Review

Dragon’s blood: Botany, chemistry and therapeutic uses

Deepika Gupta a, Bruce Bleakley b, Rajinder K. Gupta a,∗

a University School of Biotechnology, GGS Indraprastha University, K. Gate, Delhi 110006, India

b Department of Biology & Microbiology, South Dakota State University, Brookings, South Dakota 57007, USA

Received 25 May 2007; received in revised form 10 October 2007; accepted 11 October 2007
Available online 22 October 2007

Abstract

Dragon’s blood is one of the renowned traditional medicines used in different cultures of world. It has got several therapeutic uses: haemostatic, antidiarrhetic, antulcer, antimicrobial, antiviral, wound healing, antitumor, anti-inflammatory, antioxidant, etc. Besides these medicinal applications, it is used as a coloring material, varnish and also has got applications in folk magic. These red saps and resins are derived from a number of disparate taxa. Despite its wide uses, little research has been done to know about its true source, quality control and clinical applications. In this review, we have tried to overview different sources of Dragon’s blood, its source wise chemical constituents and therapeutic uses. As well as, a little attempt has been done to review the techniques used for its quality control and safety.

© 2007 Elsevier Ireland Ltd. All rights reserved.

Keywords: Dragon’s blood; Croton; Dracaena; Daemonorops; Pterocarpus; Therapeutic uses

Contents

1. Introduction ............................................................................................................ 362
1.1. Mythology ....................................................................................................... 362
1.2. Historical uses ................................................................................................. 362
1.3. Ethnomedicinal uses ........................................................................................ 363
2. Sources of Dragon’s blood ....................................................................................... 363
  2.1. Croton spp. (Euphorbiaceae) ........................................................................... 363
    2.1.1. Chemical constituents .............................................................................. 363
    2.1.2. Bioactivities and therapeutic uses ........................................................... 363
  2.2. Daemonorops spp. .......................................................................................... 371
    2.2.1. Chemical constituents .............................................................................. 371
    2.2.2. Bioactivities and therapeutic uses ........................................................... 371
  2.3. Dracaena spp. .................................................................................................. 371
    2.3.1. Chemical constituents .............................................................................. 371
    2.3.2. Bioactivities and therapeutic uses ........................................................... 371
  2.4. Pterocarpus spp. .............................................................................................. 375
  3. Quality control and safety ..................................................................................... 375
  4. Conservation needs .............................................................................................. 376
  5. Conclusion ........................................................................................................... 376
Acknowledgements .................................................................................................. 376
References ............................................................................................................... 376

* Corresponding author. Mobile: +91 9871263252; fax: +91 11 23865941/2.
E-mail address: rkg67ap@yahoo.com (R.K. Gupta).

0378-8741/$ – see front matter © 2007 Elsevier Ireland Ltd. All rights reserved.
doi:10.1016/j.jep.2007.10.018
1. Introduction

Plants are used worldwide for the treatment of diseases and novel drugs continue to be developed through research from these plants. There are more than 20,000 species of higher plant, used in traditional medicines and are reservoirs of potential new drugs. As the modern medicine and drug research advanced, chemically synthesized drugs replaced plants as the source of most medicinal agents in industrialized countries. Nevertheless plants are an important source of lead compounds. However, in developing countries, the majority of the world’s population cannot afford pharmaceutical drugs and use their own plant based indigenous medicines.

Dragon’s blood is a deep red resin, which has been used as a famous traditional medicine since ancient times by many cultures. The term “Dragon’s blood” refers to reddish resinous products, usually encountered as granules, powder, lumps or sticks used in folk medicine. Dragon’s blood has been used for diverse medical and artistic applications. It has astringent effect sticks used in folk medicine. Dragon’s blood has been used for medicinal agents in industrialized countries. Nevertheless in developing countries, the majority of the world’s population cannot afford pharmaceutical drugs and use their own plant based indigenous medicines.

The origin of Dragon’s blood is believed to be from Indian Ocean island of Socotra, now part of Yemen (Angiosperm Phylogeny Group, 1974). However, there exists a great degree of confusion regarding the source and identity of Dragon’s blood. Several alternative sources of Dragon’s blood from Canary Islands, Madeira, and South East Asia and also from East and West Africa have been identified (Alexander and Miller, 1995). Dragon’s blood was a name applied to many red resins described in the medical literature, e.g. East Indian Dragon’s blood (from the fruit of Daemonorops draco (Willd.) Blume), Socotran or Zanzibar Dragon’s blood (exudates of Dracaena cinnabari Balf. f.), Canary Dragon’s blood (exudates formed from incisions of the trunk of Dracaena draco (L.) L.), West Indian Dragon’s blood (exudates of Pterocarpus draco L.), Mexican Dragon’s blood (resin of Croton lechleri Müll. Arg.) and the Venezuelan Dragon’s blood (resin of Croton goossypifolium Vahl) (Sollman, 1920).

Mabberley (1998) suggests that Dragon’s blood was produced originally from Dracaena cinnabari, later from Dracaena draco and more recently from Daemonorops spp. Zheng et al. (2004a,b,c) confirms this view and suggests Pterocarpus spp., Daemonorops draco and Croton spp. as substitutes for Dracaena spp. Thus, the term “Dragon’s blood” in general is used for all kinds of resins and saps obtained from four distinct plant genera; Croton (Euphorbiaceae), Dracaena (Dracaenaceae), Daemonorops (Palmaceae), and Pterocarpus (Fabaceae).

1.1. Mythology

According to a Greek myth, Landon, the hundred-headed dragon, guardian of the Garden of the Hesperides (the nymph daughters of Atlas, the titan who holds up earth and heaven) was killed by either Hercules (in his quest) or Atlas (as punishment) while bringing back three golden apples from the garden, depending upon the version of the myth. Landon’s red blood flowed out upon the land and from it sprung up the trees known as “Dragon Trees” (The Eleventh Labor of Hercules: The Apples of The Hesperides).

Dragon’s blood was also called “Indian cinnabar” by Greeks writers. The name “Dragon’s blood” dates back to the 1st century AD when a Greek sailor wrote, about an island called Dioscorida where the trees yielded drops of cinnabar, in a shipping manual “Periplus of the Erythrean Sea”. Plinius (1601) also described that the resin got its name from an Indian legend based on Brahma and Shiva. Emboden (1974) and Lyons (1974) had also summarized the history and mythology of Dragon’s blood. According to Lyons, the struggle between a dragon and an elephant that, at its climax, led to the mixing of the blood of the two creatures resulted in a magical substance, “Dragon’s blood” imbued with medicinal properties.

1.2. Historical uses

The crimson red resin was highly prized in the ancient world. Dragon’s blood (Dracaena cinnabari) was used as a dye and medicine in the Mediterranean basin. Miller and Morris (1988) mention use of Dracaena resin as a coloring matter for varnishes, tinctures, toothpastes, plaster, and for dying horn to make it look like tortoiseshell. Mabberley (1998) also notes that resinous sap produced via incisions in the bark or stem of the Dracaena cinnabari was used by the Ancients to stain horn to resemble tortoiseshell. People in Socotra used resin from Dracaena cinnabari for dying wool, glue pottery, breath freshener, to decorate pottery and houses and even as lipstick (Alexander and Miller, 1996). Due to the belief that it is the blood of the mythic animal, the dragon, it is also used in alchemy and for ritual magic.

