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Rosemary

B. Sasikumar, Indian Institute of Spices Research, India

Abstract: Rosemary is an aromatic herb that has been known from ancient times as a memory herb. This chapter briefly describes the myths and folklore that are associated with this plant, and goes on to give details of the agricultural techniques used in its production, including biotechnology and developments in post-harvest processing and analytical techniques that have improved the extraction of rosemary oil and oleoresin. The culinary and medical uses of the herb are also outlined in this chapter, as is the use of rosemary as a herbal pesticide. The toxicology of rosemary and its oils is discussed at the end of the chapter, which concludes with suggestions for key topics that require ongoing research.

Key words: biomedical uses, chemical profile, oil extraction, pesticide, post-harvest technology, rosemary.

25.1 Introduction

Rosemary, the memory herb of the mint family, has been used by man since ancient times. Records of the use of rosemary appear in cuneiform on Sumerian stone tablets of the fifth millennium BC. The Chinese and Greeks used rosemary as a health conditioner; the Greeks, who wore rosemary wreaths in their hair, also believed that rosemary strengthened the brain and enhanced memory. In Egypt, the herb was buried with the pharaohs. Hungary water, an infusion of rosemary in spirits of wine, is thought to have been first prepared for Queen Izabella of Hungary in 1235 to renovate her paralysed limbs. The word rosemary is derived from the Latin word '*rosmarinus*', meaning 'sea dew'. It was also called '*antos*' by the ancient Greeks, meaning the flower of excellence or 'libanotis' for its smell of incense (Giugnolinini, 1985).

There are many myths and much folklore associated with rosemary. It is believed that placing rosemary sprigs under the pillow would ward off evil spirits and nightmares from the sleeper and that the aroma of rosemary would keep old age at bay (Rose, 1974). During the Middle Ages it was believed that burning rosemary leaves and twigs would scare away evil spirits and disinfect the surroundings; later, it was burned by judges to protect against illness brought in by prisoners. It was also known as a symbol of fidelity and in Europe wedding parties burned rosemary as incense. Rosemary has also been used as a symbol of love and loyalty. As such, in the Middle

Ages, rosemary was associated with wedding ceremonies; either the bride would wear a rosemary head piece, the groom and guests would wear a sprig of rosemary or the couple would plant a rosemary bush on their wedding day. In Hungary, ornaments made of rosemary were once used as a symbol of love, intimacy and fidelity of a couple.

Some of these myths and beliefs had an underlying scientific logic behind them, as present-day studies reveal. Now it is clear that the essential oil and tannins present in rosemary produce an aromatic smoke with cleansing and purifying properties.

25.1.1 Origin and distribution

Rosemary (*Rosmarinus officinalis* L.) syn. Compass plant, Family Lamiaceae, is native to the Mediterranean – from Spain to the Balkans and into North Africa (Giugnolinini, 1985). At present, it is widely cultivated in Spain, Morocco, Tunisia, France, Algeria, Portugal and China and, to a limited extent, in India in the Nilgiris and Bangalore. Rosemary chemotypes with distinct morphological characters and oil quality occur in Italy (Mulas *et al.*, 1998).

25.1.2 Description

Rosemary is a dense, evergreen, hardy perennial aromatic herb of 60–200 cm in height with small (2–4 cm) pointed, leaves (Fig. 25.1). The upper surface of the leaf is dark green or blue, while the underside of the leaf is white; the leaves are resinous. Branches are rigid with fissured bark and stems brown, square and woody. Flowers are whitish, blue or purple in cymose inflorescence. The leaves, flowering tops and twigs yield an essential oil and oleoresin valued in recipes, traditional medicine, modern medicine and aromatherapy as well as in the perfume and flavour industries. Although it is generally *R. officinalis* that is used for oil extraction, in Morocco *R. eriocalyx* is also used for extracting essential oil (Elamrani *et al.*, 2000).

