Biological Conservation 243 (2020) 108454

Contents lists available at ScienceDirect

Biological Conservation

journal homepage: www.elsevier.com/locate/biocon

Policy analysis

Patent analysis as a novel method for exploring commercial interest in wild harvested species

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ARTICLE INFO

Keywords:
CITES
Environmental science and management
Ethnobotany
Patents
Systematic review
Wildlife trade

ABSTRACT

Wildlife trade is a threat to species survival and wild collected orchids are a notable component of it. In the first systematic patent review of any wild species, we find many innovative and industrial uses of orchids, using the example of traditional product *salep* made with wild harvested Mediterranean and Central Asian terrestrial orchids. Despite considerable interest in the conservation of these orchids, no systematic analysis of innovation and technology transfer had been conducted for natural products using them. Our systematic review on *salep* found 244 patent applications, of which 89 were granted, spanning 163 years from 1855 to 2018. Uses included industrial materials and contemporary medicine formulations. This recalibration of the value of *salep* using patent analysis shows that, rather than being restricted to two specific products of limited regional circulation, these orchids are a rich source of unique materials with myriad applications around the world. In order to conserve wild terrestrial orchids collected for *salep*, conservation science must engage with the full extent of the utility of and commercial interest in these particular orchids. Additionally we demonstrate how conservationists can use patents as a source of information on incipient commercial interest in wild species.

1. Introduction

Wildlife trade is lucrative commercially, and also has a cost to wildlife. Global illegal wildlife trade was estimated to be US$7–23 billion annually (Nellemann et al., 2016). Quantifying illegal trade is hindered by its covert nature, but legal trade of wildlife products into the EU alone is estimated as being worth €100 billion annually (Duffy, 2016). Wildlife trade is a direct threat to wild species across a range of taxonomic groups (Esmail et al., 2019). A global analysis of wildlife trade neglected species that were not vertebrates (Scheffers et al., 2019). Plant blindness is known to skew conservation towards focusing on animals (Balding and Williams, 2016). Yet 7.5%–10% of wild plant species have documented aromatic and medicinal uses, and 60–90% of aromatic and medicinal plants in trade are wild harvested (Jenkins et al., 2018). 28,484 or 79.5% of the 35,811 species listed under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), are orchids (CITES, 2017; WCSP, 2018). Hence our selected focus on a group of wild collected orchids of commercial value to evaluate the efficacy of patent analysis as a means of informing conservation science.

Around the Mediterranean Sea and Temperate Asia *salep* is made from the tubers of wild orchids that are dug up in spring and summer. *Salep* powder is the characteristic ingredient of a drink also called *salep*, and a type of ice cream called *maraş dondurma*. After collection the orchid tubers are boiled in water, milk or *ayran* (a yogurt based drink) to render the enzymes within them inactive and prevent tubers from regrowing (Tamer et al., 2006). Rather than being a novel product, use of wild harvested orchids as *salep* has a long history. One of the earliest written references on the use of *salep* as a medicinal product is in medieval Cairo (Lev, 2002). Ice cream was not invented with the advent

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https://doi.org/10.1016/j.biocon.2020.108454
Received 10 June 2019; Received in revised form 24 January 2020; Accepted 3 February 2020

of electrical refrigeration, it was made in 16th century Levant with snow collected in winter and stored in icehouses to make iced desserts and drinks in summer (Belon, 2012). An 1882 recipe for making ice cream with *salep* powder and beating it to create a viscous texture may be the first written instructions for making *maraş dondurma* (Işın, 2013). Yet now both drink and ice cream made using *salep* powder are under scrutiny as the drivers of decline in wild populations of orchids used to make them.

Tuber collection for *salep* has been cited as a cause of orchid population decline (Delforge, 2006; Kasparek and Grimm, 1999). Orchid tuber collection in Turkey alone has been estimated to annually use tubers from 30 to 120 million orchid plants producing over 115 tones of *salep* (Kreziou et al., 2015; Sezik, 2002). Consequently in Turkey, cessation of collection of wild orchids for *salep* and ceasing consumption of *salep* has been recommended by academics and conservationists (Kasparek and Grimm, 1999; Sezik, 2002). Reports that orchids are being collected from Albania, Greece, and Iran to meet the Turkish demand for *salep* are cause for conservation concern in these countries (Ghorbani et al., 2014; Ghorbani et al., 2016; Kreziou et al., 2015; Pieroni, 2010).

The reported collection and trade of *salep* is vast (Ghorbani et al., 2014; Sezik, 2002), yet these studies focused on limited geographical regions only. This makes it difficult to predict whether harvest from the wild has changed or will increase, the full extent of use, and whether the orchids used in these traditional products will be substituted with other endangered plants in the near future after local resources become depleted.

Horizon scanning has a role in gathering evidence on emerging trends, looking ahead not only for threats but also opportunities by gathering information (Sutherland and Woodroof, 2009). It is also a tool that can be used to inform policy (Cook et al., 2014; Könnölä et al., 2012). Considering that *salep* is a product much older than existing databases on its trade such as CITES trade database it is pertinent to use a source of information that is informed by current commercial activity, but also has records spanning a longer period.