Dragon’s blood from both Dracaena and Daemonorops were also used for ceremonies in India. Sometimes Dracaena resin, but more often Daemonorops resin, was used in China as red varnish for wooden furniture. These resins were used to color the surface of writing paper for banners and posters, used especially for weddings and for Chinese New Year. These red resins were also used as pigment in paint, enhancing the color of precious stones and staining glass, marble and the wood for Italian violins. Fulling (1953) reported that Daemonorops resin was used in the preparation of drawings. Powdered forms of Daemonorops resin were used extensively as an acid resist by photoengravers during the 1930s (Pankow, 1988). In modern times Daemonorops resin is still used as a varnish for violins, in photoengraving, as an incense resin, and as body oil. Daemonorops resin is also added to red ink to make “Dragon’s Blood Ink,” which is used to inscribe magical seals and talismans.

Spanish naturalist and explorer P. Bernabé Cobo (1956) recorded for the first time that Croton’s sap was used widely throughout the indigenous tribes of Mexico, Peru, and Ecuador in 1600s. In African-American folk magic or voodoo this resin is used in mojo hands for money-drawing or love-drawing, and is used as incense to cleanse a space of negative entities or influences. In neopagan witchcraft, it is used to increase the potency of spells for protection, love, banishing and sexuality.
1.3. Ethnomedicinal uses

Dragon’s blood was used by early Greeks, Romans, and Arabs for its medicinal properties. Locals of Moomy city on Socotra island used the Dragon’s blood (*Dracaena*) as a sort of cure-all, using it for things such as general wound healing, a coagulant, curing diarrhoea, lowering fevers, dysentery diseases, internal ulcers of mouth, throat, intestines and stomach, as an antiviral for respiratory and stomach viruses and for skin disorders such as eczema. Dioscorides and other early Greek writers described its medicinal uses. Dragon’s blood (*Dracaena*) is used for treating dysentery, diarrhoea, hemorrhage and external ulcers in Yemeni folk medicine (Milburn, 1984). *Dracaena* resin has strong astringent properties and is used as a muscle relaxant (Milner, 1992). Gerarde and Johnson (1633) stated that Dragon’s blood (*Dracaena*) was used for over flow of courses (menses), in fluxes, dysenteries, spitting of blood and fastening of loose teeth. It was also used to treat gonorrhea, stoppage of urine, watery eyes and minor burns (Parkinson, 1640). In China, the red resin of *Dracaena cochinchinensis* was used by local people for treatment of wounds, leucorrhrea, fractures, diarrhoea and piles as well as for intestinal and stomach ulcers (Cai and Xu, 1979).

*Daemonorops* resin is also used in traditional Chinese medicine to stimulate circulation, promote tissue regeneration by aiding the healing of fractures, sprains and ulcers and to control bleeding and pain (Bensky and Gamble, 1993). The medical applications of Dragon’s blood resins, mainly the * Daemonorops* resin, have been attributed to the presence of benzoic acid, which show antiseptic properties (Piozzi et al., 1974; Badib, 1991). *Croton*’s sap is a common household remedy used in Peru, other Latin American countries, and among the Latin American population of the United States. *Croton*’s sap is taken orally to cure different types of diarrhoea and cholera by the indigenous people of Amazon basin (Carlson and King, 2000). Other ethnomedicinal uses of the sap of *Croton lechleri* in Peru are found in the treatment of bone fractures, leucorrhrea, piles and hemorrhoids (Soukup, 1970). Sap of *Croton lechleri* was also used to speed up internal healing after an abortion (Castner et al., 1998) and in vaginal baths taken before childbirth (Duke and Vasquez, 1994).

*Croton*’s sap has been reviewed by many researchers for its therapeutic uses (Jones, 2003; Gonzales and Valerio, 2006). Various therapeutic properties of Dragon’s blood (*Croton* spp.) have been described such as wound and ulcer healing, antidiarrhoeic, anticancer, anti-inflammatory and antirheumatic properties (Bettolo and Scarpati, 1979; Perdue et al., 1979; Chen et al., 1994; Pieters et al., 1995; Phillipson, 1995; Gabriel et al., 1999; Holodniy et al., 1999; Miller et al., 2000).

2. Sources of Dragon’s blood

Dragon’s blood is a bright red resin that is obtained from different species of four distinct plant genera; * Croton, Dracaena*, * Daemonorops*, and * Pterocarpus*. Table 1 summarizes the different botanical sources and common names of Dragon’s blood. Pearson and Prendergast (2001) have reviewed Dragon’s blood samples from different sources kept at Royal Botanic Gardens Kew. The Economic Botany Collections at the Royal Botanic Gardens Kew (curated by the Centre for Economic Botany) contains perhaps the largest (80 accessions comprising of 34 *Dracaena* accessions, 40 *Daemonorops* and 6 *Croton*) and most reliably identified assembly of Dragon’s blood resins.

In this review, we discuss chemistry and therapeutic uses of varieties of Dragon’s blood differentiated according to the plant taxa from which they are obtained. Structures of some of the compounds reported from these sources are given in Fig. 1.

2.1. * Croton* spp. (*Euphorbiaceae*)

* Croton lechleri* Müll. Arg., the tree growing in Mexico, Venezuela, Ecuador, Peru and Brazil, is possibly the best-known source for Dragon’s blood. Other species are *Croton dracooides* Müll. Arg., * Croton draco* Schlecht & Cham., * Croton urucurana* Baill., * C. xalapensis* Kunth, * Croton gossypifolium* Vahl, * Croton erythrochilus* Müll. Arg. and * Croton palanostigma* Klotzsch. When the trunk of the tree is cut or wounded, dark red, sappy resin oozes out, known as Sangre de Drago (Dragon’s blood).

2.1.1. Chemical constituents

Table 2 summarizes the compounds reported from Dragon’s blood of *Croton* spp.

2.1.2. Bioactivities and therapeutic uses

2.1.2.1. Antimicrobial and antiviral activity. Sangre de Drago (*Croton*) has been evaluated as a source of potential chemotherapeutic agents based on its ethnomedicinal uses. Chen et al. (1994) had studied the antibacterial properties of blood-red sap of *Croton lechleri* from Ecuador and reported compounds 2, 4, 6-trimethoxyphenol, 1, 3, 5-trimethoxybenzene, crolechinic acid and korberins A and B present in the sap to exhibit antibacterial activity individually.