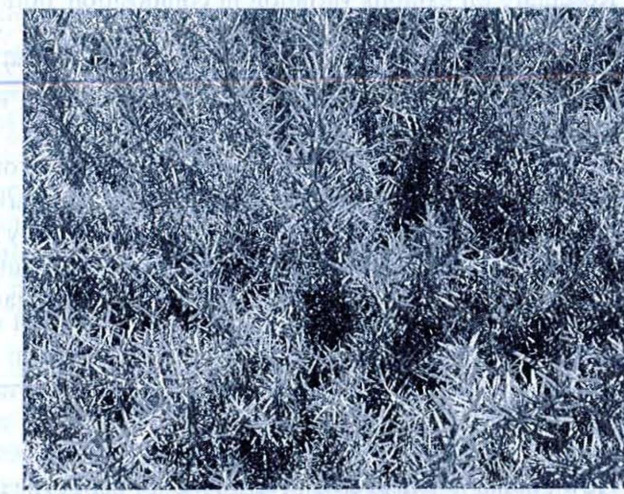

Fig. 25.1 Rosemary.

Table 25.1 Composition of dried rosemary leaves

Moisture	5.7 %
Protein	4.5 %
Fat	17.7 %
Crude fibre	19.0 %
Carbohydrates	47.4 %
Ash	6.0 %
Calcium	1.5 %
Phosphorous	0.7 %
Iron	0.03 %
Sodium	0.004 %
Potassium	1.0 %
Vitamin A	175 IU/100 g
Vitamin B	0.51 mg/100 g
Vitamin C	61.3 mg/100 g
Energy	440 calories/100 g

Source: Farooqi *et al.*, (2005).

The annual global oil production is 200–300 metric tonnes. Many different varieties and cultivars are grown, each varying in flower colour (blue/pink/white), plant habit (erect/spreading), leaf colour (olive/blue/green), size of leaves, etc.

25.1.3 Chemical composition

The composition of dried rosemary leaves is shown in Table 25.1. The main components of rosemary oil are 1,8-cineol (15–20 %), camphor (15–25 %), borneol (16–20 %), bornyl acetate (up to 7 %), α-pinene (25 %); in addition, the oil contains minor amounts of β-pinene, linalool, camphene, subinene, myrcene, α-phellandrene, α-terpinene, limonene, *p*-cymene, terpinolene, thujene, copalene, terpinen-4-ol, α-terpineol, caryophyllene, methyl chavicol and thymol. The initial distillation fraction contains mostly α-thujene, α-pinene, camphene, β-pinene and 1,8-cineol, while camphor and bornyl acetate constitute the bulk of the later distillation (Prakasa Rao *et al.*, 1999). Rosemary oil exhibits variation in composition, both profile and percentage of each component, depending on growing location and/or other factors such as source population, fertilizers and phenology (Boyle *et al.*, 1991; Arnold *et al.*, 1997; Boutekedjiret *et al.*, 1999; Ouahada, 2000; Porte *et al.*, 2000; Wolski *et al.*, 2000; Guazzi *et al.*, 2001). Pintore *et al.*, (2002) reported a total of 58 compounds from rosemary oil from Sardinia and Corsica (Italy) based on gas chromatography retention index (GC–RI), GC mass spectroscopy (GC–MS) and carbon nuclear magnetic resonance (C-NMR) studies. A study of Moroccan rosemary oil not only demonstrated the existence of three different rosemary chemotypes but also identified a total of 91 compounds, based on GC and GC–MS studies (Elamrani *et al.*, 2000).

25.2 Production and cultivation of rosemary

Rosemary can be grown either as a field crop or as an indoor plant. The plant thrives well in well-drained soils of pH 6.5–7.0 and with warm, sunny weather conditions

(Doulgas, 1971). It will also grow in a semi-arid tropical climate. The plant is, however, susceptible to severe cold and frost, although frost-resistant varieties are now available (Domokos *et al.*, 1997). Male sterility is known to occur in natural populations of rosemary. Mitochondrial genome polymorphism linked to male sterility has been reported from Spain (Hidalgo-Fernandez *et al.*, 1999). This male sterility may be responsible for spontaneous population evolution and the occurrence of chemotypes in rosemary. Rosemary is a perennial herb propagated either by cuttings or seeds. Cuttings of 10–15 cm length from selected mother plants are ideal for vegetative propagation of rosemary. Treatment of cuttings with growth hormones such as indole butyric acid (IBA), indoleacetic acid (IAA) or saponin are reported to enhance rooting of cuttings (Shah *et al.*, 1996; Silva and Pedras, 1999). The end of winter has been found to be the most successful season for rooting cuttings (Silva and Pedras, 1999). Cuttings with the lower leaves removed are first planted in raised sand beds in a protected nursery. Regular watering is needed to achieve good sprouting. It then takes about 45–50 days for the cuttings to be transplanted to the main field.