Patents are an evolving interface between knowledge, innovation, and commerce. In 1474 the Venetian Senate established the first patent code in which the concept of intellectual property was accorded legislative protection that gave privilege to inventors to practice, and excluded others from profiting from their innovations (Sichelman and O'Connor, 2012). Patents are a proxy for measuring innovation (Burhan et al., 2017). Patent analysis is an emerging field that treats patents as a knowledge base, which can be analysed for a number of purposes including to analyse trends and forecast technological development (Abbas et al., 2014). Patent applications have created a vast source of information on innovation and commerce, at a global level 50 million documents from 19th century till the present day are estimated to be held by the patent system (Oldham, 2011). Patent analysis has been applied to genetic resources and associated traditional knowledge, focusing on the ownership of intellectual property (Oldham, 2006). Patents also contain details of biological species – 76,274 species were named in 767,955 patent documents (Oldham et al., 2013).

Patents contain details of where the product is considered commercially valuable i.e. the jurisdiction, when the patent was sought, and details of method and specific components. For example *Leptotes bicolor* was described as an orchid used in Brazil, one of the countries in which it grows as a wild species, to flavour food products (Duggal, 1971). It is now listed in several patents as a spice or food flavouring in patent jurisdictions outside of Brazil (Reh et al., 2016). *Vanda coerulea* described as being used in treatment of skin ailments and having in-vitro efficacy as an anti-inflammatory on skin (Medhi and Chakrabarti, 2009; Simmler et al., 2009) is also listed in patents as a cosmetic ingredient (Andre et al., 2011). These two examples illustrate traditional uses of orchids being developed as modern products. Assembling all patents using a species or wildlife derivative offers more powerful analysis.

This study of *salep*-producing terrestrial orchids is the first application of patent analysis to inventory commercial uses of any wild species. We used patent documents as a repository of knowledge (OECD, 2009a). Patent analysis has not hitherto been used in conservation science as a tool to examine wildlife trade. However, it offers a means of aggregating information on what species are of economic interest, what properties are valuable, what form their trade may take, and where trade may take place. Patent documents as a source on commercial knowledge on orchids traded as *salep* provide an example to illustrate how the patent system offers additional information to conservation science on trade, bridging the gap in perception between commerce and conservation. We investigated whether patent analysis could identify specific taxa of interest to different internationally standardized use categories, reveal dynamics of *salep* commerce over time, and identify properties of *salep* that are of commercial interest.

2. Materials and methods

2.1. Search parameters

In accordance with guidelines on conducting systematic reviews the search for sources used a repeatable strategy tailored to likely sources as well as the research question (CEE, 2013). Scopus, Lens, and Google Patents - international databases and search engine - were searched using single word queries for patent applications containing the word "*salep*" and other known appellations: "*salepi*", "*sahlab*", "*sahleb*", "*sahlep*", "*sakhlav*" or "*saloop*". In accordance with guidance on systematic reviews the publication period was unlimited (Cook et al., 2013; Pullin and Stewart, 2006). As increasing geographical coverage tends to increase the likelihood that reviews have implications for management no geographical limitations were applied (Cook et al., 2013).

2.2. Data extraction

Patent applications are administrative data that provide technical information (OECD, 2009b) rather than a substrate for research, thereby requiring tools for search and reformatting (Jefferson et al., 2018). No single patent database or search engine identified all the patents relevant to our search. Older patents were archived as pdfs made from scanned material that were not fully machine readable for automated text searches. Consequently we extracted data and compiled our own database of patents that referred to *salep*.

Geographical location of patent application or grant, use category, specific use, nomenclature of *salep*, species and genera specified, and properties specified were coded in a spreadsheet to create a systematic database (James et al., 2016). Where possible existing categorizations were used (Sutherland et al., 2017). Use categories were assigned according to the Economic Botany Data Collection Standard (Cook and Prendergast, 1995), with an additional category for object of patent i.e. the patent was for an innovation in processing *salep* or treating orchids used for *salep*. Species names given in sources were checked using the World Checklist of Selected Plant Families (Govaerts et al., 2017) as reference for accepted names. The few species whose name was ambiguous under current nomenclature as no scientific author was listed or a spelling mistake may have been made, e.g. *Orchis latifolia* and *Orchis maculata*, were noted as potentially incorrectly named in current nomenclature. Not all data categories were known at the beginning of the process of data extraction. Therefore iterative linking of methods and results was used to supplement, refine and clarify data categories (Corbin and Strauss, 2012). For example our initial tabulation of the patents found cases where glucomannan or mannan were not specified in the text but properties such as mucilaginous or colloid derived from glucomannan or mannan were. Consequently, patents were re-read and these properties were tabulated. Our last search was run on 16th March 2018. Chi -squared analysis was used to evaluate significance of use categories.

Table 1
Search terms used in databases and search engine and numbers of documents retrieved.