The aqueous ethanol extract, some fractions of the methanol extract, catechin and acetyl aluritolic acid of Sangre de Drago obtained from * Croton urucurana* are reported to show inhibition of * Staphylococcus aureus* and *Salmonella typhimurium* (Peres et al., 1997). Later, Gurgel et al. (2005) reported in vitro antifungal activity of Sangre de Drago from * Croton urucurana*, which could be due to the presence of catechins like gallo catechin and epigallocatechin. Antiviral properties of *Croton*’s sap have also been evaluated. Extracts of Sangre de Drago have been reported to have antiviral activity against influenza, parainfluenza, Herpes simplex viruses I and II, and Hepatitis A and B (Chen et al., 1994; Ubillas et al., 1994; Sidwell et al., 1994; Meza, 1999). SP-303 from *Croton*’s sap is the most studied constituent for its antiviral activity (Wyde et al., 1991, 1993; Barnard et al., 1992; Soike et al., 1992; Gilbert et al., 1993). SP-303 has shown in vitro activity against Herpes simplex viruses (HSV-1 and HSV-2), inhibition of thymidine kinase mutants of the viruses, and pronounced activity against acyclovir-resistant strains (Barnard et al., 1993; Safrin et al., 1993; Ubillas et al., 1994). Clinical studies of SP-303 have also been done on AIDS patients (Orozco-Topete et al., 1997). Sethi (1977) reported taspine to inhibit reverse transcriptase enzyme in cultures of several tumor viruses.
Table 1
Botanical sources and common names of Dragon’s blood

<table>
<thead>
<tr>
<th>Species</th>
<th>Plant family</th>
<th>Geographical origin</th>
<th>Vernacular names</th>
</tr>
</thead>
<tbody>
<tr>
<td>Croton spp.</td>
<td>Euphorbiaceae</td>
<td>Tropics and subtropics worldwide</td>
<td>Sangre de draco (Venezuela), Dragon’s blood Croton, Arleia, Ian huiqui (Ecuador), Yawar gradwascca (Peru), Sangre de Drago/Grado</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Daemonorops spp.</th>
<th>Palmaceae</th>
<th>South East Asia</th>
<th>Jerang or Djerang (Indonesia), Longxuejie (China), Draconis Resina and Sanguis draconis (Sumatra), Kirin-kaketsu (Japan)</th>
</tr>
</thead>
<tbody>
<tr>
<td>D. draco (Wildd) Blume</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D. didymophylla Becc.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D. micracantha (Griff.) Becc.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D. motleyi Becc.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D. rubra (Reinw. ex Blume) Blume</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D. propinqua Becc.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dracaena spp.</td>
<td>Dracaenaceae</td>
<td>Socotra, Canary Islands, Madeira, East Africa</td>
<td>Zanzibar drop</td>
</tr>
<tr>
<td>D. cinnabari Balf. f.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D. cochinchinensis (Lour.) S.C. Chen</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pterocarpus spp.</td>
<td>Fabaceae</td>
<td>West Indies and South America</td>
<td>East India kino, Malabar kino, Kino gum, Guadaloupe Dragon’s blood, Padauk</td>
</tr>
<tr>
<td>P. officinalis Iacq.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2.1.2.2. Antitumor and cytotoxic activity. There are various reports showing Sangre de Drago (Croton) to exhibit cytotoxicity. Guerrero and Guzmán (2004) carried out brine shrimp lethality test (BSLT) to check the cytotoxicity of *Croton lechleri*. *Croton lechleri* sap has been reported to be used for treatment of cancer by many researchers (Hartwell, 1969; Pieters et al., 1992; Cai et al., 1993a,b). Recently, Gonzales and Valerio (2006) have reviewed *Croton lechleri* for its anticancer activity.

A number of compounds isolated from Sangre de Drago (Croton) are found to show cytotoxicity. Taspine from *Croton lechleri* sap has shown potent activity against KB and V-79 cells, while flavan-3-ols and proanthocyanidins, which are the major components of the sap, are not cytotoxic (Itokawa et al., 1991; Chen et al., 1994). Compound 3’, 4-O-dimethylcedrusin from *Croton* spp. was found not to stimulate cell proliferation, but rather protected cells against degradation in a starvation medium (Pieters et al., 1993). Chen et al. (1994) proposed that antitumor activity of *Croton’s* sap might be because of mechanisms other than cytotoxicity such as immunostimulation. Antiproliferative effect of latex of *Croton lechleri* was also determined in vitro on the human myelogenous leukemia K562 cells line (Rossi et al., 2003). Peres et al. (1997) have reported use of *Croton urucurana* against cancer. *Croton draco* is also used to treat cancer (Gupta et al., 1996). Latex of *Croton draconoides* and *Croton erythrochilus* are also reported to be used against cancer (Piacente et al., 1998). Sandoval et al. (2002) evaluated the effects of Sangre de Drago (*Croton palanostigma*) on human cancer cells, AGS (stomach), HT29 and T84 (colon) and reported induction of apoptosis, and microtubular damages in these cell lines.

2.1.2.3. Antihemorrhagic activity. Castro et al. (1999) investigated the activity of organic extracts of *Croton draco* against hemorrhagic activity induced by the venom of the snake *Bothrops asper*. Total inhibition of hemorrhage was observed, probably owing to the chelation of zinc required for the catalytic activity of venom’s hemorrhagic metalloproteinases. Aqueous extracts of *Croton urucurana* antagonized the hemorrhagic activity of the venom of *Bothrops jararaca* and proanthocyanidins were involved in this activity (Esmeraldino et al., 2005).

2.1.2.4. Immunomodulatory activity. The human immune response is a highly complex system involving both innate and adaptive mechanisms. A biological or pharmacological effect of compounds on humoral or cellular aspects of the immune response is referred as immunomodulating activity. Risco et al. (2003) determined immunomodulatory activity of Sangre de Drago from *Croton lechleri in vitro* and found that it exhibited a potent inhibitory activity on classical (CP) and alternative (AP) pathways of complement system and inhibited the proliferation of activated T-cells.
Tsacheva et al. (2004) evaluated latex of *Croton draco*, its extracts and several latex components (flavonoid myricitrin, the alkaloid taspine and the cyclopeptides P1 and P2) for their influence on both CP and AP activation pathways of the complement system using a hemolytic assay and the best inhibition was found for the classical pathway.

2.1.2.5. Antiulcer and antidiarrhoeal activity. There are reports showing potent antiulcer and antidiarrhoeal activity of Sangre de Drago (*Croton*). The extracts from *Croton* species have been shown to impair the capsaicin-stimulated ion transport across guinea pig ileum when added to the serosal bath in Ussing chambers and thus may prove to be a cost-effective treatment for gastrointestinal ulcers (Miller et al., 2000). Use of latex of *Croton lechleri* has also been reported in the treatment of different types of diarrhoea (Ubillas et al., 1994; Carlson and King, 2000). SP-303, a heterogeneous proanthocyanidin oligomer of *Croton lechleri* was found to inhibit *in vivo* cholera toxin-induced fluid secretion and *in vitro* cAMP-mediated Cl⁻ secretion and thus may provide a useful broad-spectrum antidiarrhoeal agent (Gabriel et al., 1999). Evaluation of safety and efficacy of orally administered SP-303 was done for the symp-

![Fig. 1. Structure of some of the compounds reported from different sources of Dragon’s bloods.](image-url)
tomatic treatment of diarrhoea in travelers (DiCesare et al., 2002) and in AIDS patients (Holodniy et al., 1999; Koch et al., 1999; Koch, 2000). Fischer et al. (2004) derived a novel extract SB-300 from Croton lechleri that inhibited cAMP-regulated chloride secretion, mediated by the cystic fibrosis transmembrane conductance regulator Cl− channel (CFTR) in human colonic T84 cells and may prove to be a potent antidiarrhoeal agent. Rozhon et al. (1998) have a patent on the use of proanthocyanidin polymer from Croton species as an antidiarrhoeal, which was issued to Shaman Pharmaceuticals, Inc. USA. The company has products based on extract from Croton lechleri sap in the market, named as NSF and NSF-1B, claiming “clinically demonstrated relief from diarrhoea that won’t cause constipation.”