Rosemary seeds are very small and black in colour. In India, the seed nursery is usually in operation from September to November. Seed rate is about 0.2–2.5 g seed 1 m^2 area (Farooqi and Sreeramulu, 2001). Raised seed beds with adequate shade, sufficient watering, good drainage and weeding ensure healthy seedlings. Seedlings are transplantable at 8–10 weeks; the usual spacing adopted for the rosemary plants is 45 × 45 cm as a monocrop.

Soil properties are known to influence the yield and composition of the rosemary oil harvested. Moretti *et al.* (1998a) reported that granite silt soils result in a better herb yield and oil quality when compared with calcareous soils. A fertilizer dose per hectare of 40 kg P_2O_5, 40 kg K_2O and 20 kg N with 20 metric tonnes farmyard manure is recommended for rosemary production in India (Farooqi and Sreeramulu, 2001). Furthermore, N level can be raised to 300 kg ha^{-1} in different splits to maximize oil yield. Close spacing coupled with increased nitrogen dose result in higher herbage and oil yield (Prakasa Rao *et al.*, 1999). Studies conducted in Italy (Sardinia) on fertilizer dose and weed management revealed that applying 80 kg N + 60 kg P_2O_5 ha^{-1} coupled with hand weeding of the major weeds such as *Genista corsica* and *Cytisus* spp. increased herbage yield and oil (Milia *et al.*, 1996). Biofertilizers, such as *Azospirillum*, *Azotobacter* and vesicular arbuscular mycorrhiza (VAM), applied in combination with inorganic fertilizers, have also been reported to have a beneficial effect on the herb and oil yield of rosemary (Anuradha *et al.*, 2002).

Weed control in rosemary is achieved through occasional hand weeding and intercultivation. Other husbandry techniques that have been studied include foliar spraying of iron, use of growth regulators, irrigation and pruning. The application of iron as a foliar spray in irrigated rosemary increased the verbenone concentration in the oil (Moretti *et al.*, 1998b). Studies on the effect of growth regulators (brassinosteroids and uniconazole) on growth, yield and chemical composition of rosemary in Egypt revealed the beneficial effect of growth hormones (Tarraf and Ibrahim, 1999). Irrigation is reported to be beneficial for herbage yield of rosemary. To establish the crop well in the field, two irrigations per week are recommended in India. Subsequently, irrigation once a week will be sufficient (Farooqi and Sreeramulu, 2001). Drip fertigation with water-soluble fertilizers (80 % WSF) coupled with micronutrients is reported to increase growth, yield and quality traits of rosemary (Vasundhara *et al.*, 2002). Field experiments on water requirements of rosemary in Egypt revealed that irrigation once every 14 days resulted in high herbage and oil yield (Kandeel, 2001). A study on the effect of soil moisture regime, irrigation water (IW): cumulative pan evaporation (CPE) ratios and nitrogen level on herbage and oil yield of rosemary on alfisols in Bangalore, India, indicated that a soil moisture regime maintained at 0.50 IW:CPE ratio with 150 kg N ha^{-1} significantly increased herbage and oil yield of rosemary (Singh and Ramesh, 2000). The correct soil moisture/nutrient regime is significant as unstressed rosemary plants are reported to yield higher levels of essential oil and phenolic compounds than those subjected to water/nutrient stress (Solinas *et al.*, 1996). Pruning of rosemary is advisable, though not essential, after 2 or 3 years to enhance shoot and leaf production (Farooqi and Sreeramulu, 2001). As rosemary is a perennial herb, aged plantations (10–12 years old) need to be rejuvenated by cutting back the plant to a height of 4–5 cm above ground coupled with fertigation for better herbage yield.