Search term	Google patents	Lens	Scopus patents
salep	162	147	117
salepi	10	1	0
sahlab	3	6	0
sahleb	6	0	0
sahlep	12	34	18
sakhlav	0	0	0
saloop	1	4	3

3. Results

3.1. Salep patents

A search for *salep* in Google patents found 162 results, 117 in Scopus, and 147 in Lens. Additional searches for *salepi*, *sahlab*, *sahleb*, *sahlep*, *sakhlav* and *saloop* yielded a further 98 patent applications (see Table 1.). Removing duplicate listings of patents, false results caused by Optical Character Recognition errors (OCR), the use of 'salep' to mean something other than orchid tubers, e.g. as an abbreviation of 'surface attached light emissive point source', or author surname 'Saloop', and patents that referred to *salep* as an example but did not apply to *salep* left 244 patent applications or grants that referred to using *salep*. From the total of 244 patent documents referring to *salep*, 89 were granted. In 147 *salep* occurred amongst a list of ingredients or components, and in 97 documents *salep* was specifically referred to.

3.2. Terminology

A range of names, in addition to those used as our search terms, were applied to *salep*. Some refer to the plant or part of the plant it is derived from: *salep* tuber, tuber *salep*, *salep* bulbs, *salep* root, *salep* tubers, tuber orchis, *salep*-root, tubera *salep*, and *salep* orchid. Others refer to properties or chemical components of *salep*: mannan *salep*, *salep* mannan, *salep* mannan sugar, *salep* gum, *salep* mucilage, *salep* mannan, *and salep* gum tragacanth. Some patent applications specified the form of *salep* as *salep* powder or orchid powder. Words from non-English languages used to refer to salep were: *eorchideenknollen*, *knabenkraut*, *sahlep*, *salepknolle*, *salepschleim*, *salrep*, *salep misri*, *su lai fu*, and *tsuberasareppu*. Additionally *solap*, *salep cat*, *saelrep*, and *salep* manuan may have been typos, as separate searches for these words did not find them in other patents.

3.3. Properties

Only nine patent documents specifically referred to the flavour or taste of *salep*, while properties of *salep*, or properties that may be attributed to *salep* and glucomannan were specified in 115. Many different terms were used relating to mucus. In alignment with this, references were also made to gel-like properties. Physical properties or components were also noted. Descriptive phrases connecting its interaction with other organisms were used. In some cases terms incorporating words used in medicine were applied. Many of these properties were overlapping elements as illustrated in Fig. 1 and listed in Appendix 1.

3.4. Use categories

Uses within patent documents were significantly unevenly distributed across most of the different categories (X^2 (7) = 165.77, $p < 0.000$). Most applications were in the medicine category (70), followed by food and beverages (61), and materials (50). The fewest were in animal food (8), cosmetics (2) and dental products (2). A middle position was held by patent applications that treated *salep* as the object of the patent (27) and nutraceuticals (24), neither of which were significantly different from the average number of patents (standardized residuals 0.63–1.18, p-values 0.52–0.24).

3.5. Medicinal uses

Of the total of 70 patent applications using *salep* as a medicine, 31 were for treating inflammation. When comparing inflammatory use to all other medicinal uses combined the number of applications did not differ significantly (X^2 (1) = 0.91, p = 0.34).

3.6. Material uses

We found numerous uses of *salep* not previously reported in ethnobotanical or conservation science literature. The selected examples listed below illustrate the range of these applications. In a patent granted in 1922 *salep* was a component of "…. a new and useful improvement in explosives…"(Symmes, 1922). Several other applications were for use in handling textiles, e.g., in the manufacture of viscose in 1924 (Huber and Eckert, 1924) and printing on textile fabrics in 1933 (Kaestner, 1933). *Salep* is also included in an application for manufacturing biodegradable materials in 1990 (Oishi et al., 1991). Applications in the petro-chemical industry included *salep* as a means of improving properties of lubricating oil compositions in internal combustion engines applied for in 1958 and granted in 1962 (Emrick, 1958), in a gas lift system applied for in 1963 and granted in 1965 (McLeod, 1963) and for well-working in 1992 (Mondshine, 1991). These and other material uses are listed in Table 2.

3.7. Orchid taxa

A total of six species are named as components of *salep*: *Orchis mascula* (L.) L. (in 79 applications), *Anacamptis morio*(L.) R.M.Bateman (in 39), *Orchis militaris* L. Pridgeon & M.W.Chase (in 30), *Anacamptis pyramidalis* (L.) Rich. (in 28), *Platanthera bifolia* (L.) Rich. (in 33), and *Anacamptis sancta* (L.) R.M.Bateman, Pridgeon & M.W. Chase (in 1). Additionally, nine genera were named: *Aceras*, *Anacamptis*, *Dactylorhiza*, *Himantoglossum*, *Neotinea*, *Ophrys*, *Orchis*, *Platanthera* and *Serapias*. In total, 70 patent applications referred to *salep* being derived from or composed of orchids.

3.8. Geographical jurisdictions

Most patent applications were made for the USA (75) followed by all over the world and not limited to any smaller jurisdictions (41). Jurisdictions with an intermediate position were China (26), Germany (26) and Japan (21) and the region of Europe (19). In each jurisdiction, the range of use categories is equally diverse.

Combining patent applications for jurisdictions covering countries and regions, the number of patents applied for in each country ranges from 41 under 'world jurisdiction', and 42 in Greece and Bulgaria, to 86 in Germany and 116 in the USA (see Fig. 2).