Gurgel et al. (2001) evaluated antidiarrhoeal activity of red sap obtained from Croton urucurana on castor oil-induced diarrhoea in rats, cholera toxin-induced intestinal secretion in mice and on small intestinal transit in mice and suggested potential utility of the red sap from Croton urucurana in controlling secretory diarrhoea associated diseases.

2.1.2.6. Analgesic activity. Peres et al. (1998a) isolated several compounds showing analgesic activity, namely campesterol, sitosterol, stigmasterol, acetyl aleuritolic acid, catechin, gallo catechin and sitosterol glucoside from Croton urucurana and suggested existence of more potent analgesic compounds or existence of a synergistic effect.

2.1.2.7. Antioxidative activity. Desmarchelier et al. (1997) suggested that Sangre de Drago (Croton lechleri) is highly effective in scavenging peroxyl and hydroxyl radicals at high concentrations. However, prooxidant activity was observed at lower concentrations. When administered to mice subcutaneously, latex of Peruvian Croton lechleri inhibited hepatic lipid peroxidation but only at concentration of 200 mg/kg in the livers of the animals; higher concentrations showed toxicity (Desmarchelier and de Moraes Barros, 2003).

Later, Risco et al. (2003) reported that depending upon the concentration, latex of Croton lechleri showed antioxidant or prooxidant properties, and stimulated or inhibited the phagocytosis. Lopes et al. (2004) also evaluated antioxidant activity of Croton lechleri sap against the yeast Saccha-
romyces cerevisiae and against maize plantlets treated with the oxidative agents, apomorphine and hydrogen peroxide and found that sap inhibited the cytotoxic effect of the alkaloid apomorphine in haploid yeast cultures as well as in maize plantlets.

2.1.2.8. Anti-inflammatory activity. In a study on edema in rats, Perdue et al. (1979) reported, for the first time, anti-inflammatory activity of alkaloid taspine isolated from Croton latex. Later, Miller et al. (2001) concluded from a series of studies that the Croton sap inhibits neurogenic inflammation by directly block-
Fig. 1. (Continued)
ing sensory afferent nerve activation at both the prejunctional and postjunctional level. The latex from *Croton lechleri* has strong anti-inflammatory activity when administered i.p. (Risco et al., 2003).

### 2.1.2.9. Mutagenic and antimutagenic activity

The mutagenic and antimutagenic activity of *Croton lechieri* sap was examined through the Ames/Salmonella test and no mutagenicity of 2-aminoanthracene was found in the *Salmonella typhimurium* strains T98 and T100 (Rossi et al., 2003). Later, Lopes et al. (2004) reported mutagenic activity of *Croton lechieri* sap for strain TA1535 of *Salmonella typhimurium* in the presence of metabolic activation, a weak mutagenic activity for strain TA98 and in a haploid *Saccharomyces cerevisiae* strain XV185-14c for the lys1-1, his1-7 locus-specific reversion and hom3-10 frameshift mutations.

### 2.1.2.10. Wound healing activity

*Sangre de Drago* (*Croton*) is commonly used as liquid bandage in the Amazon (Jones, 1995, 2003). Vaisberg et al. (1989) reported a significant increase
Table 2
Chemical constituents reported from *Croton* spp.

<table>
<thead>
<tr>
<th>Compound name</th>
<th>Bioactivity</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Croton draco</em> Schltdl. &amp; Cham.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-Hydroxyjunenol; 2,3-dihydrovomifoliol; 3,4,5-trimethoxycinnamyl alcohol; 9(11)-dehydrokaurenic acid; 9-dehydrovomifoliol; hardwickiic acid; p-hydroxybenzal-dehyde; p-methoxybenzoic acid; scopoletin; taspine (1)</td>
<td>Antibacterial activity, Analgesic activity</td>
<td>Murillo et al. (2001)</td>
</tr>
<tr>
<td>Acetyl aleuritolic acid</td>
<td>Antibacterial activity, Analgesic activity</td>
<td>Peres et al. (1997, 1998a)</td>
</tr>
<tr>
<td>β-Sitosterol; β-sitosterol-O-glucoside; campesterol; catechin; galloccatechin; stigmasterol 12-Epi-methyl-barabascoate (3); 15,16-epoxy-3,13(16)-clerodatriene-2-one (4) Fucoarabinogalactan (CU-1)</td>
<td>Analgesic activity</td>
<td>Peres et al. (1998b)</td>
</tr>
<tr>
<td>Procyanidin B-1 and B-4 (27)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Catechin; epigallocatechin; epicatechin; galloccatechin Catechin (4-α-g)-galloccatechin (4-α-6) galloccatechin; catechin (4-α-8)-galloccatechin; galloccatechin (4-α-6)-epicatechin; galloccatechin (4-α-8)-epicatechin; galloccatechin (4-α-8)-epigallocatechin; galloccatechin (4-α-8)-epicatechin</td>
<td>Cytotoxic activity, antibacterial activity, Antifungal activity</td>
<td>Cai et al. (1991), Cai et al. (1991), Chen et al. (1994), Cai et al. (1991), Phillipson (1995)</td>
</tr>
<tr>
<td>Benzofuran-5-yl,2-3-dihydro:2-(3-dimethoxy-phenyl) 7-methoxy-3-methoxy-carbonyl-propan-1-oic acid methyl ester; benzofuran-5-yl,2-3-dihydro:2-(4-hydroxy-3-methoxyphenyl)-7-methoxy-3-methoxy-carbonyl-propan-1-oic acid methyl ester</td>
<td></td>
<td>Pieters et al. (1992)</td>
</tr>
<tr>
<td>β-Sitosterol; bincatriol; crolechinol (10); crolechinic acid (11); daucosterol; hardwickiic acid</td>
<td></td>
<td>Cai et al. (1993a), Chen et al. (1994)</td>
</tr>
<tr>
<td>1,3,5-Trimethoxybenzene</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2,4,6-Trimehtoxyphenol 3,4-Dimethoxbenyl alcohol; 3,4-dimethoxy phenol; 4-hydroxyphenethyl alcohol and its acetate; β-sitostenone; sitosterol-β-D-glucopyranoside</td>
<td>Cytotoxic activity, antibacterial activity, Antifungal activity</td>
<td>Cai et al. (1993a)</td>
</tr>
<tr>
<td>Korberin A (5); korberin B (6)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4-O-Methylcedrusin (8)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SP-303 (MW = 2200 Da)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Catechin-(4-α-g)-epigallocatechin Ethyl acetate; ethyl propionate; 2-methyl butanol; 2-methylbutyl acetate; propyl acetate; 3-methylbutyl acetate; eucalyptol; 1-butyl acetate; 3-methyl-2-pentanol</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Isoboldine (13); norisoboldine (12); magnoflorine (14) SB-300 (MW = 3000 Da)</td>
<td>Antidiarrhoeal activity</td>
<td>Milanoński et al. (2002)</td>
</tr>
</tbody>
</table>

in the rate of wound repair on topical application of the *Croton lechleri* sap to skin wounds of mice and found taspine as the cicatrizant (wound healing) principle. A significant increase in numbers of migrating cells in an *in vitro* test for wounding of human fibroblasts also suggested role of taspine for wound healing (Vaisberg et al., 1989). From the sap of Peruvian Sangre de Drago (*Croton* sp.), a lignan known as 3′, 4-O-dimethylcedrusin was isolated which protected endothelial cells from undergoing degradation in a starvation medium and stimulated endothelial cells, however at high concentrations it inhibited the cell proliferation (Pieters et al., 1992, 1993). Porras-Reyes et al. (1993) performed a number of tests...
to determine how taspine accelerated wound healing and found that taspine enhanced wound healing via increased fibroblast migration.

