices passed on by oral tradition, which are also vulnerable now.

Materials and methods: Based on documentary sources from the beginning of the twentieth century to the present, we systematically searched old monographs, regional documents, technical papers, project reports, as well as the international and national databases and the available scientific literature, without restrictions regarding the language of the publications consulted.

Results: A total of 39 remedies for healing wolf bite injuries in humans and domestic animals was reported, highlighting the medicinal use of 33 species of vascular plants, mostly wild herbs, belonging to 18 botanical families. The use of wood ashes was also reported. The number of use-reports found represents a very high number considering similar European studies. Leaves were the predominant plant part mentioned. Boiling plant materials in water for topical uses was the most frequent method of preparation found. Some traditional remedies combined two or more plant species in order to potentiate their effects. Moreover, some plant-based traditional practices and rituals to ward off wolves and to prevent wolf attacks were also documented. In these practices eleven other species (belonging to seven more families) were used.

Conclusions: Despite the decline of the Iberian wolf over the last few decades, wolves are still in the imaginary of rural communities that perceive this large carnivore as both a diabolic creature and a mythic and benign animal. Wolf-related cultural heritage is of great interest in terms of conservation strategies. This review emphasises the importance of local knowledge and provides useful information about several potential sources of phytochemicals and their claimed therapeutic effects, aiming at contributing to the conservation and appreciation of the Iberian biocultural heritage.

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Fig. 1. A specimen of Iberian wolf showing the characteristic black marks on the front legs (photo by J. A. González). Current geographical distribution of the subspecies [Source: the authors based on national and regional censuses].

1. Introduction

For many centuries, the Iberian Peninsula (Portugal and Spain) was a region where wolves were abundant (Gragera, 1996; Grande del Brío, 1984, 2000; Massip, 2011; Pimenta et al., 2005). The Iberian wolf (*Canis lupus signatus* Cabrera, 1907), an endemic subspecies smaller than the other European wolves and exhibiting a reddish coat and characteristic dark signs –*signatus*– (Fig. 1) (Grande del Brío, 2000; Iglesias et al., 2017; Torres and Fonseca, 2016), is an important element of biocultural diversity (i.e. a rich patrimony combining wild resources, habitat and landscape, and cultural heritage) in the Iberian territory.

A long coexistence between man and wolves provided unique cultural manifestations such as myths, legends, superstitions, tales and peculiar ways to defend against attacks by wolves and to hunt these predators –e.g. particular and varied wolf traps known as *loberas*, *callejos*, *chorcos*, *fosos*, *fojos*, *cortellos*, *cousos*– (Álvares et al., 2000, 2011; Grande del Brío, 1984, 2000; Valverde and Teruelo, 2001). Emblematic Portuguese and Spanish literary works (e.g. Martínez-Barbeito, 1947; Ribeiro, 1918, 1958) and hundreds of tales and stories that have been passed down orally through generations (e.g. Riego Celada and Galhano Alves, 2006) highlight the common presence of wolves and how they are key elements of regional identity.

The range of the Iberian wolf declined throughout the last decades of the twentieth century due to human expansion and persecution, habitat loss, scarcity of natural prey, and forests fires. More recent estimates suggest that in the Iberian Peninsula there are no more than 2500 wolves (more or less 80% in Spain and 20% in Portugal), most of the individuals occurring in a large and continuous population in the north-western region, and some others in two isolated populations in Sierra Morena (Andalusia, southern Spain) and in the southern area of the Douro River (central Portugal) (see Fig. 1) (Blanco et al., 2007; MAPAMA, 2015; Pimenta et al., 2005; Sáenz de Buruaga et al., 2015; Torres and Fonseca, 2016).

Important conservation strategies improving recolonisation (e.g. Grupo de Trabajo del Lobo, 2006; MEDWOLF, 2016) and national and European regulations, some providing compensation programmes for damages by wolves, partly managed to control wolf numbers and their distribution (Eggermann et al., 2011; Fernández-Gil et al., 2016). However, this subspecies is still threatened as rural abandonment increases, and flora and fauna changes affecting wolves' food sources and conflicts with livestock producers and farmers are still occurring.

At the present time, livestock attacks attributed to the wolf are more and more frequent in the Iberian Peninsula (see De la Cal, 2016; Pimenta et al., 2017; Sereno, 2017), resulting in serious social problems. The non-profit organization *Fondo para la Protección de los Animales Salvajes* (FAPAS) argues that the main causes are the fragmentation of wolf packs (unable to capture large wild prey), the significant decrease in wild ungulates populations and the indiscriminate elimination of wolf specimens without technical or scientific basis (see FAPAS, 2016).

In depopulated areas, with no human-wolf potential conflicts, wolves mainly predate wild ungulates, i.e. roe deer (*Capreolus capreolus* (Linnaeus, 1758)), red deer (*Cervus elaphus* Linnaeus, 1758) or wild boar (*Sus scrofa* Linnaeus, 1758), while domestic animals are consumed occasionally (e.g. Barja, 2009). However, wolves having some contact with human activities feed mainly on livestock, being stocks density (number of animals) the factor that better explain wolf occurrence and persistence. For instance, in Portugal, domestic goat (*Capra hircus* Linnaeus, 1758) predominates in wolf diet (> 60%), followed by cattle (*Bos taurus* Linnaeus, 1758) and sheep (*Ovis aries* Linnaeus, 1758) (Eggermann et al., 2011; Torres et al., 2015). Otherwise, in the Spanish Autonomous Communities of Asturias and Galicia large livestock species, horses (*Equus caballus* Linnaeus, 1758) and cattle (primarily foals and calves), are the dominant prey, due to important changes in environmental and agricultural policies affecting these regions (Lagos and Bárcena, 2015; Llaneza and López-Bao, 2015).

Livestock' availability near villages attracts wolves to the outskirts resulting in their adaptation to human presence and thus increasing predatory attacks (Eggermann et al., 2011; Llaneza et al., 2012).

According to data from the Spanish Ministry of Environment, in 2016 more than 4600 wolf attacks were registered for eight Spanish Autonomous Communities (De la Cal, 2016). Data from Castile and León and Asturias Communities are particularly noticeable, as 216 of the 297 wolf packs identified in Spain inhabit these areas. In Castile and León ca. 1800 attacks resulted in about 3300 dead animals having been reported. In Asturias the 37 packs registered caused 2126 attacks on livestock. Overall the number of farm animals affected by wolf damages in Asturias averaged annually ca. 3000 and compensation costs more or less 600,000€ (Fernández-Gil et al., 2016). Likewise, wolf attacks are growing in those territories that are being recolonised, such as the Sierra de Madrid. The number of cases recorded in this area increased over time from 91 attacks in 2015 to 209 in 2016, corresponding to 337 domestic animals killed and 89,625€ paid as compensations (De la Cal, 2016).

Considering the Portuguese territories, during 2012–2013 wolves were responsible for about 2725 attacks to all livestock species per year. The annual compensations paid for damages approximately correspond to 820,000€ (Pimenta et al., 2017). These authors also reported that 83% of the farmers affected (total of 260 farms) suffered between 1 and 3 attacks per year, while only 3.8% suffered ten or more attacks per year (Pimenta et al., 2017).

The number of animals compensated by depredations amounted to

< 1% of free-ranging livestock (Fernández-Gil et al., 2016). Even so, most problems are due to economic damage caused to domestic animals in isolated rural areas and to the lack of funding for damage compensation (ASCEL, 2016; Cerrillo, 2017; Rejón, 2016); several cases of fraud in relation to the payment system with public money have also been reported (Planelles, 2016a, 2016b).

Moreover wolves wounds on cattle are greatly feared by rural people because it is believed that these wounds "turn black" (undergo necrosis) and gangrene easily (e.g. Arízaga, 1915; Martínez González and Lastra, 2006). It is well known that wolf bite wounds may lead to serious infection. The microorganisms involved tend to originate from the oral cavity of the biting animal, which can also be influenced by the microbiome of their ingested prey and other foods, as well as the environment where the injury occurred. A variety of aerobic and anaerobic microorganisms have been isolated from large carnivore bite wounds, with infection ranging from localised cellulitis to systemic dissemination, leading to severe complications ranging from abscess to bone and joint infection, to endocarditis and brain abscess (Abrahamian and Goldstein, 2011; Brook, 2009; Thomas and Brook, 2011).