In patent applications that specify orchid species used the jurisdictions applied for are not identical to the natural distributions of the orchids. For example *Orchis mascula* occurs in the wild in Europe and temperate Asia (WCSP, 2018)(). Of the 76 applications specifying *Orchis mascula*, 30 are within its natural distribution, 13 applications for World jurisdiction may be within or outside of the natural distribution, and 33 occur outside the natural distribution (see Table 3).

China was the jurisdiction within which there was the greatest diversity of medicinal uses with 8 different medical categories, but not for inflammation, which was the most common medicinal use in other jurisdictions.

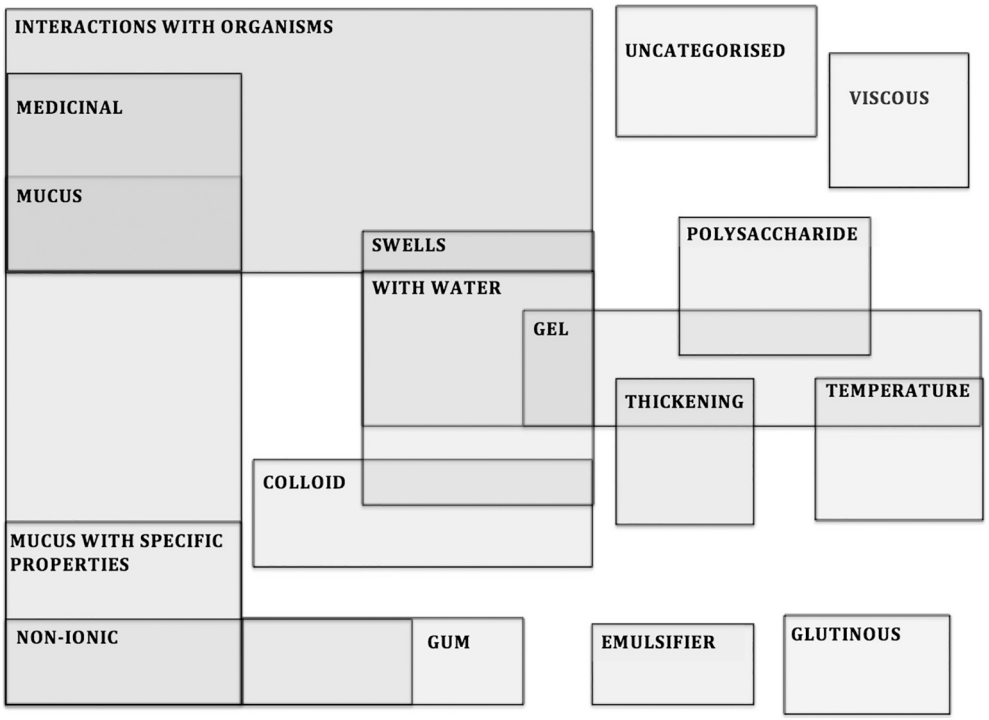

Fig. 1. *Salep* patent documents' description of *salep* properties summary.

3.9. Chronology

Recent years have seen a marked increase in the number of *salep* patent applications. There is a low number of applications from 1885 to 1985, and then the number of applications rises exponentially, with occasionally lower numbers.

For the period from 2003 onwards we looked in more detail at the different use categories and they seemed to increase over time from 1 to 3 until 2007, to 1–6 until the present (Fig. 3). The use category of food or beverage was applied for throughout this period. A relatively new category for *salep* is dental applications with the first patent applied for in 2014.

4. Discussion

Analysing commercial literature shifts perspective from attributing regional wild species decline to pressure from traditional use to acknowledging international and commercial stakeholders in a range of contemporary applications. Our method tested on *salep* can be used to examine trade in other wild species. For example use of powdered Bitter aloe (*Aloe ferox*) fibres as a nutraceutical is specified in a patent, which is an addition to known raw products of leaf exudate and leaf mesophyll and uses as cosmetic, food and horticultural plant (Melin et al., 2017; Taylor, 2005). *Aloe ferox* is also one of three aloe species suggested as suitable for modification to create transgenic aloe for production of biopharmaceuticals that can easily be harvested from the leaf mesophyll (Lowther et al., 2014). Venus flytrap (*Dionaea muscipula*) is considered to be one of the plants most threatened by poaching, and this is attributed to horticultural use (Outland, 2018). But Venus flytrap appears in patents as a cosmetic ingredient and in formulations to promote healing (Dahlgren et al., 2011; Hall, 2008). Equally patents can provide additional information on uses of animal species. For example CITES database does not reflect the full drivers of trade in pangolins (*Manis* spp.) (Challender et al., 2015). While their natural diet is considered difficult to replicate in captivity there are applications for pangolin cub feeding formulas in patent databases as well as the expected applications of medicinal formulations containing pangolin derivatives (Yin, 2014). Here patents are also a source of information on potential solutions – identifying groups working on farming pangolins, as well as providing an inventory of uses. Seahorses (*Hippocampus* spp.) are traded dried as ornaments and traditional medicine ingredients, and as live fish for aquariums (Foster et al., 2016). There are patent applications for methods of breeding seahorses, and in a patent approved for a product for treating hepatic fibrosis seahorses are used as an ingredient and listed as 'hippocampus extract' (Lin et al., 2015; Min-ho, 2019). Again, patent documents contain potential solutions as well as delivery of Traditional Chinese Medicine ingredients in pharmaceutical formulations.