Chen et al. (1994) studied the wound healing activity of Croton lechieri sap and concluded that several factors—the ability to form a film that protects against microbial invasion of wounds; free radical scavenging activity of procyanidins; the high content of polyphenolics capable of binding proteins and enzymes; and the anti-inflammatory and strong antibacterial action of polyphenols, together facilitating improved healing of damaged tissue, may contribute to the wound repairing properties of sap. They tested individual constituents of the sap and found endothelial cell proliferation was increased by Procyanidin B-4 and most potently by (-)-epigallocatechin and (+)-gallocatechin. Lewis et al. (1992) has patented for taspine in DMSO (solvent), which healed wounds faster than DMSO alone.

2.2. Daemonorops spp.

Dragon’s blood resin is also obtained as deep red teardrop-shaped lumps, separated physically from the immature fruit of the South-East Asian rattan- or cane-palm, Daemonorops spp. of the Indonesian islands. The botanical source was previously identified as Calamus draco Willdl. (Daemonorops draco Willdl. Blume) by Barry et al. (1926), who also described the resinous layer as being isolated by placing the fruits in sacks and pounding them and the pulp being treated with boiling water. Subsequently the resin was kneaded into balls or long sticks. Various grades have been identified by Howes (1949). Other species as source of resin are D. didymophylla Becc., D. micracantha (Griff.) Becc., D. motleyi Becc., D. rubra (Reinw. ex Blume) Blume and D. propinqua Becc.

2.2.1. Chemical constituents

Table 3 summarizes the compounds reported from resin of Daemonorops draco (Willdl.) Blume.

2.2.2. Bioactivities and therapeutic uses

2.2.2.1. Antimicrobial and antiviral activity. Previously, Mitscher et al. (1972) reported in vitro activity of commercial resin obtained from Daemonorops draco against Staphylococcus aureus and Mycobacterium smegmatis. This led to further evaluation of resin’s components exhibiting antimicrobial activity. Rao et al. (1982) reported that the antimicrobial activity of the resin from Daemonorops draco was due to the presence of compounds Dracorhodin and Dracorubin. These compounds were found to be active against Staphylococcus aureus (ATCC 13709), Klebsiella pneumoniae (ATCC 10031), Mycobacterium smegmatis (ATCC 607) and Candida albicans (ATCC 10231).

2.2.2.2. Antitumor and cytotoxic activity. Dracorhodin perchlorate, a synthetic analogue of Dracorhodin, red pigment isolated from exudates of the fruit of Daemonorops draco, has been reported to induce human melanoma A375-S2 cell and human premalignant leukemia HL-60 cell death through the apoptotic pathway (Xia et al., 2005, 2006). M. Xia et al. (2004), M.Y. Xia et al. (2004), also studied the mechanism of Dracorhodin perchlorate induced apoptosis and concluded that Dracorhodin perchlorate induced cell death via alteration of Bax/Bcl-XL ratio and activation of caspases.

2.2.2.2. Hemostatic and anti thrombotic activity. Daemonorops draco has been studied for its ‘hemostatic’ and ‘vasoactive–antithrombotic’ activity in Chinese medicinal system (Kiangsu Institute of Modern Medicine, 1977). Studies have provided evidences that (2S)-5-methoxy-6-methyl-flavan-7-ol (MMF) possess antiplatelet activity (Tsai et al., 1995). Later, underlying mechanism for antiplatelet activity of MMF was related to inhibition of thromboxane formation via the inhibition of cyclooxygenase and suppression of [Ca2+] i (intraplatelet Ca2+) increase (Tsai et al., 1998).

2.3. Dracaena spp.

The name Dracaena is derived from the Greek word ‘drakaina’ meaning a female dragon (Stern, 1992). The most striking source is the Dracaena cinnabari Balff. f. which is endemic to the island of Socotra (Yemen) west of Somalia. Palinurus, a survey ship of Leut. J.R. Wellsted of the East India Company gave first description of the Dragon’s blood tree, Dracaena cinnabari, calling it Pterocarpus draco (http://www.rbg-web2.rbge.org.uk/sqoatra/history/page07.html) while undertaking a survey of Socotra for the Indian Government in 1835. However, the species was first named and described by the Scottish botanist Sir Isaac Bailey Balfour when he visited the island in 1880 (Balfour, 1888). Three grades of Dracaena resin were identified by Balfour (1883), the most valuable being tear-like in appearance, followed by one made of small chips and fragments, and the cheapest being a molten mixture of fragments and refuse.

Voyagers to the Canary Islands in the 15th century obtained Dragon’s blood as dried garnet colored drops from another species Dracaena draco (L.) L., a native to the Canary Islands and Morocco. The canarian dragon tree Dracaena draco was first described in 1402 (Boutier and Le Verrier, 1872). The resin is exuded from the wounded trunk or branches of the tree. Dracaena cochinichinensis (Lour.) S.C. Chen is another species used in China as source of Dragon’s blood.

2.3.1. Chemical constituents

Table 4 summarizes the compounds reported from Dracaena spp., used as source of Dragon’s blood.

2.3.2. Bioactivities and therapeutic uses

2.3.2.1. Antimicrobial and antiviral activity. Mothana and Lindequeist (2005) reported antimicrobial activity of chloroform and methanol extract of Dracaena cinnabari resin from island Soqotra against Staphylococcus aureus (ATCC 6538), Bacillus subtilis (ATCC 6059), Micrococcus flavus (SBUG 16) and Escherichia coli (ATCC 11229). Kumar et al. (2006) also reported antimicrobial activity of exudes of red resin of Dracaena cinnabari collected from India against Bacillus cereus var mycoides (ATCC 11778), Bacillus pumilus
2.3.2. Antitumor and cytotoxic activity. Vachalkova et al. (1995) studied carcinogenicity of three homoioflavanoids and four flavanoids isolated from the resin of *Dracaena cinnabari*. Al-Fatimi et al. (2005) reported cytotoxic activity of resin of *Dracaena cinnabari* from Yemen against human ECV-304 cells. *Dracaena draco* has been found to be a rich source of cytotoxic steroidal saponins. Darias et al. (1989) reported, for the first time, the use of sap of *Dracaena draco* as an anticarcinogen. Steroidal saponins, (25R)-spirrost-5-en-3β-ol 3-O-\{α-L-rhamnopyranosyl-(1 → 2)-β-D-glucopyranoside\} and (23S,24S)-spirosta-5,25(27)-diene-1β,3β,23,24-tetrol 1-O-\{O-2,3,4-tri-O-acetyl-α-L-rhamnopyranosyl-(1 → 2)-α-L-arabinopyranosyl\} \(\rightarrow\) β-fucopyranoside, isolated from the aerial parts of *Dracaena draco* are reported to show potent cytostatic activity against HL-60 cells with IC\textsubscript{50} value being 1.3 and 2.6 μg/ml, respectively compared with etoposide (IC\textsubscript{50} 0.3 μg/ml) used as a positive control (Mimaki et al., 1999). González et al. (2003) also reported new steroidal saponins, Draconin A and Draconin B with cytotoxic activities against HL-60 cells from bark of *Dracaena draco*. The mechanism of these compounds’ cytotoxicity was also evaluated and found to be via activation of apoptotic process. Recently a new cytotoxic steroidal saponin, Icogenin, has been isolated from *Dracaena cochichinensis* (Wang et al., 2013). Icogenin also inhibited growth of HL-60 cells by induction of apoptosis (Hernández et al., 2014). Dioscin, from *Dracaena draco* also displayed cytotoxic activity similar to Icogenin.