Frequently people receiving a relatively minor bite from domestic or feral dogs (*Canis lupus familiaris* Linnaeus, 1758) develop extremely serious complications (diverse infections, septicaemia, paralysis and renal failure) that might result in death (Linnell et al., 2002; Thomas and Brook, 2011). Apparently such medical conditions are also associated with wolf bite injuries.

Wolf biting has additional problems because rabies represents the most feared potential complication after wolf bites in many regions worldwide (e.g. Linnell et al., 2002; Simani et al., 2012; Türkmen et al., 2012). Rabies has not been present in the Iberian Peninsula for a long time. This viral zoonosis never became established in wildlife and was eradicated in domestic dogs by the 1970s within the territories of Portugal and Spain (Linnell et al., 2002).

In Spain, there are a number of reported cases where wolves have attacked or threatened adults in self-defence (defensive attacks by a wolf that was trapped or cornered, or a wolf protecting a den site with pups) and well documented episodes where predatory attacks by wolves have occurred on humans. In the latter case, all accidents happened in the 1950s and 1970s in Galicia, and were associated with specific circumstances increasing the probability of carnivores' undesirable behaviour. For instance, landscapes with fragmented habitats, low densities of wild prey, high level of wolf dependence on livestock and anthropogenic foods, great human densities experiencing poor rural lifestyles. Such episodes were mostly focused on defenceless children placed in vulnerable situations (Linnell et al., 2002; Valverde and Teruelo, 2001). Linnell and Alleau (2016) state that nowadays rural population generally do not carried out activities that would constitute potential hazards (e.g. using children as shepherds). This fact implies a very low risk for people, being the real social economic problem the damages on livestock.

According to several scientists and researchers, some interesting strategies for wolf conservation might be related to traditional livestock practices and new approaches to cattle grazing (Álvares and Blanco, 2014; MEDWOLF, 2016; Signatus.org, 2016; Torres and Fonseca, 2016; WOLF, 2014). For example, some projects conducted in Portugal and Spain are studying the advantages of having a donkey (*Equus asinus* Linnaeus, 1758) among the herd (e.g. ASZAL, 2014; Ramos, 2015). It seems donkeys are particularly aggressive against wolves, their behaviour warning of imminent attacks as well as driving back the pack (Mettler, 2014). Likewise, the presence of guardian dogs may also prevent livestock predators. These guardians are mastiff type dogs with stud collars protecting their neck from bites, traditionally known as *carlanca* or *carranca*, fitted with sharp points and metal studs. They bark loudly and are large enough to keep wolves away (MEDWOLF, 2016; Nieto Maceín, 2016; Rosa, 2013).

This paper assumes that medical and veterinary popular remedies and practices used in the past, many of them largely forgotten and already abandoned, might contribute to Iberian wolf conservation strategies, as well as minimise the causes of livestock damage, reducing potential conflict and allowing traditional systems of grazing. Thus, the aims of the present review are as follows: (1) to document and analyse traditional knowledge about the medicinal and veterinary use of plants to treat wolf bites in the Iberian Peninsula; (2) to document traditional plant-based practices to prevent wolf attacks; (3) to make results available within the scientific community in order to provide information for future complementary research, for instance into the validation of the effects of some plants and practices, and (4) to contribute to the conservation of biocultural diversity.

2. Materials and methods

2.1. Data collection

To access the maximum number of documentary sources, a qualitative systematic review of international and national databases was conducted. The ISI Web of Science and Anthropology Plus and JSTOR III – Arts and Sciences international databases were consulted.

The Spanish resources referenced include the database of Ph.D. Theses, TESEO; the information system of the databases of the Spanish Research Council (Spanish acronym CSIC); the Dialnet bibliographic website; Google Scholar and the catalogue of Public State Libraries (BPE). Furthermore, all ethnobotanical studies included in the repository of the *Spanish Inventory of Traditional Knowledge related to Biodiversity* –IECTB for its acronym in Spanish– were checked (see Aceituno-Mata et al., 2014).

Most of the Portuguese documentary sources are the direct result of an intensive review of the literature using search engines and the repository of B-on (Biblioteca do Conhecimento Online). A few old ethnographic documents were retrieved in Bragança Public Libraries. Ph.D. and Master Theses were accessed online, as well as a number of academic and project reports, conference proceedings, published papers and other non-refereed publications, such as several ethnobotanical guides and books. Most of the sources found focused on the distribution of the Iberian wolf, its diet, behaviour, health and genetics. Quite a few works provided useful data about wild species used in the context of attacks by wolves and on the cultural dimensions of wolves. Nevertheless, Portuguese ethnobotanical studies exist, carried out in the areas of Iberian wolf distribution, and reporting on the use of different plants to heal injuries caused by animals, for example wild boars, feral dogs and wolves to humans, livestock and other domestic animals. At times, these use-reports have a global approach and do not specify the exact agent causing the injury. It was therefore assumed that these species and remedies were also used in the case of wolf bites and wounds.

The overall search pattern covered the title, abstract and key words concerning ethnobotany-related disciplines that have UNESCO codes (e.g. anthropology, the history of medicine, botany) and the terms wolf/wolves, wolf bite, wolf attack, folk medicine, folk veterinary medicine, folklore, pastoralism, ethnobiology, ethnobotany, ethnopharmacology, ethnomedicine and ethnoveterinary medicine, in conjunction with the Iberian geographical context. No restrictions regarding the language of the publications consulted were imposed (e.g. Spanish, Portuguese, Galician, English, etc.).

This review was carried out using data found in ca. 50 documentary sources from the beginning of the twentieth century to the present. As for the type of these documentary sources, we obtained empirical use-reports from 22 books, 10 within the scope of ethnobotany, seven concerning folklore or ethnography and only five directly related to ethnomedicine or ethnoveterinary medicine. It was also included, information from 10 journal papers, mostly published in seven journals in the field of folklore and ethnography, five theses, four of which focused on ethnobotanical studies carried out in particular geographi-

Table 1
Vascular plant species traditionally used in the Iberian Peninsula for healing wounds done by wolves.

Botanical families Species	Vernacular name (s)	Common English name	Status[a]	Use-category[b]	Part (s) used	Method of preparation	Geographical location	References
POLYPODIOPSIDA								
OSMUNDACEAE								
Osmunda regalis L.	Llantosil, untosil, ventosil	Royal fern	W	EVM (all livestock)	Rhizome	Decoction	Piloña and Sobrescobio (Asturias), SPAIN	Álvarez Peña (2004)
MAGNOLIOPSIDA								
ADOXACEAE								
Sambucus nigra L.	Sabugueiro, caneleiro	Elderberry	W, C	MED / EVM (all livestock)	Flowers	Decoction	Mogadouro (Natural Park of Douro Internacional), PORTUGAL	Carvalho and Ramos (2012)
					Bark	Ointment (with olive oil, or with beeswax, red wine, sheep fat and wheat bran)	Mogadouro (Natural Park of Douro Internacional), PORTUGAL	Carvalho and Ramos (2012)
ARALIACEAE								
Hedera helix L. [and *H. hibernica* (G. Kirchn.) Carrière]	Edra, hera	Ivy	W, C	MED	Cordiform leaves from the sterile stems	Decoction	Vinhais and Bragança (Natural Park of Montesinho), and Natural Park Serra da Estrela, PORTUGAL	Carvalho (2010); Silva et al. (2011)
						Poultice (warm up)	Vinhais and Bragança (Natural Park of Montesinho), and Natural Park Serra da Estrela, PORTUGAL	Carvalho (2010); Silva et al. (2011)
CISTACEAE								
Cistus albidus L.	Lobera, hierba lobera	Grey-leaved cistus	W	MED	Aerial parts	Decoction	South part of the province of Alava, SPAIN	Alarcón et al. (2015)
Cistus populifolius L.	Jara, jara de Salentinos	–	W	EVM (all livestock, mainly horses)	Aerial parts	Decoction	Palacios del Sil (León), SPAIN	García Jiménez (2007)
Cistus salviifolius L.	Lobera, hierba lobera, bedarra, iñerra zurie, árnica	Sage-leaved rock-rose	W	MED	Aerial part or leaves	Decoction	Northwest of the Basque Country (Biscay and Alava), SPAIN	Menendez-Baceta et al. (2014); Alarcón et al. (2015)
Tuberaria lignosa (Sweet) Samp.	Erva-loba, yerba-lhoba, alcária, erva-arcádia	–	W	MED / EVM (all livestock)	Whole plant, aerial parts	Decoction	Vinhais and Bragança (Natural Park of Montesinho), and Miranda do Douro (Natural Park of Douro Internacional), PORTUGAL	Carvalho (2010); Carvalho and Ramos (2012)
COMPOSITAE								
Carlina hispanica Lam.	Cardo de arzolla	–	W	EVM (all livestock)	Whole plant	Decoction	Comarca de Campoo (Cantabria), SPAIN	Pardo-de-Santayana (2008)
Carthamus carduncellus L. [syn. *Carduncellus carduncellus* (L.) Huth]	Cardo de arzolla, cardo las zolla	–	W	MED / EVM (all livestock)	Whole plant	Decoction	Panzuegos (La Rioja) and the Montaña Palentina district (Palencia), SPAIN	Arízaga (1915); Oria de Rueda et al. (1996)
Carthamus mitissimus L. [syn. *Carduncellus mitissimus* (L.) DC.]	Cardo de arzolla, arzolla	–	W	MED / EVM (all livestock)	Inflorescences or whole plant	Decoction	Comarca de Campoo (Cantabria), SPAIN	Pardo-de-Santayana (2004, 2008)
Centaurea lagascana Graells	Arzolla	–	W	MED / EVM (all livestock)	Whole plant (in flower)	Decoction	Cantabria, SPAIN	Pardo-de-Santayana (2004)
Centaurea ornata Willd.	Arzolla	–	W	EVM (all livestock)	Root	Decoction	Northwest of the Zamora province, SPAIN	Talegón (2016)
Chamaemelum nobile (L.) All.	Manzanilla, manzanilla de campo, manzanillón	Roman chamomile	W	MED	Inflorescences (flower heads)	Infusion	Comarca de Campoo (Cantabria), SPAIN	Pardo-de-Santayana (2008)
Jurinea humilis (Desf.) DC.	Arzolla	–	W	MED / EVM (all livestock, mainly sheep)	Whole plant	Poultice (boiled)	Natural Park of Fuentes Carrionas y Fuente Cobre (Palencia), SPAIN	Pascual Gil (2013)
						Decoction	Natural Park of Fuentes Carrionas y Fuente Cobre (Palencia), SPAIN	Pascual Gil (2013)
GENTIANACEAE								
Gentiana lutea L.	Genciana, janciana,	Great yellow	W	EVM (cattle,	Rhizome	Decoction	Concejo de Aller (Asturias), SPAIN	Martínez González and