25.2.1 Diseases and pests

The important diseases affecting rosemary are: collar and root rot (*Phytophthora incognitae, P. drechsleri*), blight (*Rhizoctonia* spp., *Phytocoris rosmarini* and *Orthotylus ribesi*), foliar necrosis/leaf spot (*Alternaria alternata*), aerial blight (*Ralstonia solani* AG-4), hook disease (*Botrytis cinerea*) and powdery mildew (*Oidium* spp.) (Perello and Dal Bello, 1995; Minuto and Garibaldi, 1996; Cacciola *et al.*, 1997; Conway *et al.*, 1997; Villevieille *et al.*, 1999). *Alternaria* leaf spot will be severe in humid and less well-ventilated areas, whereas powdery mildew can be severe in shaded conditions. Aerial blight is a major disease in greenhouse-grown rosemary. Various crop husbandry measures can reduce the severity of the impact of these diseases: (i) harvesting before blooming will help to restrict the crop loss due to hook disease; (ii) improved drainage can reduce the risk of root rot; (iii) spraying and drenching with the fungicide Maneb (1 %) are effective against root rot and blight; (iv) sulphur dusting is recommended against powdery mildew. Biological control agents have also been investigated for use on rosemary. Biocontrol of powdery mildew with a commercial formulation of *Ampetomyces quisqualis* gave partial control (Minuto and Garibaldi, 1996). An isolate of the biocontrol agent, *Laetisaria arvalis*, if incorporated in the pots, followed by foliar spray of fungicides at a low dose, was found to check aerial blight of rosemary better than separate applications of fungicide or biocontrol agent alone (Conway *et al.*, 1997). Biocontrol agents such as *Trichoderma* spp., and fluorescent pseudomonads are worth trying, as there is a premium price for organically produced herbs. These biocontrol agents can be components in an integrated disease management approach for rosemary. However, in the case of aerial blight of rosemary no synergistic effect of soil amendment with *Trichoderma harzianum* and foliar spray with iprodione (fungicide) was observed (Conway *et al.*, 1997). Mites are a serious insect pest in rosemary grown in India (Farooqi *et al.*, 2005). Spraying of Ethion (0.05 %) is recommended to control the infestation.

25.2.2 Biotechnology

In vitro studies of rosemary are in progress in several laboratories worldwide. Published research has focused on several topics: the callus induction potential of various explants from rosemary; the essential oil profile of *in vitro* cultures under salt stress; the *in vitro* production of the pigment shisonin; and the *in vitro* production of carnosic acid in callus cultures and regenerated shoots (Zhu-Ru *et al.*, 1996; Tawfik, 1997; Yang-Rong Hui *et al.*, 1997; Hashimoto *et al.*, 1997; Caruso *et al.*, 2000). However, despite the ongoing research, large-scale downstream processing of value-added products of rosemary using these *in vitro* techniques, or scale-up of the process for commercial exploitation, is still in its infancy.

25.3 Post-harvest technology and further processing

Rosemary leaves, flowering tops, flowers and twigs are of economic importance. The first harvesting is carried out about eight months after planting, with the onset of flowering or just before flowering. In the first year, two crops can be taken, whereas in the subsequent years two to four harvests are possible at an interval of 100–120 days. Generally, harvesting of the plants can be carried out until 50 % flowering. At above 90 % flowering, harvesting is not desirable (Farooqi and Sreeramulu, 2001). Tender, non-hardy shoots are also harvested for distillation upon attaining full size. Usually the harvested leaves, flowering tops and shoots are used for downstream processing without drying. However, the leaves and twigs can also be used after drying for oil extraction. Drying studies in normal conditions at 50°C and in dehydrated air (30°C) revealed that in terms of percentage values of the characteristic volatile oil compounds, the dehydrated air dried product is on par with raw leaves (di Cesare *et al.*, 2001). However, Ibanez *et al.*, (1999) reported that, of the different drying methods, the traditional method (drying in a ventilated room) was the best in terms of the yield and quality of the antioxidant principles of rosemary. The genotype of the plant, the age of the leaf and growing conditions are known to affect the oil quality, especially the quantities of the antioxidant principle, carnosic acid, in the oil (Hidalgo *et al.*, 1998). Boutekedjiret *et al.*, (1999) reported a phenology-dependent variation in yield and quality. For best oil yield, the flowering stage of rosemary is preferable, although the oil quality from plants at this growth stage is slightly inferior. To achieve high yields of good-quality oil, the grower has to select an appropriate growth stage when harvesting.

25.3.1 Extraction of rosemary oil

Rosemary oil is colourless to pale yellow and its properties are shown in Table 25.2. Rosemary oil is usually recovered by steam or water distillation, although supercritical fluid extraction (SFE) using CO_2 as a solvent is also now being used (Coelho *et al.*, 1997; Bicchi *et al.*, 2000). Detailed studies aimed at standardizing the various parameters for supercritical CO_2 extraction of the oil – such as pressure, temperature, particle size, CO_2 rate, etc. – are in progress (Carvalho *et al.*, 2005; Bensebia *et al.*, 2009; Ivanovic *et al.*, 2009; Zermane *et al.*, 2010). A new extraction process, the Fast Control Pressure Drop method, has also been reported (Rezzoug *et al.*, 2005).