### Table 3

<table>
<thead>
<tr>
<th>Compound name</th>
<th>Bioactivity</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dracorhodin (17)</td>
<td>Apoptotic activity</td>
<td>Brockmann and Junge (1943),</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Robertson and Whalley (1950),</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rao et al. (1982), Gao et al. (1989),</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Xia et al. (2005), Cardillo et al. (1971)</td>
</tr>
<tr>
<td>2,4-Dihydroxy-5-methyl-6-methoxychalcone;</td>
<td>Anti-platelet effects</td>
<td>Cardillo et al. (1971), Rao et al. (1982)</td>
</tr>
<tr>
<td>2,4-dihydroxy-6-methoxychalcone;</td>
<td></td>
<td>Cardillo et al. (1971), Tsai et al. (1995, 1998)</td>
</tr>
<tr>
<td>5-methoxy-7-hydroxyflavan (15)</td>
<td></td>
<td>Cardillo et al. (1971), Arnone et al. (1997)</td>
</tr>
<tr>
<td>Nordracorhodin (16); nordracorubin (18)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(25)-5-Methoxy-6-methylflavan-7-ol (21)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(25)-5-Methoxyflavan-7-ol (22);</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5,7-dimethoxy-6-methylflavan</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abietic acid; dehydroabietic acid; isopimaric acid; pimaric acid; sandaracopimaric acid</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Secobiflavanoid</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dracorubin (19)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polysaccharide (MW = 25,000)</td>
<td>Anticoagulant activity</td>
<td></td>
</tr>
<tr>
<td>Dracoolban; dracoresene; dracoresinotannol</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dammaradienol</td>
<td>Antiviral activity, Anti-inflammatory activity, cytotoxic activity</td>
<td></td>
</tr>
<tr>
<td>Dracooxepine</td>
<td>Anti-inflammatory activity</td>
<td></td>
</tr>
<tr>
<td>Dracolavan A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2,4-Dimethoxy-3-methylphenol; dracolavan B1; B2; C1; C2; D1; D2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1,6-Germacradien-5-ol; benzoic acid; bicyclogermacrene; cis,9,10-dihydrocapsenone; germacrene-α; α-copaene; α-cubebene; α-humulene; β-caryophyllene; β-cubebene; β-elemene; δ-cadinene</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4,6-Dihydroxy-2-methoxy-3-methylhydrochalcone</td>
<td></td>
<td>Shen et al. (2007)</td>
</tr>
</tbody>
</table>

(AtCC 14884), *Bacillus subtilis* (AtCC 6633), *Bordetella bronchiseptica* (ATCC 4617), *Micrococcus luteus* (ATCC 9341), *Staphylococcus aureus* (ATCC 29737), *Staphylococcus epidermidis* (ATCC 12228), *Klebsiella pneumoniae* (ATCC 10031), *Pseudomonas aeruginosa* (ATCC 9027), *Streptococcus faecalis* (MTCC 8043), and *Aspergillus niger* (MTCC 1344). Recently, Mothana et al. (2006) also reported antiviral activity of methanol extract of resin of *Dracaena cinnabari* against Herpes simplex virus and Human influenza virus.

Thus, *Dracaena* resin could be a rich source of antimicrobial agents with possibly novel mechanisms of action. Interestingly, resin from *Dracaena cochinchinensis* has been produced by infection with *Fusarium* and *Cladosporium* spp. (Wang et al., 1999). In another study done by Jiang et al. (2003), inoculation of fungi *Fusarium* 9568D in abiotic branch and wood of *Dracaena cochinchinensis* resulted in emergence of red resin from the inoculation points after 4–5 months incubation. The emerged resin was found to resemble the natural resin by UV-IR spectra analysis.

2.3.2.3. Analgesic activity. Liu et al. (2004) observed that both Dragon’s blood resin (*D. cochinchinensis*) and loureirin B could suppress TTX-S voltage-gated sodium currents depending upon dose, which could be reason for its analgesic effect. Later, Liu et al. (2005) studied the effects of Dragon’s blood and its component loureirin B on tetrodotoxin-sensitive (TTX-S) and tetrodotoxin-resistant (TTX-R) sodium currents in trigeminal ganglion (TG) neurons using the whole-cell patch-clamp technique and found that both Dragon’s blood and loureirin B suppressed two types of peak sodium currents depending...
### Table 4
Chemical constituents reported from *Dracaena* spp.

<table>
<thead>
<tr>
<th>Compound name</th>
<th>Bioactivity</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Dracaena cinnabari</em> Balf. f.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(±)-7,4′-Dihydroxy-3′-methoxyflavan</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4,4′-Dihydroxy-2′-methoxychalcone (9)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7,4′-Dihydroxyflavone (23)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(2S)-7-Hydroxyflavan; (2S)-7-hydroxyflavan-4-one (20); 7-hydroxy-3-(4-hydroxybenzyl)-8-methoxychroman; 7-hydroxy-3-(4-hydroxy benzyl) chroman; loureirin C (24)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3-(4-Hydroxybenzyl)-7,8-methylendioxychroman</td>
<td>Antioxidant activity</td>
<td></td>
</tr>
<tr>
<td>2′-Methoxysocotrin-5′-ol, socotrin-4′-ol; homoisosocotrin-4′-ol</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cinnabarone (29)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(2S)-7,3′-Dihydroxy-4′-methoxyflavan; 4-hydroxy-2-methoxydihydrochalcone; 7-hydroxy-3-(3-hydroxy-4-methoxybenzyl)chroman</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24-Methylenecycloartanol; 31-norcycloartanol; 4α, 14α-dimethylcholest-8-en-3β-ol; 4α-methylcholest-7-en-3β-ol; betulin; campesterol; cholest-4-en-3-one; cholesterol; cycloartenol; lanost-7-en-3β-ol; lupenol; sitosterol; stigmaster-22-en-3β-ol; stigmastanol; stigmasterol</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Damalachawin (30)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2,4,4′-Trihydroxydihydrochalcone</td>
<td>Antitumor activity, chemoprotective effects</td>
<td></td>
</tr>
<tr>
<td>Dracophane (27)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2,4′-Dihydroxy-4,6-dimethoxydihydrochalcone; 3-(4-hydroxy-2-methoxyphenyl)-1-phenyl-1-propanone; 3′,7-dihydroxy-4′-methoxyflavan; 3′,7-dihydroxy-4′-methoxyhomoisoflavan; 4′,6-dihydroxy-7-methoxyhomoisoflavan; 4′,7-dihydroxy-5-methoxyhomoisoflavan; 4′,7-dihydroxy-3′-methoxy flavan; 4′,7-dihydroxyxomisoisoflavan; 4′,7-dihydroxy-8-methylflavan; 4′,7,8-trihydroxyxomisoisoflavan; 7-hydroxy-5-methoxy-6-methylflavan; 7-hydroxy-3-(4-hydroxy benzyl)-4-chromanone; 7,10-dihydroxy-11-methoxydracae none; 10-hydroxy-11-methoxydracae none;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loureirin A; loureririn c (24); loureririn B</td>
<td>Analgesic activity</td>
<td></td>
</tr>
<tr>
<td>7,4′-Dihydroxyflavane</td>
<td>Antifungal activity</td>
<td></td>
</tr>
<tr>
<td>7-Hydroxy-4′-methoxyflavan; 6-hydroxy-7-methoxy-3-(4′-hydroxybenzyl)chromane; 2,3,5,6-tetrachloro-1,4-dimethoxybenzene; 4′-hydroxy-3,5-dimethoxyxystilbene</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2, 4, 4′-Trihydroxydihydrochalcone; 2, 4, 4′-trihydroxy-6-methoxydihydrochalcone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2′-Methoxysocotrin-5′-ol, socotrin-4′-ol;</td>
<td>Analgesic activity</td>
<td></td>
</tr>
<tr>
<td>2′-Methoxy-4′,4-dihydroxychalcone (9)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dracaenoides A; B; C; D</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Dracaena cochinchinensis* (Lour.) S.C. Chen