(continued on next page)

Table 1 *(continued)*

Botanical families Species	Vernacular name (s)	Common English name	Status[a]	Use-category[b]	Part (s) used	Method of preparation	Geographical location	References
	xanzaina, xanceina	gentian		equines)				Lastra (2006)
				EVM (sheep)	Rhizome, roots	Decoction	Cuevas del Sil (León), SPAIN	García Jiménez (2007)
JUGLANDACEAE								
Juglans regia L.	Nogal, nozal, nogueira	Common walnut	C	EVM (cattle)	Leaves	Decoction	Concejo de Aller (Asturias), SPAIN	Martínez González and Lastra (2006)
				EVM (sheep)	Leaves	Decoction	Cuevas del Sil (León), SPAIN	García Jiménez (2007)
				EVM (all livestock)	Leaves (dried)	Decoction	Vinhais and Bragança (Natural Park of Montesinho), PORTUGAL	Carvalho (2010)
LAMIACEAE								
Rosmarinus officinalis L.	Romero	Rosemary	C	EVM (sheep)	Branches	Decoction (in wine)	Riofrío de Aliste (and other localities of Northwest of the Zamora province), SPAIN	Gallego (2009); Talegón (2016)
Salvia officinalis L.	Sálvia, salva	Sage	C	MED / EVM (cattle, sheep, goats)	Leaves	Decoction	Vinhais and Bragança (Natural Park of Montesinho), PORTUGAL	Carvalho (2010)
Salvia sclarea L.	Bálsamo, esclareia	Clary sage	W	MED	Leaves and flowers	Decoction	Miranda do Douro (Natural Park of Douro Internacional), PORTUGAL	Frazão-Moreira and Carvalho (2009); Carvalho and Ramos (2012)
				MED	Root	Decoction	Vinhais and Bragança (Natural Park of Montesinho), PORTUGAL	Frazão-Moreira and Carvalho (2009); Carvalho (2010)
				MED	Leaves	Poultice (warm up and with olive oil or pork lard)	Vinhais and Bragança (Natural Park of Montesinho), and Miranda do Douro (Natural Park of Douro Internacional), PORTUGAL	Frazão-Moreira and Carvalho (2009); Carvalho (2010); Carvalho and Ramos (2012)
Teucrium scorodonia L.	Hierba de lobo, hojas de lobo	Woodland germander	W	MED	Aerial part	Decoction	Northwest of the Basque Country (Biscay and Alava), SPAIN	Menendez-Baceta et al. (2014)
				MED / EVM (sheep)	Leaves	Decoction	Valle de Carranza (Biscay), SPAIN	Díaz García (2001)
LEGUMINOSAE								
Genista tridentata L. [syn. *Pterospartum tridentatum* (L.) Willk.]	Carqueja, carqueija	–	W	MED	Flowers (dried)	Decoction	Bragança (Natural Park of Montesinho) and Miranda do Douro (Natural Park of Douro Internacional), PORTUGAL	Frazão-Moreira and Carvalho (2009)
Trifolium angustifolium L.	Rabo de zorra	Narrow clover	W	MED	Aerial part	Decoction	Valle de Carranza (Biscay), SPAIN	Díaz García (2001)
Lythraceae								
Lythrum salicaria L.	Salgueira, salgueirinha, salicária, erva-carapau	Purple loosestrife	W	MED / EVM (all livestock)	Leaves and flowers	Decoction	Miranda do Douro and Mogadouro (Natural Park of Douro Internacional), PORTUGAL	Carvalho and Ramos (2012)
MELANTHIACEAE								
Veratrum album L.	Vegambre, verdegambre	White hellebore	W	EVM (cattle, equines)	Root	Decoction	Concejo de Aller (Asturias), SPAIN	Martínez González and Lastra (2006)
OLEACEAE								
Fraxinus angustifolia Vahl	Fresno	Narrow-leafed ash	W	MED	Bark	Decoction	Valle de Carranza (Biscay), SPAIN	Díaz García (2001)
PAPAVERACEAE								
Chelidonium majus L.	Cirigüeña, cirigoña	Greater celandine	W	EVM (cattle, equines)	Aerial part	Decoction	Concejo de Aller (Asturias), SPAIN	Martínez González and Lastra (2006)
PLANTAGINACEAE								
Digitalis purpurea L.	Hoja de la lobera, digital	Foxglove	W	MED / EVM (all livestock)	Leaves	Decoction	San Roque de Riomiera (Cantabria), SPAIN	Pardo-de-Santayana (2004)
						Poultice (fresh and crushed)	San Roque de Riomiera (Cantabria), SPAIN	Pardo-de-Santayana (2004)
Plantago major L.	Llantén	Broadleaf	W	EVM (cattle)	Leaves	Decoction	Concejo de Aller (Asturias), SPAIN	Martínez González and

(continued on next page)

Table 1 (*continued*)

Botanical families Species	Vernacular name (s)	Common English name	Status[a]	Use-category[b]	Part (s) used	Method of preparation	Geographical location	References
		plantain						Lastra (2006)
RHAMNACEAE								
Rhamnus cathartica L.	Espino negro	Buckthorn	W	MED	Root	Decoction	Valle de Carranza (Biscay), SPAIN	Díaz García (2001)
				MED	Bark	Decoction	Valle de Carranza (Biscay), SPAIN	Díaz García (2001)
SANTALACEAE								
Viscum album L.	Almuérdago	Mistletoe	W	MED	Whole plant	Decoction	Valle de Carranza (Biscay), SPAIN	Díaz García (2001)
SCROPHULARIACEAE								
Scrophularia canina L.	Erva-da-quinta	Dog figwort	W	EVM (cattle, sheep, goats)	Leaves	Decoction	Bragança (Natural Park of Montesinho), PORTUGAL	Carvalho (2010)
	Hierba lobuna, hierba del lobo, hierba lobera			MED / EVM (all livestock)	Whole plant	Decoction	El Cerro, Valdelamatanza and Valero (Salamanca), SPAIN	Criado Coca (2010)
URTICACEAE								
Urtica dioica L.	Ortiga, ortiga blanca, ortega, urtiga, estruga, sanpedriñas, herba do cego	Common nettle	W	EVM (cattle, equines)	Root, leaves	Decoction, poultice	Concejo de Aller (Asturias), SPAIN	Martínez González and Lastra (2006)
				EVM (cattle, goats)	Flowering tops	Decoction	As Pontes de García Rodríguez (La Coruña), SPAIN	Latorre (2008)

[a] Status: W, wild; C, cultivated.
[b] Use-category: MED = ethnomedicine; EVM = ethnoveterinary medicine.

cal areas, and two communications presented in Conferences. On the other hand, most of the data related to the use of plants in rituals to ward off wolves and to prevent wolf attacks have been found in ethnographic works.