As a search term "*salep*" captured the majority of patents concerning *salep*. However, some additional information was found using different appellations.

Searching '*salep*' in a wider selection of documents, for example on Google Scholar, generates a return of 10,900 results, in which case searching across additional languages while germane for regional coverage may increase the risk of fatigue-induced bias (Danziger et al., 2011). Limiting the corpus of documents by restricting our search to patents allowed optimal sensitivity, detecting regional variation by using different names for *salep* (Westgate and Lindenmayer, 2017). Therefore when reviewing *salep* it is germane to run searches using all known names. In commercial areas such as patent applications where a species name is not necessarily present and the number of documents returned by the search are smaller, a more detailed inventory of applications could be conducted using the supplementary terms listed in our results.

Applications for patents concerning *salep* are an indication of commercial interest in the product itself. Furthermore these applications are worth evaluating from a conservation perspective as a source of information on innovation in cultivation e.g. producing more than one tuber per plant, which may have utility for conservation projects (Tutar and Kanbur, 2013).

Surprisingly, taste, aroma or flavour are not the most important properties of *salep* in the context of its applicable uses. Physical and relational properties i.e. its behaviour in combination with other elements for example as a colloidal agent were found to be significant.

Table 2
Patent documents for material uses.

Year of application	Jurisdiction	Publication number of last application or grant	Title
1886	US	US 341239 A	Fining composition
1905	US	US 832024 A	Process for the electrodeposition of metals
1922	US	US 1478588 A	Explosive
1923	GB	GB 220282 A	To prepare a fine viscose silk
1924	US	US 1550361 A	Manufacture of fine viscose silk
1925	US	US 1632759 A	Process for treating rubber latex
1925	US	US 1777045 A	Method of treating rubber latex and product obtained thereby
1926	GB	GB 275617 A	A process for strengthening and rendering impermeable paper or similar materials
1928	US	US 1870516 A	Printing on textile fabrics
1933	GB	GB 444838 A	Improvements in and relating to processes for the production of prints on cloth
1935	US	US RE19434 E	Method of treating rubber latex and product obtained thereby
1937	GB	GB 490781 A	Process for preparing a concentrated rubber dispersion from rubber latex
1955	US	US12885 A	Improvement in dressing sewing thread
1960	US	US 3208524 A	Process for controlling lost circulation
1962	USA	US 3067192 A	Process for preparing acyl polysac-charide borates
1962	USA	US 3215634 A	Method for stabilizing viscous liquids
1963	USA	US 3215087 A	Gas lift system
1966	USA	US 3411580 A	Mud removal method
1968	Australia	AU 431489 B2	Mud removal method
1974	Denmark	DK141253 B	A method and composition for the preparation of pullulanase
1987	Germany	DE 3744009 A1	Pharmaceutical composition with a neutral flavour and containing one or more amino acids
1987	Germany	DE 3724890 C3	A method for producing a preparation with an oil-in-water emulsion
1990	USA	US 5158810 A	Melt-molded articles and laminates derived therefrom, and their use
1990	Japan	JP 3026825 B2	Biodegradable laminate molded
1990	Japan	JP 3029280 B2	Preparation of the biodegradable molded article
1990	Japan	JP 3091235 B2	Laminate moldings
1990	Japan	JP 3050908 B2	Waste storage container
1990	Europe	EP 0474173 B1	Biodegradable melt-molded articles and laminates derived therefrom and their use
1991	Japan	JP 2961178 B2	Process for the preparation of B-1,4- mannase by microorganisms
1992	USA	US 5253711 A	Process for decomposing polysaccharides in alkaline aqueous systems
1992	Europe	EP 0559418 B1	Process for decomposing polysaccharides in alkaline aqueous systems
1998	World	WO 2000032262 A1	Tubus with sealed cuff
1998	Germany	DE 19855521 A1	Sealed tube with a cuff
1998	Canada	CA 2353007 A1	Tubus with sealed cuff
1998	Japan	JP 2002531187 A	Tube having sealed cuff
1998	Europe	EP 1135184 A1	Tubus with sealed cuff
1998	World	WO 2000032262 A1	Tubus with sealed cuff
1998	Australia	AU 2000/017714 A	Tubus with sealed cuff
1999	Japan	JP 2001002942 A	Flame-retardant material
2003	Japan	JP2005110675 A	Method for producing low-molecular polysaccharide and/or oligosaccharide, and functional low-molecular polysaccharide and/or oligosaccharide
2003	Japan	JP 2004254646 A	Method for producing mannan oligosaccharide
2013	USA	US 2015/0071978 A1	Clothing and covering system with various functions
2014	USA	US 2017/0174404 A1	Reconstituted plant material and its use for packaging, wrapping and food appliances
2014	South Korea	KR 20160138266 A	Reconstituted plant material and its use for packaging, wrapping and food appliances
2014	China	CN 106414847 A	Reconstituted plant material and its use for packaging, wrapping and food appliances
2014	Europe	EP 3122941 A1	Reconstituted plant material and its use for packaging, wrapping and food appliances
2014	Japan	JP 2017518229 A	Reconstituted plant material, as well as packing, packaging and its use for food supplies
2014	World	WO 2015/144893 A1	Reconstituted plant material and its use for packaging, wrapping and food appliances
2016	USA	US 2017/0290870 A1	Ingestible films having substances from hemp or cannabis
2016	World	WO 2017/180707 A1	Ingestible films having substances from hemp or cannabis