Loureirin A; loureririn c (24); loureririn B

Analgesic activity

Antifungal activity

7-Hydroxy-4′-methoxyflavan; 6-hydroxy-7-methoxy-3-(4′-hydroxybenzyl)chromane; 2,3,5,6-tetrachloro-1,4-dimethoxybenzene; 4′-hydroxy-3,5-dimethoxyxystilbene

2, 4, 4′-Trihydroxydihydrochalcone; 2, 4, 4′-trihydroxy-6-methoxydihydrochalcone

2′-Methoxysocotrin-5′-ol, socotrin-4′-ol; 2′, 4′, 4′-trihydroxychalcone; 2-methoxy-4′, 4′-dihydroxychalcone; cochincheninins

2′-Methoxy-4′,4-dihydroxychalcone (9)

Analgesic activity

7-Hydroxy-4′-methoxyflavan; 6-hydroxy-7-methoxy-3-(4′-hydroxybenzyl)chromane; 2,3,5,6-tetrachloro-1,4-dimethoxybenzene; 4′-hydroxy-3,5-dimethoxyxystilbene

2, 4, 4′-Trihydroxydihydrochalcone; 2, 4, 4′-tri hydroxy-6-methoxydihydrochalcone

2′-Methoxysocotrin-5′-ol, socotrin-4′-ol; 2′, 4′, 4′-tri hydroxychalcone; 2-methoxy-4′, 4′-dihydroxychalcone; cochincheninins

2′-Methoxy-4′,4-dihydroxychalcone (9)

Analgesic activity

Zhou et al. (2001a,b), Zheng et al. (2006a,b)

Lu et al. (1998)

Zhou et al. (2001a,b), Liu et al. (2006)

Wang et al. (1995), Zhou et al. (2001a,b), Zheng et al. (2006a,b)

Lu et al. (1998), Zhou et al. (2001a,b)

Lu et al. (1998), Zhou et al. (2001a,b)

Wang et al. (1995), Zhou et al. (2001a,b), Zheng et al. (2006a,b)

Zhou et al. (2001a,b), Zheng et al. (2006a,b)

Zhou et al. (2001a,b), Zheng et al. (2006a,b)
<table>
<thead>
<tr>
<th>Compound name</th>
<th>Bioactivity</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table 4 (Continued)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25(R,S)-Dracaenoides E–H; M; O–Q; dracaenoides</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1–L; R; 25(S)-dracaenoides N; 25(R,S)-spirost-5-en-3-ol</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3-O-α-L-rhamnopyranosyl-(1,2)→[α-L-rhamnopyranosyl-(1,4)]-β-D-glucopyranoside; 25(R,S)-spirost-5-en-3-ol 3-O-α-L-rhamnopyranosyl-(1,2)→[α-L-rhamnopyranosyl-(1,4)]-β-D-glucopyranoside; 26-O-β-D-glucopyranosyl</td>
<td>Zheng et al. (2004a,b)</td>
<td></td>
</tr>
<tr>
<td>7-Hydroxy-3-(4-hydroxybenzyl)chroman</td>
<td>Camarda et al. (1983), González et al. (2000, 2004)</td>
<td></td>
</tr>
<tr>
<td>7,4′-Homoisoflavone (1); 25(S)-arabinopyranoside</td>
<td>Zheng et al. (2006a,b)</td>
<td></td>
</tr>
<tr>
<td>1–L; R; 25(S)-dracaenoides N; 25(R,S)-spirost-5-en-3-ol</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3-O-α-L-rhamnopyranosyl-(1,2)→[α-L-rhamnopyranosyl-(1,4)]-β-D-glucopyranoside; 25(R,S)-spirost-5-en-3-ol 3-O-α-L-rhamnopyranosyl-(1,2)→[α-L-rhamnopyranosyl-(1,4)]-β-D-glucopyranoside; 26-O-β-D-glucopyranosyl</td>
<td>Zheng et al. (2004a,b)</td>
<td></td>
</tr>
<tr>
<td>7,4′-Homoisoflavone (1); 25(S)-arabinopyranoside</td>
<td>Zheng et al. (2006a,b)</td>
<td></td>
</tr>
<tr>
<td>1–L; R; 25(S)-dracaenoides N; 25(R,S)-spirost-5-en-3-ol</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3-O-α-L-rhamnopyranosyl-(1,2)→[α-L-rhamnopyranosyl-(1,4)]-β-D-glucopyranoside; 25(R,S)-spirost-5-en-3-ol 3-O-α-L-rhamnopyranosyl-(1,2)→[α-L-rhamnopyranosyl-(1,4)]-β-D-glucopyranoside; 26-O-β-D-glucopyranosyl</td>
<td>Zheng et al. (2004a,b)</td>
<td></td>
</tr>
<tr>
<td>7,4′-Homoisoflavone (1); 25(S)-arabinopyranoside</td>
<td>Zheng et al. (2006a,b)</td>
<td></td>
</tr>
<tr>
<td>1–L; R; 25(S)-dracaenoides N; 25(R,S)-spirost-5-en-3-ol</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3-O-α-L-rhamnopyranosyl-(1,2)→[α-L-rhamnopyranosyl-(1,4)]-β-D-glucopyranoside; 25(R,S)-spirost-5-en-3-ol 3-O-α-L-rhamnopyranosyl-(1,2)→[α-L-rhamnopyranosyl-(1,4)]-β-D-glucopyranoside; 26-O-β-D-glucopyranosyl</td>
<td>Zheng et al. (2004a,b)</td>
<td></td>
</tr>
<tr>
<td>7,4′-Homoisoflavone (1); 25(S)-arabinopyranoside</td>
<td>Zheng et al. (2006a,b)</td>
<td></td>
</tr>
</tbody>
</table>
upon dose. Further, Liu et al. (2006) explored the material basis for efficacy of modulation of Dragon’s blood on the tetrodotoxin-resistant (TTX-R) sodium currents in dorsal root ganglion (DRG) neurons. They suggested that analgesic effect of Dragon’s blood may be explained on the basis of interference with pain messages caused by the modulation of Dragon’s blood on TTX-R sodium currents in DRG neurons and could be due to the synergistic effect of three components cochinchinenin A, cochinchenin B, and loureirin B. Recently, Chen and Liu (2006) carried out a computer simulation research for the effects of Dragon’s blood and its component loureirin B on sodium channel in dorsal root ganglion cells.