2.2. Plant taxonomy and nomenclature

To avoid ambiguities and errors in botanical scientific nomenclature, pharmacological or biomedical studies on plants require correct spellings, accepted names, author citations and current family designations (see Bennett and Balick, 2014; Rivera et al., 2014). In order to properly use botanical nomenclature we checked The Plant List (www.theplantlist.org/). Botanical families, local names and common English names, if available, are also provided.

3. Results and discussion

3.1. Quantitative ethnobotanical analyses

A total of 39 herbal remedies to treat wolf bites was recorded, all of which are based on the medicinal use of 33 species of vascular plants, belonging to 18 botanical families (Table 1). Moreover, 14 of the reported remedies were exclusively prescribed for the treatment of persons with wolf bites, 12 were used for sheep, goats, equines and cattle, and 13 applied to humans and domestic animals.

Most of the compiled remedies were found in documentary sources published between 2001 and 2016, as only two of all the references providing herbal remedies date from the beginning of the 20th century (Arízaga, 1915; Oria de Rueda et al., 1996).

Plants, preparations and uses mentioned have been registered within the current geographical areas of wolf distribution in the Iberian Peninsula (Fig. 2). The only exceptions are two remedies based on the use of ivy –*Hedera helix* L., *H. hibernica* (G. Kirchn.) Carrière– documented by Silva et al. (2011) in the Serra da Estrela (Portugal). The Estrela mountain range in the centre of Portugal used to be a traditional area of wolf occurrence. During the 1980s the subspecies almost disappeared due to landscape humanisation (Cândido and Petrucci-Fonseca, 2000; Pimenta et al., 2005).

Considering the biological types, most of the taxa cited are herbs (21). Shrubs represent about one-fifth of the useful plant species. Three trees and three climbers were also reported. The three most relevant botanical families regarding their contribution to treat wolf bites in the Iberian Peninsula are Compositae (7 species) and Cistaceae and Lamiaceae (4 species in both cases).

The taxa obtained are mainly wild; however, five plant species cultivated were also reported. According to the phytosociological category to which each plant species belonged, most plants were collected from forest, woodland, scrub vegetation and synanthropic vegetation zones, modified by human activity.

The total number of 39 remedies registered constitutes a very high number of use-reports, considering that among several recent ethnopharmacological studies, herbal medicines for wolf injuries are rarely mentioned. Four studies, carried out in Italy and Albania, were retrieved while searching the European literature on-line. They specifically report that infection from wolf bites in cows and sheep was prevented in Latium and Liguria (Italy) by a poultice made of olive oil and the boiled rhizome of *Veratrum lobelianum* Bernh. (Melanthiaceae) (Viegi et al., 2003), and in Central Italy (Marche, Abruzzo and Latium) by a poultice prepared from the boiled root of *V. nigrum* L. (Guarrera, 2005). To treat animals bitten by wolves, the cinders of aerial parts of *Pteridium aquilinum* (L.) Kuhn (Dennstaedtiaceae) were topically applied with olive oil in the Italian region of Basilicata (Guarrera et al., 2005). Fresh seeds of *Aesculus hippocastanum* L. (Sapindaceae) were crushed and rubbed on the necks of sheep to cure wolf bites in the Rraicë and Mokra areas (Albania) (Pieroni et al., 2015).

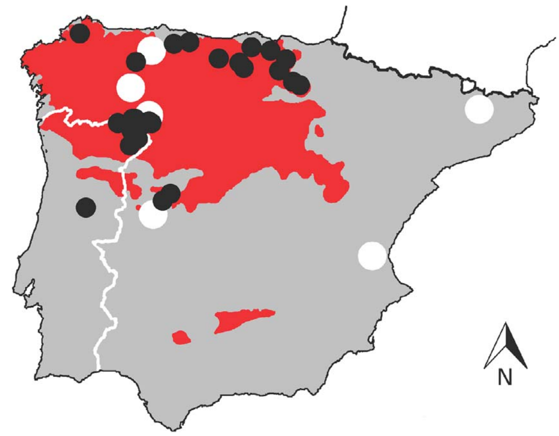

Fig. 2. Geographical location of the documented herbal remedies (black spots) and rituals (white spots); in red current geographical distribution of the Iberian wolf.

3.2. Plant parts used and methods of preparation and application

Leaves are the most frequently sought plant parts, accounting for 12 of the claimed medicinal plants. Of a total of nine species the whole plant and for seven the aerial part are used (flowered or not), and of other seven species, their flowers or inflorescences. Few were harvested for their bark, roots and/or rhizomes. The majority of the remedies were harvested for immediate use. Small proportions were reported to be stored for future use.

All herbal remedies documented are based on topical use, including direct application to injured surfaces of the human or animal body.

The predominant method of preparation is that commonly known as *cocimientos* or *cozimentos* (made by boiling plant materials in water for more than 15–20 min) (Table 1). These are water extractions (decoctions) that correspond to the method of preparation of 85% of all the remedies recorded (39). Another practice involves plant materials, such as branches of rosemary (*Rosmarinus officinalis* L.), boiled in wine. Likewise, infusion was the method employed in another registered remedy. In that case, the plant parts are not subjected to boiling water; extraction is accomplished by steeping the material in very hot water. The residual liquid of decoctions and infusions is used externally, soaked in pieces of cloth or directly applied to the skin and wounds.

Some interesting examples of species and practices were registered. For instance, *Carthamus mitissimus* L. was the most useful vulnerary plant documented in Campoo (Cantabria, Spain). The species was claimed to have wound-healing action, being a powerful disinfectant and known for cicatrising wounds in humans and animals (Pardo-de-Santayana, 2004). A method mentioned as both simple and highly effective against severe wounds (wolf bites and injuries) involved inflorescences and whole plant decoctions. These materials were boiled for a long time in order to obtain a solution with a high concentration, that was used to wash the injuries or was applied using wet pads (Pardo-de-Santayana, 2004, 2008). In the early 20th century, shepherds from Panzuegos (La Rioja, Spain) and the Montaña Palentina district (Palencia, Spain) also employed, in the same way, the decoctions of a similar species, *Carthamus carduncellus* L., for the treatment of humans and livestock injured by wolves. It is said that the healing process was short, only taking a few days (Arízaga, 1915; Oria de Rueda et al., 1996).

Poultices were a common technique for providing the plants' active principles to the injured area. Some herbal substances were prepared with soft leaves, previously heated and greased with olive oil, pig fat and/or beeswax; other plant parts were boiled and mashed, used raw and then crushed or ground, and applied as pastes. As many as six remedies are related to these methods of preparation (Table 1).

Some examples cited are the balsamic leaves of *Salvia sclarea* L. used in north-eastern Portugal. Large and smooth leaves of clary sage (best harvested before the plant came into flower) were heated up in the fireplace, greased with olive oil or pig fat and applied directly to the injured skin (Carvalho, 2010; Carvalho and Ramos, 2012; Frazão-Moreira and Carvalho, 2009). In Mogadouro (NE Portugal), a semi-solid oily preparation was obtained with the bark of elderberry (*Sambucus nigra* L.) crushed with wheat bran and olive oil, or with beeswax, red wine or sheep fat. This ointment was kept in a small glass container and used for its antiseptic qualities, especially in the case of injuries caused by wolves and wild boars (Carvalho and Ramos, 2012).

3.3. Mixtures

Several herbal medicines for healing wolf injuries were prepared combining different species and parts of plants to enhance their potential therapeutic properties, which might be related to synergistic effects.

Gentiana lutea L. and *Juglans regia* L. are well known species and have a long history of use as herbal medicines for their antiseptic and anti-inflammatory characteristics (Font Quer, 1961). The dried underground parts of yellow gentian (i.e. roots and rhizome) and the leaves of the walnut tree were cooked together in water and the remaining liquid was used to clean the wounds in Cuevas del Sil (León, Spain) (García Jiménez, 2007).