These noted properties should also be considered when looking at substituting ingredients for *salep* as recommended by previous publications (Kasparek and Grimm, 1999), or when positing cultivated *salep* as an alternative to wild-harvested *salep*. Furthermore, users of *salep* are not operating on homogenous criteria: depending on intended use, different properties may be required. While flavour may be important to people consuming *salep* as a food (Pieroni, 2000), glucomannan content may be considered critical by those following commercial uses attached to that constituent of *salep* (Farhoosh and Riazi, 2007; Sezik, 2002; Tekinşen and Güner, 2010). Noted properties of *salep*, as summarized in Fig. 1, enhanced understanding of its material uses.

Our results show that more information is revealed about *salep* and its trade if it is viewed as a commodity and not solely as a product. We found that its applications are not only as *salep* (the drink or orchid tuber powder) or *maraş dondurma* (the ice cream), but that it is an ingredient across a range of categories used in combination with other components as well as a defining ingredient of two products. By applying an external categorization of uses – the Economic Botany Data Standard (Cook and Prendergast, 1995) – outlying areas of use were detected and a wider set of data was collected than if the search had only been conducted within the previously known use of *salep* as a medicinal or food or beverage. Medicinal, food and beverage, and material uses of *salep* together were found to be the most significant categories.

Patent documents illustrated a far greater diversity of uses of *salep* than expected. The earliest granted patent using *salep* described incorporating it in a mixture applied to thread which, improves strength and creates a smooth surface with high lustre (Heck, 1855). It has been used as a saccharide source in the creation of flame-retardant material (Kitajima and Mihara, 1999). Salep is one of the ingredients included in an application for a gas lift system, used to produce crude oil from low pressure wells, in which it functions as a highly viso-elastic liquid that is immiscible with the wellbore liquids and does not stick to equipment

Table 3
Species named in patent documents referring to *salep* and jurisdictions.

Jurisdiction	*Anacamptis morio*	*Anacamptis pyramidalis*	*Anacamptis sancta*	*Orchis mascula*	*Orchis militaris*	*Platanthera bifolia*
Australia	0	0	0	**2**	0	0
Bulgaria	1	0	0	1	1	0
Canada	0	0	0	**1**	0	0
China	**7**	0	0	**11**	0	**6**
Germany	13	13	0	13	13	12
Denmark	0	0	0	0	0	0
Spain	2	2	0	2	2	2
Great Britain	0	0	0	1	0	0
Greece	0	0	0	1	0	0
Japan	**2**	0	0	**4**	0	0
South Korea	0	0	0	**1**	0	0
Russia	1	1	0	1	1	1
USA	**1**	0	0	**14**	**1**	0
Europe	6	6	0	11	6	6
World	**6**	**6**	**1**	**13**	**6**	**6**

Shaded grey where species used are not native to jurisdiction.
Jurisdictions where the species are not native, or in the case of 'world' jurisdiction may or may not be native depending on where within the world.

(e.g. casing or tubing) (McLeod, 1963). These kinds of uses were entirely unexpected as they are absent from conservation science literature on *salep*.

Food and medicine have been blurred use categories since Hippocrates and possibly earlier; plants used as food are also used as medicines, and foods can be consumed for their medicinal nature (Jennings et al., 2015). Nutraceutical is a term invented in 1989 loosely defined as referring to a food or component of food that has a medical or health benefit (Aronson, 2017). Numerous patents using *salep* fit within this marketing concept. For example protein supplements (Scheele, 2005), health-care food composition (Wang, 2012), and nutrient food composition (Gökaltay, 2016).

Patents show *salep* use in a wider range of medicinal treatments than previously reported, medicinal applications not just for pharmacological activity but in one example as a free flowing coating that can swell providing a seal between intubating tubus and patient trachea (Waldeck, 1998). Our findings are also reflective of differences in plant use under different systems of medicinal knowledge. There was divergence in medicinal applications of *salep*. Patent documents with Chinese jurisdictions were directed at a wider range of conditions e.g. pulmonary heart disease, brain protection effect, and yang-tonifying (Jinan Xingi Med Tech, 2015a, 2015b; Xinjiang Institute of Physics and Chemistry, 2016). But patent documents within Chinese jurisdiction did not address the condition of inflammation, which was otherwise *salep*'s most significant medicinal use.