Table 25.2 Physical properties of rosemary oil

Specific gravity (25°/25 C)	0.894–0.912
Optical rotation (20 °C)	–5° to +10C
Refractive index (20 °C)	1.464–1.476
Esters as bornyl acetate	Minimum 1–5 %
Total alcohol as borneol	Minimum 8 %
Solubility (90 % ethanol)	1 vol. (EOA)

This process involves exposing the rosemary leaves for a brief period of time to steam pressure varying from 0.5–3 bar followed by an instantaneous decompression to vacuum (about 15 mbar). Most of the oil (90 %) comes out within the first 60 minutes of the conventional distillation, although distillation can be continued for 120 minutes for full recovery of rosemary oil under field distillation conditions (Prakasa Rao *et al.*, 1999).

It has been found that the oil obtained from leaves and flowering tops is of better quality than the oil obtained from whole-plant distillation. It has also been reported that, in terms of the yield and quality profile of the rosemary oil, steam distillation is preferable to water distillation (Boutekedjiret *et al.*, 1997). Blanching (microwave blanching for 1 min) is observed to have a positive effect on retention of the antioxidant principles, green colour and texture of rosemary; however, blanching leads to total loss of volatile oils (Singh *et al.*, 1996).

The oils and extracts obtained from rosemary by steam distillation, water distillation and controlled instantaneous decompression were analysed by GC and GC–MS in order to determine their chemical composition (Boutekedjiret *et al.*, 2004). It was observed that steam distillation seemed to be the most appropriate process for oil isolation of rosemary since it gave the highest yield, and an oil composition similar to values quoted in the literature and in commercial standards. The composition and antioxidant properties, as well as antimicrobial activities, of oil extracted using supercritical CO_2 have also been confirmed (Genena *et al.*, 2008).

The oil content of fresh rosemary leaves is 1 % and in shade-dried leaves it increases to 3 % (Farooqi and Sreeramulu, 2001). In theory, the yield from 1 ha is approximately 10–12 tonnes of herbs per year, yielding 25–100 kg oil (Farooqi and Sreeramulu, 2001). However, in field distillation conditions, the oil yield varies from 0.5–0.9 % (Prakasa Rao *et al.*, 1999), so annual yields may be lower.

25.3.2 Extraction of active compounds

For the extraction of the active compounds of rosemary, conventional solvent extraction techniques using solvents such as hexane, benzene, ethylene, chloroform, dioxane and methanol (Chang *et al.*, 1977) besides distillation and SFE are routinely employed. SFE using CO_2 has been reported to be superior to liquid solvent sonication for the maximum recovery of carnosic acid in its pure form (Tena *et al.*, 1997). Recent research on improving the yield and quality of rosemary extract with new techniques has shown encouraging results. Superheated water under pressure between 125 and 175 °C has been shown not only to extract high-quality oxygenated fragrance and flavour compounds from rosemary rapidly but also to produce higher

yields than steam distillation (Basile *et al.*, 1998). Ibanez *et al.*, (1999) proposed a two-step SFE and fractionation of essential oil-rich oleoresin and antioxidant compounds by varying the pressure and temperature requirements. Enzyme-assisted ensiling (ENLAC) prior to polyphenol extraction is reported to double the yield of polyphenol from rosemary (Weinberg *et al.*, 1999).

Rosemary oleoresin, also known as rosemary oil extract, is a green to brownish green semi-olid to pasty extract which is fluid when warmed to 50 °C. Different grades of rosemary oleoresin are available, with the grade being dependent on the volatile oil concentration, in particular the carnosic acid concentration (Heath, 1981). It is the carnosinic acid that is believed to be responsible for the potent antioxidant properties of rosemary oleoresin. These properties will be discussed in a later section of the chapter.

25.4 Main uses of rosemary

25.4.1 Culinary uses and food processing

Rosemary leaves and flowering tops have many culinary uses: lamb roast, mutton preparations, marinades, bouquet garni, baked fish, rice, soups, salads, occasionally with egg preparations, dumplings, apples, summer wine cups and fruit cordials, in vinegar and oil (Bonar, 1994). The fresh and dried leaves of rosemary are used frequently in traditional Mediterranean cuisine as they have a bitter astringent taste and are aromatic. Dried and powdered leaves are added to cooked meat, fish, poultry soup, stews, sauces, dressings, preserves and jams. Mixed with sage, the leaves are also used in pork preparations. When burned the leaves give off a distinct mustard smell which is favoured in barbecuing.