In the Concejo de Aller (Asturias, Spain), wounds caused by the wolf on the legs of cows and mares were cleaned and disinfected with decoctions prepared using walnut leaves, broadleaf plantain leaves (*Plantago major* L.) and the roots of *Urtica dioica* L. and *Veratrum album* L. Another folk remedy consisted of the liquid resulting from the decoction of the rhizome of yellow gentian together with the aerial part of *Chelidonium majus* L. and the same two roots mentioned above. In both cases, after washing the wound carefully with these decoctions, a daily poultice of cooked nettles was applied to the wound (Martínez González and Lastra, 2006).

In Valle de Carranza (Biscay, Spain) a decoction was prepared combining three different plant materials: *hojas de lobo* (i.e. the leaves of *Teucrium scorodonia* L.), the bark of the common ash tree (*Fraxinus angustifolia* Vahl.) and *rabos de zorra* (i.e. the aerial parts and inflorescences of *Trifolium angustifolium* L.). The extract obtained was kept in a bottle for subsequent use. However, the solution was heated before being used with a pad or cloth to disinfect the wounds (Díaz García, 2001).

Use-reports from Bragança (Portugal) also highlight some traditional healing practices combining two different herbal remedies: for instance, the external use of clary sage leaves (*Salvia sclarea*) previously heated and greased combined with a decoction of dog figwort leaves (*Scrophularia canina* L.) (Carvalho, 2010). Clary sage leaves are vulnerary, relieving pain and sterilising wounds (Peana and Moretti, 2002; Gülçin et al., 2004a; Džamić et al., 2008; Sienkiewicz et al., 2015); the water extract of figwort leaves cleans, protects from re-infection and promotes cicatrisation (Santos Galíndez et al., 2002; Venditti et al., 2016).

3.4. Potential pharmacological uses

Wound healing is a continuous and complex pathophysiologic process divided in well defined phases: haemostasis, inflammation, cellular migration and proliferation, protein synthesis and wound contraction (Dreifke et al., 2015; Velnar et al., 2009).

Herbal approaches to the treatment of wounds focus the use of healing species with antiseptic, anti-inflammatory and analgesic properties (Merino and Blanquer, 2016; Nagori and Solanki, 2011; Raina et al., 2008). There is currently a great interest in isolating and identifying active constituents from plant species and in screening those active compounds for pharmacological activities. Many ethnopharmacological studies of wound healing plants have been carried out around the world (e.g. Adetutu et al., 2011; Kumar et al., 2007). Several papers on particular medicinal plant species controlling various phases of the wound healing process are also available in the scientific literature (e.g. Mukherjee et al., 2000; Rashed et al., 2003).

Medicinal plants beneficial to skin and wound healing concern antifungal, antiviral and antibacterial activities against infections and activity against inflammatory disorders affecting skin (Mantle et al., 2001; Nagori and Solanki, 2011; Pazyar et al., 2014). Moreover, wound healing protocols depend on each type of injury, considering the level of contamination, extension and size, as well as the cause and depth of the wound (Kasote et al., 2015; Pazyar et al., 2014; Pereira and Bártolo, 2016). In the case of clean wounds (i.e. injuries with a low level of contamination, where skin is likely to heal without complications), apart from suturing, washing with herbal preparations with the above-described properties may be sufficient. On the other hand, infected wounds (exhibiting clinical signs of infection, as well as the presence of pathogenic microorganisms) will need more effective treatments, such as poultices or compresses prepared with extracts of the same plants. Minor and small wounds may be treated with plants with antiseptic properties (antibacterial, antifungal and antiviral). Wounds requiring a healing process are treated with antiseptic species too, but plants and herbal preparations with powerful cicatrisation action are also fundamental to speed the rate of healing and reduce the risk of infection (Merino and Blanquer, 2016).

A number of secondary metabolites-active compounds isolated from plants and tested in animal models (in vivo) have been reported as active principles responsible for facilitating wound healing. Some of the most important ones are phenolic compounds, tannins, alkaloids (monoterpenes, triterpenes), flavonoids and secoiridoid glycosides, among others (Dreifke et al., 2015; Kumar et al., 2007). For example, tannins have been also reported to have antiviral and antibacterial effects (Akiyama et al., 2001). There is a strong association between tannin content and the effects popularly attributed to wound healing and anti-inflammatory plants (Araújo et al., 2008). Tannins might be included in haemostatic formulations, not only to check bleeding by contracting the tissues but also to promote wound healing internally, as they have the ability to form a protective layer over the exposed tissue preventing reinfection (Ashok and Upadhyaya, 2012). Triterpenes proved to increase the rate of successful healing, as well as of epithelialisation and collagen deposition, because they are effective in accelerating re-epithelialisation and improving scar formation (Agra et al., 2015; Kindler et al., 2016). Plant flavonoids have antioxidant activity that destroy free radicals and favour wound healing, as described in several studies (e.g. Rasik and Shukla, 2001).

Most frequently, wolves' attacks on flocks and free-ranging livestock involve the combined effort of the group or pack, in a similar way they predate on large wild ungulates (Grande del Brío, 2000). Sometimes, they capture domestic animals by the neck or throat and many of these animals perish; other times hindquarters (including tail, groin and perineal regions, vulva and scrotum) are the main focus of the attempts; face, front legs and flanks are also potentially highly exposed to wolf attacks. Wolf nasty bites usually cause damage in the underlying tissues, frayed wounds and lacerations, crushed skull, broken spine, disembowelment and massive tissue damage. Injured animals experience blood loss, get in shock, lie down and eventually succumb. However, under certain conditions some more or less seriously wounded animals can survive (Acorn and Dorrance, 1990; Vantassel, 2012).

The literature systematically searched provided ethnopharmacological information about some of the reported vascular plant species used in the Iberian Peninsula to treat wolf bites. Table 2 summarises the known therapeutic activities of these species related to the wound healing process, based on laboratory and clinical evidence, according to the reviewed literature.

Therefore, considering the different stages of the wound healing process and the most relevant therapeutic properties and effects promoting and speeding the cure, it seems that most of the documented plants and herbal preparations used in the Iberian Peninsula might control and reduce the inflammatory phase (antiseptic activity), and promote the onset of the proliferative phase, improving wound contraction, re-epithelialisation, angiogenesis and collagen deposition.

Several authors provided scientific evidence that many of the species listed in Table 2, or at least other species in the same genera, have analgesic activity. Nine of the reported plant species present antinociceptive effects (inhibits nociception, the sensation of pain). For instance, *Plantago major* (e.g. Gonçalves and Romano, 2016) and *Rosmarinus officinalis* (e.g. Rahbardar et al., 2017). Other works highlight important bioactive properties of some species and there are clinical data available for their medicinal and veterinary uses.

The Committee on Herbal Medicinal Products (HMPC) of the European Medicines Agency (EMA) develop monographs in accordance with European Union (EU) regulations, covering the therapeutic uses and safe conditions of well-established and/or traditional use for herbal substances and preparations (EMA, http://www.ema.europa.eu/ema/). Some of the reported species used within the Iberian Peninsula for healing wounds caused by wolves are included in EU Monographs and has a simplified registration procedure for traditional herbal medicinal products in EU Member States, considering the HMPC's scientific opinion on safety and efficacy data about such herbal substances and preparations. Moreover such monographs inform of interesting constituents and possible pharmacodynamic actions although they might not play a role for the already known traditional use. Examples are *Fraxinus angustifolia* (EMA, 2012a, 2012b), *Genciana lutea* (EMA, 2010c, 2010d), *Juglans regia* (EMA, 2014a, 2014b), *Salvia officinalis* L. (EMA, 2010a, 2010b) or *Rosmarinus officinalis* (EMA, 2011b).

Several studies and monographs consulted concern some of the species listed in Table 2 and show that such plants are used worldwide in the treatment of a number of diseases and particularly skin diseases. The chemical constituents of selected examples from Table 2 and their biological activities are described considering different authors findings.