In conservation science literature *salep* is recorded as being used as a food or in traditional medicine, and no references are made to material uses of *salep*. So in the context of conservation science, material uses of

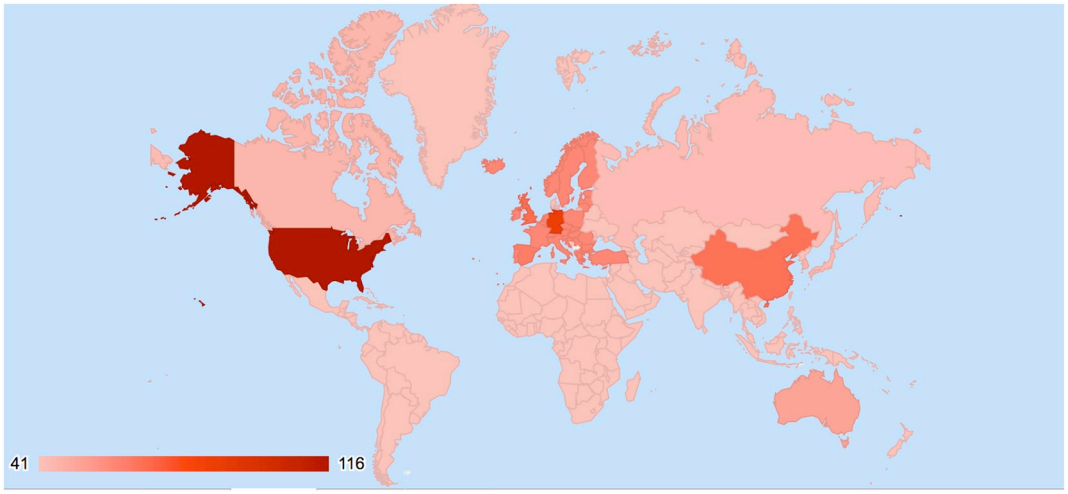

Fig. 2. Map of jurisdiction of patent applications. Shading ranges from 41 (world jurisdiction) to 116 (USA).

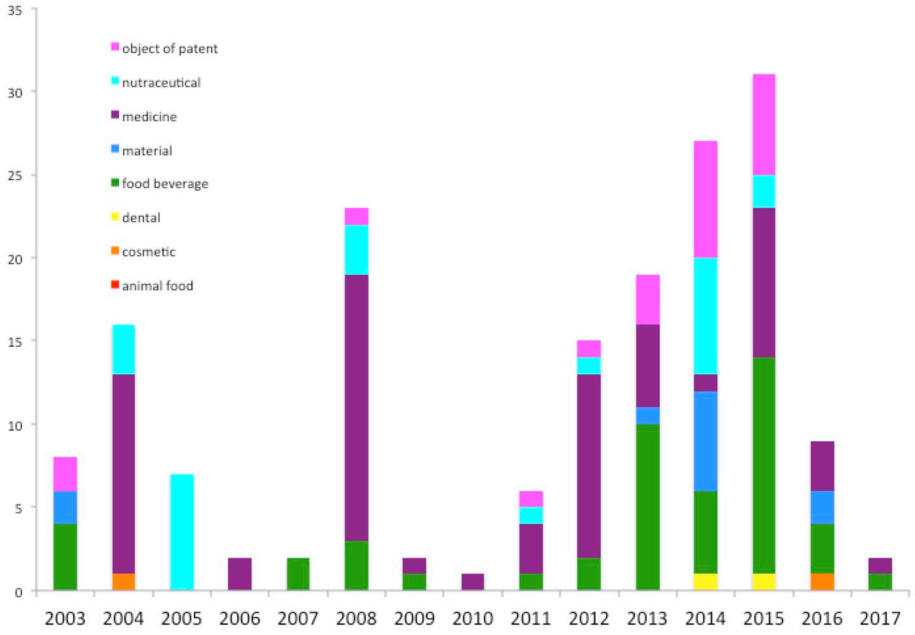

Fig. 3. Recent chronology of use of *salep* in patent documents for the period 2003–2017.

salep are a novel finding. Described properties of *salep* were linked to its material use e.g. in stabilization of colloidal systems. Additionally, material use of *salep* is corroborated by publications in other domains of research such as material science. Examples include *salep* as a biodegradable edible film, in fertilizer formulation, and biodegradable environmentally friendly flocculent for treating wastewater (Dao et al., 2016; Kurt and Kahyaoglu, 2014; Olad et al., 2018). In a search for *salep* in Scopus sorted by subject area, 63 were in Agricultural and Biological Sciences, 58 in Chemistry, 39 in Chemical Engineering, 37 in Materials Science, while only 9 were in Environmental Science (Scopus, 2018). Our finding of materials being a significant use category for *salep* is congruent with other indications of a rising interest in *salep* outside of traditional uses. For example after legalization of medicinal marijuana and recreational marijuana in some states in the USA, there has been an increase in consumption of marijuana in edible forms e.g. sweets, and a patent was applied for using *salep* to make an ingestible film containing hemp or cannabis (Lamy et al., 2016; Schaneville, 2016). Salep has also been listed in patents for similarly zeitgeist developments such as biodegradable material and formulations for managing the human microbiome (Oishi et al., 1991; Rahm, 2015). Consequently it is vital to include material consumers of *salep* within assessments of its trade and engage with them on conservation measures.