Rosemary is a most effective herb with a wide range of uses in food processing. In Europe and the USA, rosemary is commercially available for use as an antioxidant, though not technically listed as natural preservative or antioxidant, especially in Europe (Yanishlieva-Maslarova and Heinonen, 2001). Rosemary has potential applications in the suppression of warmed over flavour (WOF) (Valenzuela and Nieto, 1996). The main antioxidant principles in rosemary are carnosic acid, 12-methoxy carnosic acid and carnosol, as well as the antioxidative diterpenes such as epirosmarinol, isorosmanol, rosmaridiphenol, rosmariquinone and rosmarinic acid (Richheimer *et al.*, 1996). The antioxidant properties of rosemary are attributed to its ability to scavenge superoxide radicals, lipid antioxidation, metal chelating, etc. Extracts and essential oil of rosemary can be used to stabilize fats, oils and fat-containing foods, e.g. butter, against oxidation and rancidity (Zegarska *et al.*, 1996; Pokorny *et al.*, 1998) and also to stabilize fermented meat products (Korimova *et al.*, 1998). A useful review by Yanishlieva-Maslarova and Heinonen (2001) discusses the literature on rosemary and sage antioxidant principles, covering their extraction, properties and applications, and the chemistry involved. Deodorized liquid, commercial antioxidant formulations of rosemary, either as mono-herbal or as poly-herbal (rosemary, thyme, sage, oreganum) formulations, i.e. 'Herbor 025', 'Spice Cocktail', etc., are available (Aruoma *et al.*, 1996).

Rosemary oil also has applications in meat preservation. The addition of rosemary oleoresin to ground chicken had an overall positive effect on raw meat appearance during storage and on the flavour of the cooked meat (Koekamnerd *et al.*, 2008). The antioxidative properties of rosemary oleoresin and its inhibition of off-flavours in pre-cooked roast beef slices have also been reported (Murphy *et al.*, 1999).

25.4.2 Aromatherapy and cosmetics

Rosemary oil is used in aromatherapy to stimulate the central nervous system and blood circulation, to relieve muscular pain. Add a few drops of rosemary essential oil to any massage oil, such as sweet almond oil, blend together and massage gently into the area affected by pain.

It also has beneficial effects in promoting hair growth. Massaging a cocktail of essential oils of rosemary, thyme, cedar wood and lavender in carrier oils of jojoba and grape seed over a period of 7 months into the scalp of patients with *Alopecia areata* was found to be a safe and effective treatment (Hay *et al.*, 1998). Rosemary oil stimulates hair follicles and circulation in the scalp and thus may also be helpful in premature baldness (http://www.holistic-online.com/Herbal-Med/_Herbs/h228.htm). Rosemary is used in curing acne (Baumann, 2007).

In addition to its use in aromatherapy, rosemary also has several cosmetic applications. When used in a shampoo, rosemary oil can help to control dandruff and greasy hair; it is also known to impart a black colour to hair. Rosemary cleansing cream can be used for oily skin (Bonar, 1994). Rosemary oil is a component in soaps, room fresheners, deodorants, perfumes, skin lotions, etc., either in formulations with other herb oils or singly. The traditional Hungary water is a perfume based on rosemary oils. The flower, calyx and leaves of rosemary are used in potpourri and herb pillows (Bonar, 1994).

25.4.3 Traditional medicinal uses

Hungary water prepared from rosemary is considered to be a revitalizing agent and the herb has an old reputation for improving memory. The presence of rosemary in one's body is believed to enhance clarity of mind and memory, akin to the belief surrounding sweet flag (*Acorus calamus*) in India. In traditional medicine, herbalists recommend rosemary oil for a wide range of disorders including pulmonary diseases. Rosemary oil has been described as having the following properties: stomachic, wound healing (poultice), choleretic, antidiabetic, diuretic, antidepressant and antispasmodic (Oury, 1984; Giugnolinini, 1985; Erenmemisoglu *et al.*, 1997). The whole plant, in the form of decoction, infusion, extract in ethanol (for external application) and essential oil, is administered against digestive disorders, vaginitis, leucorrhoea, respiratory diseases, varicose vein, heart pain, inflammation and dizziness by the native people of Mexico and Central America (Santos García-Alvarado *et al.*, 2001). In Russia and the Central Asian countries of the former Soviet Union, leaves of rosemary preparation (gallenical and powder made into cigarettes) are used to treat asthma (Mamedov and Craker, 2001). The abortifacient (anti-implantation) effect of rosemary extract is also known (Lemonica *et al.*, 1996). A distilled water obtained from rosemary flower is used as an eye lotion (Farooqi *et al.*, 2005).