Roman chamomile flowers (Chamomillae romanae flos) are commonly used within the Iberian territory. Preparations derived from the flower heads of *Chamaemelum nobile* (L.) All. are externally applied to treat skin inflammation and irritation; they have also emollient properties and are protective for cracks, abrasions, frostbites, chaps and insect bites (Edwards et al., 2015; EMA, 2012f). Besides many medicinal and veterinary purposes and different solid and liquid formulations for oral or topical application, the consumption of *C. nobile* flower heads infusion (capitula) is also widespread as recreational herbal tea or as an ingredient to prepare other traditional beverages (e.g. Carvalho, 2010; Pardo-de-Santayana, 2008). The species contains an essential oil (up to about 1.75%) with complex composition: esters of angelic and butyric acids, sesquiterpene lactones of the germacranolide type, mainly nobilin and 3-epinobilin. The dried flowers have many terpenoids and flavonoids, as well as 1–2% volatile oils including alpha-bisabolol, alpha-bisabolol oxides A and B, and matricin (Edwards et al., 2015; Srivastava et al., 2010). Major constituents of Roman chamomile are related with its medicinal properties, particularly with anti-inflammatory effects. Moreover, trials in human volunteers showed that such flavonoids and essential oils entered into the deeper skin layers, an important characteristic for a topical anti-inflammatory. Srivastava et al. (2010) reviewed the use of chamomile in traditional medicine and described its curative and preventive properties to enhance wound healing, as well as the results of some trials. The findings reported highlight the efficacy of chamomile extracts on wound drying and in speeding epithelialisation, in addition to antimicrobial activity against various microorganisms. According these authors, such effects validate the use of Roman chamomile in wound management (Srivastava et al., 2010).

Chelidonium majus, greater celandine, is commonly known for its

Table 2
Scientific evidence of medicinal properties of vascular plants used in the Iberian Peninsula to treat wolf bite injuries.

Plant species	Therapeutic activities[a]							References (chronologically arranged)
	WH	AS	AI	AT	AO	AA	HS	
Carlina hispanica[b]		+	+	+				Ivancheva et al. (2006)[b]; Herrmann et al. (2011)[b]
Carthamus (*C. carduncellus* and *C. mitissimus*)[b]		+	+		+	+	+	Almeida et al. (2001)[b]; Ivancheva et al. (2006)[b]; Mothana et al. (2010)[b]; Kuete et al. (2012)[b]; Asgarpanah and Kazemivash (2013)[b]; Turgumbayeva et al. (2014)[b]
Centaurea (*C. lagascana* and *C. ornata*)[b]	+	+	+		+	+		Barbour et al. (2004)[b]; Borchardt et al., 2008b[b]; Koca et al. (2009)[b]; Khammar and Djeddi (2012)[b]; Zater et al. (2016)[b]
Chamaemelum nobile	+	+	+	+	+	+		Chao et al. (2000); Bail et al. (2009); Srivastava et al. (2010); EMA (2012f); Zhao et al. (2014); Edwards et al. (2015); Kazemian et al. (2015); Al-Snafi (2016)
Chelidonium majus		+	+			+		Kokoska et al. (2002); Zuo et al. (2008); WHO (2010); EMA (2012e); Gynovian and Trchounian (2017)
Cistus albidus[b]		+	+	+	+	+	+	Papaefthimiou et al. (2014)[b]
Cistus populifolius		+	+	+	+	+	+	De Andrés et al. (1999); Barrajón-Catalán et al. (2010); Papaefthimiou et al. (2014)
Cistus salviifolius		+	+	+	+	+	+	Abouzeed et al. (2013); Tomás-Menor et al. (2013); Papaefthimiou et al. (2014); El Euch et al. (2015); Habibi et al. (2015); Mahmoudi et al. (2016); Rebaya et al. (2016)
Digitalis purpurea								–
Fraxinus angustifolia	+	+	+	+	+	+		EMA (2012a) (2012b); Moulaoui et al. (2015)
Genista tridentata		+	+		+	+		Pinela et al. (2011); Martins et al., 2015; Aires et al. (2016)
Gentiana lutea	+	+	+	+	+	+	+	Mathew et al. (2004); Oztürk et al. (2006); WHO (2007); Singh (2008); Šavikin et al. (2009); EMA (2010c) (2010d); Azman et al. (2014); Edwards et al. (2015)
Hedera helix		+	+		+	+		Gepdiremen et al. (2005); Lutsenko et al. (2010); Uddin et al. (2011); Rashed (2013); EMA (2015, 2016)
Juglans regia	+	+	+	+	+	+	+	Vanaclocha and Cañigueral (2003); Santos et al. (2013); Sharma et al. (2013); EMA (2014a) (2014b); Panth et al. (2016)
Jurinea humilis[b]		+	+		+			Oztürk et al. (2011)[b]
Lythrum salicaria	+	+	+	+	+	+		Becker et al. (2005); Tunalier et al. (2007); Borchardt et al. (2008a), (2008b); Humadi and Istudor (2009); Vafi et al. (2016)
Osmunda regalis	+	+						Banerjee and Sen (1980); Thomas (2011)
Plantago major	+	+	+	+	+	+	+	Samuelsen (2000); Vanaclocha and Cañigueral (2003); Mahmood and Phipps (2006); Stanisavljević et al. (2008); WHO (2010); Gonçalves and Romano (2016)
Rhamnus cathartica		+			+	+		Borchardt et al. (2008a); Locatelli et al. (2011); Hamed et al. (2015)
Rosmarinus officinalis	+	+	+	+	+	+		Vanaclocha and Cañigueral (2003); Moreno et al. (2006); Bozin et al. (2007); Takaki et al. (2008); Martínez et al. (2009); WHO (2009); Abu-Al-Basal (2010); EMA (2011b); Lai et al. (2012); Abuzeid et al. (2014); Pazyar et al. (2014); Edwards et al. (2015); Rahbardar et al. (2017)
Salvia officinalis	+	+	+	+	+	+	+	Baricevic et al. (2001); Vanaclocha and Cañigueral (2003); Mitić-Ćulafić et al. (2005); Bozin et al. (2007); Delamare et al. (2007); EMA (2010a) (2010b); WHO (2010); Abouzeed et al. (2013); Edwards et al. (2015); Kadhim et al. (2016); Karimzadeh and Farahpour (2017)
Salvia sclarea	+	+	+		+	+		Peana and Moretti (2002); Gülçin et al. (2004a); Džamić et al. (2008); Sienkiewicz et al. (2015)
Sambucus nigra	+	+	+	+	+	+	+	WHO (2004); EMA (2008a); Hearst et al. (2010); Mogoşanu et al. (2014); Edwards et al. (2015); Gynovian and Trchounian (2017); Viapiana and Wesolowski (2017)
Scrophularia canina	+	+	+					Santos Galíndez et al. (2002); Venditti et al. (2016)
Teucrium scorodonia[b]	+	+	+	+	+	+		Alahtavakoli et al. (2012)[b]; Bahramikia and Yazdanparast (2012)[b]; Tabatabaei Yazdi and Alizadeh Behbahani (2013)[b]
Trifolium angustifolium[b]	+	+	+		+		+	Kolodziejczyk-Czepas (2012)[b]; Renda et al. (2013)[b]
Tuberaria lignosa		+	+		+			Pinela et al. (2012)
Urtica dioica	+	+	+	+	+	+	+	Almeida et al. (2001); Vanaclocha and Cañigueral (2003); Gülçin et al. (2004b); WHO (2004, 2010); EMA (2008b) (2011a) (2012c) (2012d); Modarresi-Chahardehi et al. (2012); Salehzadeh et al. (2014); Edwards et al. (2015); Babaei et al. (2017)
Veratrum album	+	+						Tosun et al. (2005); Redzic and Ferrier (2011); Gynovian and Trchounian (2017)
Viscum album	+	+	+		+	+		Ertürk et al. (2003); Orhan et al. (2006); Sengul et al. (2009); Hegde et al. (2011); EMA (2013); Kuonen et al. (2013); Gynovian and Trchounian (2017)

[a] Therapeutic activities: WH = wound-healing (vulnerary, cicatrizant, skin regeneration, angiogenic); AS = antiseptic (antibiotic, antimicrobial, antibacterial, bacteriostatic, bacteriocidal, antifungal, fungistatic, antiviral); AI = anti-inflammatory; AT = astringent; AO = antioxidant; AA = analgesic (including antinociceptive effects); HS = haemostatic.
[b] Information provided for other species of the same genus.

orange coloured latex which topical traditional use against warts, moles, callus and corns is frequent (EMA, 2012e). Major constituents of dried aerial parts (Chelidonii herba) are over 20 different alkaloids, belonging to the benzylisoquinoline group. The plant also contains flavonoids, saponins, organic acids, vitamins, carotenoids, and several hydroxycinnamic acid derivatives including caffeoylmalic, chelidonic, malic and citric acids, as well proteolytic enzymes detected in the latex (EMA, 2012e; WHO, 2010). Experimental pharmacology describes anti-inflammatory activity in vitro during a test conducted to determine constituent's ability to inhibit enzymes in the inflammatory cascade (WHO, 2010).