2.3.2.4. Antioxidative activity. Juránek et al. (1993) have reported antioxidant activity of three homoisoflavans isolated from resin of Dracaena cinnabari. Machala et al. (2001) studied homoisoflavonoids and chalcones, isolated from the Dracaena cinnabari, for their potential to inhibit cytochrome P4501A (CYP1A) enzymes and Fe (II)/NADPH dependent in vitro peroxidation of microsomal lipids isolated from C57B1/10 mouse liver and found chalcones were poor antioxidants while 7,8-methylenedioxy-3-(4-hydroxybenzyl) chromane, a homoisoflavonoid, exhibited a strong antioxidant activity.

2.4. Pterocarpus spp.

Pterocarpus officinalis Jacq., previously known as Pterocarpus draco L., is the only species known as a source of Dragon’s blood. According to a description in the Bulletin of the Botanical Department, Jamaica, No. 45, July, 1893, when an incision is made in the bark, drops of red sap ooze out, flow slowly down the bark and gradually harden. No major studies have been done on this source of Dragon’s blood. Trimble (1895), studied resin from Pterocarpus draco L. and obtained 34.85% tannins from this resin.

3. Quality control and safety

Since Dragon’s blood, as a name, has been applied to resins obtained from different species from different continents; there is a great need to identify them apart. There are other substitutes as well, which are available in the market for Dragon’s blood such as Eucalyptus resinifera Sm. (Edwards et al., 2001). A powdered dark red coral from the Indian Ocean is also sold in Yemeni markets as “Dragon’s blood”. Glasgow’s Professor of Chemistry, J. Dobbie and G. Henderson first tackled the issue of chemical identification of the various resins under the name of Dragon’s blood in 1883, on request of Prof. Bayley Balfour (Pearson, 2002). They reported, “the resins known as Dragon’s blood differ widely from one another, not only in their degree of purity, but also in their appearance” and that “specimens labeled as having come from the same locality must, in reality, in some cases, have been derived from very different sources” (Dobbie and Henderson, 1883). Dobbie and Henderson (1884) arranged red resins in four distinct groups: 1. Those soluble in chloroform, carbon disulphide, and benzene completely; 2. Those soluble in chloroform, but insoluble in carbon disulphide and benzene; 3. Those soluble in chloroform and benzene and partly in carbon disulphide; and 4. Those, which are insoluble in all three reagents.

Edwards et al. (1997) described Dragon’s blood resin (Dracaena spp.) found on Socotra Island as the probable genuine
source in antiquity, on the basis of Fourier transform Raman spectroscopic studies of several resins generically known as Dragon’s blood from different botanical and geographical sources. They have since described a Raman spectroscopic method to identify fake and unknown Dragon’s blood resins from different botanical origins (Edwards et al., 2001, 2004). All Dracaena spectra show the strong bands in the wave number region 1605–1500 cm\(^{-1}\) and can be generally identified by the strongest band at 1605 cm\(^{-1}\), the shoulder at ca. 1560 cm\(^{-1}\). However, specimen degradation can be recognized by the loss of this shoulder at 1560 cm\(^{-1}\). Also, vibrational bands near 1170 cm\(^{-1}\) seen in the Dracaena draco spectra could be used as biomarkers for Dracaena species. The main feature distinguishing Daemonorops Dragon’s blood resins from those of Dracaena is the presence of the narrow and intense band at 1600 cm\(^{-1}\), the doublets at 1510–1540 cm\(^{-1}\) and 1420–1450 cm\(^{-1}\) region and also the medium intensity band at 1001 cm\(^{-1}\). Croton species is distinguished by a broad band at 1612 cm\(^{-1}\), and also by the medium intensity band at 784 cm\(^{-1}\). Later, Edwards et al. (2004) identified the key molecular biomarker bands of Dragon’s blood in the region 1400–1700 cm\(^{-1}\), which could be adopted as a protocol for the identification of the botanical and possible geographical sources of modern Dragon’s blood resins.

No major toxicity has been reported from Dragon’s blood. The American Herbal Products Association (1997) lists Sangre de Drago (Croton) as Class I, meaning it can be consumed safely when used appropriately. There are some instances when Dragon’s blood has been misrepresented as ‘opium’ and distributed for use as a ‘drug’. Ford et al. (2001) had identified a red substance as Dragon’s blood incense from Daemonorops draco that was being mixed with marijuana and smoked as an alternative to opium in Virginia. They also screened the substance for toxicity in various in vitro tests and suggested that that the abuse potential for Dragon’s blood incenses is minimal.

4. Conservation needs

Dragon’s blood is used in traditional medicine for diverse applications. Overexploitation of sources of Dragon’s blood is a matter of concern as is the case of Croton lechleri, in Peru and Ecuador. Because of the overexploitation and trade, it was identified as potentially threatened amongst the 22 species in the Workshop of Specialists in Ethnobotany and Economic Botany held in 1997 (http://www.traffic.org/ecuador/executivesummary.html). Dracaena cinnabari was also listed as vulnerable in the IUCN red list of threatened species (Miller, 2004). Dracaena draco was reported as vulnerable species on the Canary Islands due to overexploitation of the trees for Dragon’s Blood in the middle ages (Lucas and Syngé, 1978). It was also cited in IUCN Red List of Threatened Species (2006). Predominantly, resin of Daemonorops draco is the principal source of commercially harvested Dragon’s blood. Plant cell, tissue and organ culture could be an alternative approach for economic production of Dragon’s blood plants and the secondary metabolites they produce.

5. Conclusion

Although Dragon’s blood has proved to be popular alternative or complementary medicine used in the treatment of many diseases, clinical trial evaluation of these claims using currently accepted protocols is needed. One such potential new drug for AIDS-related diarrhoea is, “Crofelemer” developed originally by Shaman Pharmaceuticals from Croton lechleri. Since 2001, “Crofelemer” has been purchased by the American pharmaceutical company, Napo Pharmaceuticals and is currently undergoing clinical trials (http://www.aumag.org/lifeguide/WWSeptember05.html, http://www.botanical.com/botanical/mgmh/d/dragon20.html, http://www.drugs.com/npp/dragon-s-blood.html#ref3).

This resin offers huge potential and we need to investigate whether purified compounds isolated from Dragon’s blood may have better therapeutic potential as compared to crude extract. Since there is considerable variation in the chemical composition among various samples of Dragon’s Blood, quality control/assurance needs to be established for the traditional medical trade. This review is an effort to highlight the potential and problems related to the sources and possibilities of isolating new pharmaceutically active molecules, using traditional knowledge in our search, for new and effective drugs molecules.

Acknowledgements

We are grateful to Prof. Ulrike Lindequist, Institute of Pharmacy, Ernst-Moritz-Arndt-University, Germany for her thorough revision of this review and providing us with her invaluable suggestions. We acknowledge the financial support from AICTE (8023/RID/NPROJ/RPS-38/2004-05).

References


Draco and their cytotoxic activities. Journal of Natural Products 66, 793–798.