Lack of specificity in commercial knowledge of *salep* may confound conservation efforts. Full disclosure of biodiversity utilization within patents is hindered by commercial secrecy of intellectual property and resistance to the patent system being used for purposes other than providing inventors with monopoly on innovation (Oldham and Burton, 2010). With the majority of patents not referring to *salep* by species name, or even as orchids it is less likely that commercial users of *salep* know it is subject to CITES and local nature protective legislation. Consumers are also more vulnerable to variable composition of the product they use, since it has been found that different species of orchid traded as *salep* have different chemical compositions (Tekinşen and Güner, 2010). Correct identification of species is particularly pertinent to food and beverage use (Nesbitt et al., 2010). Other commercial systems making use of plants have uniform systems of nomenclature. For example International Nomenclature of Cosmetic Ingredients (INCI) is a list maintained by the Personal Care Products Council, which is used by companies in the USA, Europe, China, Japan and other countries (González Abellán and Martínez Pérez, 2018). Even though INCI names may not keep pace with taxonomic changes updated by the Angiosperm Phylogeny Group, e.g. APG IV 2016, it is a system that allows monitoring of ingredients as they are all named specifically. If patent applications adopted a standard for nomenclature it would provide better clarity for intellectual property claims made via patents, and would also allow monitoring of species of commercial interest. Patents are a powerful information source for developing conservation policy and practice. In the case of a product made from assorted species use of scientific taxonomy rather than a vernacular term would allow better monitoring of what products contain and what species are of commercial interest.

Stakeholders of *salep* are much wider spread than previously thought: it is a commodity subject to global trade. This is in contrast to previous studies situating *salep* consumption and trade within the Mediterranean, Germany and Iran (Ghorbani et al., 2014; Kasparek and Grimm, 1999; Kreziou et al., 2015). With patent applications made for jurisdictions outside of the species distribution it would be relevant to check the CITES database to see if permits covering trade across CITES boundaries are present. However as most patent applications do not use species or genus names this is not possible.

Our detected trend in an increasing numbers of patent applications referring to *salep* fits within the general trend of an increasing number of patent applications in general (OECD, 2009b). We found a decrease in applications on *salep* in the most recent years. This is congruent with the time delay in applications being processed and publicly published. Consequently, the same search conducted two years from now would likely find more applications within the same time period as records not currently available would be released. Contemporary applications for patents that include *salep* indicate it is not a relic of traditional plant use but a substance of current value. This means that the common perception of traditional use depleting environmental resources has not been entirely accurate (Ghorbani et al., 2014; Kasparek and Grimm, 1999; Kreziou et al., 2015). Contemporary (since 1855) and on-going innovation in uses of *salep* are probably also responsible for the perceived decline of wild orchids used for *salep*.

4.1. Limitations

Some older patents archived by scanning and converting physical documents into pdf or image format may not have been accessed via

our electronic database search as text in these documents is not always entirely machine readable. In addition, not all patents for all jurisdictions are available in electronic databases as our search was limited to those available at the time of our search in Google, Lens, and Scopus patents. Furthermore, some potential uses of *salep* are masked, such as in granted applications in the petrochemical industry that use *salep* in drilling. Due to public pressure some companies have disclosed chemicals used in fracking fluids, but they still withhold ingredients that are trade secrets. Consequently our findings are not drawn from a complete record of all patents applied for pertaining to *salep*. However, the scope of our search was wide enough to offer an overview based on a sample size that was the most comprehensive that could be accessed at the time.

5. Conclusions

Patent analysis generated an inventory of the forms in which *salep* is traded and demonstrates the dynamics of *salep* commerce over time. There has been a gap between reported use of *salep* as a food and medicine in conservation literature and potentially wider use of *salep* in other products and processes. In order to assess threats to wild orchid populations collected for *salep*, accounting for use in traditional medicine and as a food product within Turkey and Greece and their diaspora, and the Mediterranean area is not sufficient. Rather, incipient usage in categories and regions that have previously been omitted, but were identified in our inventory, may also be exerting an impact on wild orchid populations. Initiatives aimed at addressing trade in *salep* need to engage with a wider group of consumers than previously thought.

Commercial literature, in this case patent applications, is a notably pertinent source of knowledge for conservation science. Patent analysis can now be incorporated into horizon scanning as an indicator of developments in commercial interest in wild species. We encourage the use of patent analysis to examine the commercial potential of endangered species of plants and animals exploited by wildlife trade. In particular as a tool for bridging unknown gaps between conservation science and commerce.

CRediT authorship contribution statement

Susanne Masters:Conceptualization, Methodology, Validation, Investigation, Data curation, Writing - original draft, Visualization.**Tinde van Andel**:Writing - review & editing, Supervision.**Hugo de Boer**:Writing - review & editing, Supervision.**Reinout Heijungs**:Formal analysis, Writing - review & editing, Visualization.**Barbara Gravendeel**:Conceptualization, Validation, Writing - review & editing, Supervision, Project administration.

Appendix A. Supporting information

Tabulated data are available as csv file. Pdfs of patents used in this review are deposited in Zenodo (https://doi.org/10.5281/zenodo.3628651).

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