Fraxinus angustifolia provides different traditional herbal medicinal products: the leaves are reported for minor joint pain (EMA, 2012a, 2012b), and the bark as diuretic and for gastrointestinal complains in veterinary (Moulaoui et al., 2015; Viegi et al., 2003). The active components of leaves and bark ethanolic extracts and their content in polyphenols were assessed by HPLC to elucidate the polyphenolic composition of *F. angustifolia* extracts, and to evaluate their efficacy in wound healing. Quercetin, catechin, rutin and tannic acid were identified as the main components. *In vivo* results showed that the highest antioxidant and anti-inflammatory effects were provided by the polyphenolic phytocomplexes that consequently promote wound healing (Moulaoui et al., 2015).

Gentiana lutea is another species documented by WHO and EU monographs on selected medicinal plants (EMA, 2010c, 2010d; WHO, 2007). Plant materials correspond to dried underground organs, roots and rhizomes (Gentianae radix). Different types of extracts proved to have antimicrobial activity, i.e. inhibition of bacteria and fungi growth (WHO, 2007). It seems that gentian leaves and roots exhibit considerable antioxidant properties, expressed either by their capability to scavenge DPPH or superoxide radicals; however further research is needed to confirm these observations (EMA, 2010c, 2010d). According to Oztürk et al. (2006) and Singh (2008) active principles responsible for wound healing are: gentianine a monoterpene alkaloid with anti-inflammatory, analgesic and antibacterial properties; gentianadine, an alkaloid that possesses anti-inflammatory activity; and sweroside, a secoiridoid glycoside with antimicrobial and antifungal action. Šavikin et al. (2009) point out that the methanolic extracts of flowers and leaves of *G. lutea* have a good antimicrobial effect on a variety of Gram-positive and Gram-negative bacteria as well as on the yeast *Candida albicans*, which is related with their secoiridoid glycoside content. Antioxidant activity has been attributed to the phenolic content of gentian extracts, especially gentiopicroside, which also exhibited analgesic properties (Edwards et al., 2015).

Juglans regia leaves (drug Juglandis folium) are usually boiled in water to make a decoction which is applied to mild and superficial skin inflammations. Walnut leaves contain approximately 10% tannins and about 3.4% of flavonoids (EMA, 2014a, 2014b). Santos et al. (2013) identified and quantified twenty-five phenolic compounds in walnut leaves decoctions prepared for topical applications, as also the presence of pro-cyanidins, taxifolin derivatives, and tocopherols. According to Panth et al. (2016), the volatile oil obtained from *J. regia* leaves and its key constituents (β-pinene, α-pinene, limonene, germacrene D and β-caryophyllene) exhibited strong activity against bacteria (primarily Gram-positive bacteria). Wynn and Fougère (2007) suggest veterinary indications for walnut leaves, applied topically for focal inflammation and skin lesions.

Plantago major (broadleaf plantain) and other species of the genus *Plantago* are plants which seeds, leaves and aerial parts have widespread medicinal uses. Plantain fresh leaves have been used externally for a long time as an antiseptic for the treatment of skin irritations and skin inflammations (Samuelsen, 2000). WHO monographs (WHO, 2010) document the dried leaves of plantain as useful plant material with different therapeutic properties: antimicrobial due to the pectic polysaccharide fraction that protects against bacterial infections; antinociceptive and anti-inflammatory as ursolic and oleanolic acids were isolated from a hexane extract of dried leaves using bioactivity-directed fractionation. Such components have important wound-healing activity. The pectin-type polysaccharide fraction (PTPF) isolated from the leaves of *P. major* is a potent complement activator with an activity of the same order of magnitude as that of aggregated human immunoglobulin G (WHO, 2010). *Plantago major* might have also veterinary interest being topically used in poultices for skin wounds (Wynn and Fougère, 2007).

Rosmarinus officinalis, known as rosemary, has great aromatic and medicinal potential. The most valuable plant materials are the leaves and the flowering aerial parts that are used in solid and liquid herbal preparations for skin affections, among other therapeutic purposes (EMA, 2011b). Both leaves and the essential oil obtained by steam distillation of the flowering aerial parts are considered by EMA (2011b) and WHO (2009) monographs. Experimental pharmacology shows antimicrobial and inflammatory activities as well as antioxidant and pro-oxidant properties both in vitro and in vivo (WHO, 2009; Edwards et al., 2015). Rosemary essential oil exhibit peripheral antinociceptive activity in animal models (Takaki et al., 2008). Besides the chief constituents of the essential oil (e.g. camphor, limonene and others) and phenolic compounds (e.g. flavonoids and phenolic acids), tricyclic diterpenes such as rosmaridiphenol, carnosol and carnosic acid are interesting constituents. Carnosol presented potent antioxidant activity when compared with other compounds extracted from rosemary. Moreover, possible mechanisms for anti-inflammatory activity are related with carnosol that suppresses nitric oxide production and inducible nitric oxide synthase gene expression by inhibiting activation of nuclear factor-B (WHO, 2009; Edwards et al., 2015).

Salvia officinalis leaves (Salviae folium) are traditionally used as a vulnerary and an antiseptic. They contain thujone, cineol and camphor, and other constituents such as tannins, diterpene bitter principles, triterpenes, and flavonoids (such as luteolin and salvigenin). Several studies performed show positive antibacterial and anti-inflammatory effects of *Salvia officinalis* extracts. Specifically, flavonoids and phenolic acids such as rosmarinic acid found in sage may be responsible for some of the biological activities, as these compounds have known antiviral, antibacterial, anti-inflammatory and antioxidant properties (see Peterson and Simmonds, 2003). Sage oil has antimicrobial properties; the oil shows inhibitory activity against Gram-positive and Gram-negative bacteria and against a range of fungi. Most frequent dermatological therapeutic indications concern minor skin inflammation (EMA, 2010a, 2010b; WHO, 2010; Edwards et al., 2015). Karimzadeh and Farahpour' recent research (2017) reports that the hydroethanolic leaves extract has a high total flavonoid and phenolic content and antioxidant capacity. The topical application of ointments with different doses of hydroethanolic sage leaf extract improved wound healing process in rats, as significantly increased the percentage of wound contraction, and promoted the period of re-epithelialisation, and the new vessel formation and fibroblast distribution. Thus, it can be considered an appropriate potential compound for clinical application (Karimzadeh and Farahpour, 2017).

Urtica dioica dried leaves and rhizome, as well as fresh and dried aerial parts harvested during the flowering period (Urticae folium and Urticae herba), are reported for their traditional medicinal applications (EMA, 2008b, 2011a, 2012c, 2012d; WHO, 2004). Major constituents of underground organs (Urticae radix) are many compounds with different polarity and belonging to various chemical classes, such as triterpenes, phenylpropanes, lignans, coumarins, ceramides, sterols and lectins (WHO, 2004; Edwards et al., 2015). Principal components of *Urticae herba* are flavonoids, caffeic acid esters (mainly caffeoylmalic acid, chlorogenic, neochlorogenic), chlorophyll degradation products and carotenoids, coumarins, triterpenes and sterols, leukotrienes (EMA, 2008b, 2012c; Edwards et al., 2015). Experimental pharmacological assays proved anti-inflammatory activity; an ethanol extract inhibited the activity of human leukocyte elastase and reduced the amount of the enzyme released by activated polymorphonuclear granulocytes during the inflammatory response (WHO, 2004, 2010). Topical ointments prepared from the extracts of *Urtica dioica* and *Sambucus ebulus* L. and their combination showed strong wound healing properties. It is postulated that a synergistic effect may exist between the two extracts since the combination 2% showed better results than the sole extracts (Babaei et al., 2017).

Viscum album L. lipophilic extract contains pharmacologically active pentacyclic triterpenes that are known to exhibit wound healing activity. Preliminary clinical observations indicate that this extract was able to influence cutaneous wound healing in vivo. Data support the casual observation that it might modulate wound healing related processes in vivo (Kuonen et al., 2013).

Among the plant species for which there is no clinical data available regarding medicinal and veterinary uses, highlight *Cistus albidus* L., which chemical composition is one of the most studied within the genus *Cistus*. This perennial shrub has been highly reported for its traditional use in ethnomedicine (Alarcón et al., 2015; Gonçalves et al., 2013). Some of the compounds identified among their volatiles such as the phenolic monoterpenes thymol or carvacrol, are well known as antimicrobial compounds, exhibiting significant growth-inhibitory effects on bacteria (Maccioni et al., 2007). Gonçalves et al. (2013) experimental research showed that *C. albidus* extracts are exceptionally effective and potentially new sources of antioxidants, confirming the folk use of species, particularly for the prevention and treatment of diseases that are known to be caused or accelerated by oxidative stress.

On the other hand, the traditional use of the leaves of foxglove (*Digitalis purpurea* L.) or of woodland germander (*Teucrium scorodonia*) as a healing remedy for wolf bites and infected wounds seems to be an exception. For example, foxglove preparations were applied to humans and domestic animals bitten by wolves in different Spanish regions, as reported by Pardo-de-Santayana (2004), Verde et al. (2008) and Criado (2010), and woodland germander is one of the ingredients present in a patented homeopathic formulation (https://www.google.com/patents/WO2013189908A1?cl=en) for healing wounds. Moreover, in many Spanish regions, such as the Basque Country, the common name of woodland germander, *hierba de lobo* (literally "wolf herb") is linked with the carnivore presence or its injuries' treatment (Díaz García, 2001; Menendez-Baceta et al., 2014). Besides *T. scorodonia*, other five plants also used for healing wolf bites are locally know by popular names related with wolves, e.g. *lobera, hierba lobera, hierbalobuna, erva-loba* (see Table 1). However, assays to determine the antimicrobial activity of foxglove extracts (e.g. Dogruoz et al., 2008) or of woodland germander essential oils (e.g. Djabou et al., 2013) did not confirm bacterial inhibition. Hydroalcoholic extract of *Teucrium polium* L. has antimicrobial effect and decreases the duration of complete wound healing process in rats (Alahtavakoli et al., 2012; Bahramikia and Yazdanparast, 2012; Tabatabaei Yazdi and Alizadeh Behbahani, 2013), emphasising the importance of ethnopharmacological approaches and the development of new studies.

3.5. Incertae sedis

A common practice of Spanish shepherds from Zafra (Badajoz) and Tierra de Cameros (La Rioja) consisted of making plasters with wood ashes that were then applied to wolf bites. It was claimed that such preparations dried and healed the injury (Elías and Muntión, 1989; Penco, 2005). Ashes, salt and water were the main ingredients to prepare a decoction that was used to cure bites in Asturias (Spain) (Castañón, 1976; Junceda Avello, 1987).

In Sardinia (Italy), Piluzza et al. (2015) have documented the use of ash in water, wrapped with a cloth around the wounds from red fox – *Vulpes vulpes* (Linnaeus, 1758)– or dog bites. In fact, several tests conducted with animal models have confirmed that the topical administration of ashes (corresponding to complete burning of woody materials) accelerates the wound healing process, enhances epithelialisation and reduces infection (Hamid and Shaikh, 2009; Shaikh and Hamid, 2009). The analysis of different types of wood ashes revealed that they contain the appropriate combination of metals required to heal a wounded area faster (Hamid and Shaikh, 2009; Shaikh and Hamid, 2009).

3.6. Plant-based traditional practices to ward off wolves

Until recently and within the Iberian territories wolves were scared away by several peculiar methods such as: tying a red cloth ribbon around the lambs' necks (Aguirre Sorondo, 1996; Penco, 2005); playing the *zambomba*, a traditional musical instrument similar to a friction drum (Barandarián and Manterola, 2000; Goñi, 1975); or reciting a set of prayers to St. Antony to get protection from wolves (e.g. Domínguez Moreno, 1994; Mariño Ferro, 1985; Prieto, 1949; Valverde and Teruelo, 2001; Vidal-González, 2013). Moreover, the literature also refers to the use of plant species in some practices to prevent attacks by wolves (see Fig. 2). In the Sierra de la Culebra (Zamora, Spain), livestock was kept temporarily in the mountain inside the so-called *corralas* or *corrales*. These safe enclosures were erected with stone walls and topped with a vegetal parapet made of heather species (*Erica arborea* L. and *E. australis* L., Ericaceae), gorses (*Genista* spp., Fabaceae) and/or elm-leaf blackberry (*Rubus ulmifolius* Schott., Rosaceae) (Dacosta, 2010). In the case of the Pallars region (Lérida, Spain), shepherds carved thick pointed branches of box wood (*Buxus sempervirens* L., Buxaceae) to use in enclosures to prevent or, at least, to hinder the carnivores (Agelet, 1999). In Valencia (Spain) shepherds believed that the sound produced by flutes made with the wood of *lledoner* (the honeyberry or nettle tree, *Celtis australis* L., Cannabaceae) would ward off wolves (Zurriaga, 2012). These last two use-reports are very interesting, as they are practices to ward off wolves documented in geographical areas where this large carnivore disappeared in the early twentieth century (see Fig. 2) (Grande del Brío, 1984, 2000; Massip, 2011).

3.7. Plant-based rituals for the prevention of the wolf attacks

Different magic-religious rituals, based on the use of certain very fragrant plant species, are among several traditional practices that were used to protect livestock and people from wolves. Thus, in Teverga (Asturias, Spain) bunches of fennel (*Foeniculum vulgare* Mill., Apiaceae) were left on the streets during the Feast of Corpus Christi. It was believed that the branches would be blessed as the priest wandered the streets carrying the custodia. Later, on the eve of St. John's Day, these holy fennel bunches would feed domestic animals that would be protected against wolves (Castañón, 1966).

On the same day, St. John's Eve, the inhabitants of Ahigal (Cáceres, Spain) implemented a *sahumerio* made of aromatic plants. This Spanish word, which is derived from the Latin *suffumāre*, is related to the combustion of aromatic biotic material which releases fragrant smoke and is used to purify. Bunches of *cantueso* (*Lavandula pedunculata* (Mill.) Cav., Lamiaceae) and rosemary, previously blessed during the procession at Corpus Christi, were burned and the smoke spread throughout the house, the barn and the stable. It was considered that being exposed to the blessed smoke would keep everybody and everything safe from wolf attacks. For the same purpose, domestic animals were passed over ashes at dawn to get protection against wolves (Grande del Brío, 1984).

The purifying power and the beneficial virtues of fire and smoke were also claimed to prevent wolf attacks in El Bierzo (León, Spain). Piles of burning fragrant plants were used to frighten the beasts, such as *ruda* (rue, *Ruta* spp., Rutaceae), *caléndula* (field marigold, *Calendula arvensis* M. Bieb., Compositae), *cantueso* or rosemary (Criado, 2012). Furthermore, in Tierra de Granadilla (Cáceres, Spain), making bonfires using rosemary near houses was a common practice during St. John's Eve. The next day, the livestock would walk over the ashes and such cinders would be distributed over the sheepfolds (Domínguez Moreno, 1991, 1994).

4. Conclusions

Despite the decline of the Iberian wolf during over the last few decades, wolves are still in the imaginary of rural communities that perceive this large carnivore as both a diabolic creature and a mythic and benign animal. The wolf-related cultural dimension is of great interest in terms of conservation strategies and local knowledge is intrinsically bound up with cultural legacies. Thus, it has great significance to assess local knowledge about 39 plant-based remedies traditionally used for healing injuries from wolves in humans and domestic animals within the Iberian territory, including all the areas of wolf distribution, as well as to describe the practices and rituals for improving preventive methods and warding off wolves that involved eleven plants. Additionally, the gathered information may contribute to the conservation of the Iberian biocultural patrimony by recognising, understanding and valuing natural resources, as well as rural beliefs and practices.

The vascular plants reported are claimed to have analgesic and antiseptic properties, to reduce inflammation and improve wound contraction, re-epithelialisation, angiogenesis and collagen deposition. Some specific uses currently cannot be explained as they concern the magic-ritual domain.

The documented species are culturally important plants and may be potential sources of phytochemicals. Although it was found that certain species mentioned for healing injuries from wolves are effective in the wound-healing process, there is clearly a need for further phytochemical and pharmacological research and bioassays, in order to better understand the properties and effects of these interesting plant resources.

Plants and their extracts have great potential for the management and treatment of wounds in domestic animals. Phytomedicines for wound healing are not only less expensive and affordable but are also purportedly safe as hyper sensitive reactions are rarely encountered with the use of these agents. Nevertheless, there is a need for scientific validation, standardization and safety evaluation of the plants used in Ethnoveterinary Medicine (EVM) before they could be recommended for treatment of the wounds. Further clinical studies of phytoconstituents should be carried out to determine safety, efficacy and doses. The combination of traditional and modern knowledge can produce better drugs for wound healing with fewer side effects.

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