25.4.4 Modern research into medicinal properties

Rosemary is today credited with having many varied medicinal properties. Modern analysis techniques have enabled the individual components of the oil to be identified and their effects investigated. The medicinal properties and the chemical constituents/part of the plant that are now thought to be involved in these effects are listed below:

- carminative properties – flavanoids;
- antidepressant, antispasmodic properties – volatile oils;
- rubefacient properties – phenolics;
- antimicrobial properties – diterpenes;
- emmenagogue properties – oleanolic acid;
- anti-inflammatory properties – carnosol;
- carcinogen blocking and liver detoxifying properties – carnosol and whole-plant extract;
- antirheumatic properties – ointment of rosemary oil;
- abortifacient properties (aqueous extract).

HIV treatment

Liquid deodorized extract of rosemary ('Herbor 025') and oily extract of mixture of herbs such as rosemary, thyme, sage and oreganum ('Spice Cocktail') inhibited human immunodeficiency virus (HIV) infection at very low concentrations though they were cytotoxic. Carnosol and carnosic acid were found top be the main active constituents of the extracts (Aruoma *et al.*, 1996). Purified carnosol @ 8 μM exhibited anti-HIV activity besides beingon-cytotoxic.

Cardiovascular effects

The cardiovascular effects of rosemary extract on the isolated intact rabbit heart demonstrated significant positive inotropic effect and coronary vasodilatation (Khatib *et al.*, 1998). Administering an infusion of dried rosemary leaves resulted in decrease of blood glucose levels in normoglycaemic and diabetic mice and had no toxic effects (Erenmemisoglu *et al.*, 1997).

Cancer prevention

Rosemary is now gaining importance in cancer treatment. Rosemary has been shown to have potential as a source of anticancer molecules and as a treatment to enhance the bioavailability of cancer drugs (Plouzek *et al.*, 1999; Huang *et al.*, 2009; Rasha and Abdella, 2010; Yesïl-Celïktas *et al.*, 2010). The major anticancer compounds identified from rosemary are: carnosol, carnosic acid, ursolic acid, befulinic acid, rosmaridiphenol and rosemanol. Carnosol is found to reduce cellular nitric oxide in mice, a free radical that can damage DNA (Chan *et al.*, 1995). It is also reported, in rats, that administering a whole-plant extract of rosemary is more effective in preventing the carcinogen 7,12-dimethyl benz(a)anthracene (DMBA) from binding to breast cell DNA than administering carnosol or ursolic acid alone (Singletary *et al.*, 1996).

Extract of rosemary is found to increase the intracellular accumulation of the common chemotherapy drugs such as dexorubicin (DOX) and vinblastine (VIN) in drug-resistant MCF-7 human breast cancer cells leading to increased availability of the drugs for bioactivity (Plouzek *et al.*, 1999). Adding rosemary extract to cooked beef reduces the formation of heterocyclic amines, a carcinogen (Puangsombat and Smith, 2010).

Diuretic and other effects
Haloui *et al.*, (2000) reported a diuretic effect of aqueous extract of rosemary (8 % concentration) on Wister rats. Carnosic acid in rosemary is reported to shield the brain from free radicals, lowering the risk of strokes and neurodegenerative diseases like Alzheimer's and Lou Gehrig's (Lipton, 2007). Hyperglycaemic and insulin release inhibitory effects of the herb have also been reported (Al-Hader *et al.*, 1994). Rosemary extract also prevents binding of aflatoxins to human liver cells and benzo(a)pyrenene to bronchial tissue (Offord *et al.*, 1995).

Administration
Rosemary can be administered in the form of infusion, decoction, ethanol extract (external use), tinctures, rosemary wine, drug-containing volatile oil, powdered drug, liquid extract, dry extract and rosemary oil (mainly for external use). The infusion is prepared by adding 2 g of herb to 1 l of boiling water (Santos Garcìa-Alvarado *et al.*, 2001).

25.4.5 Herbal pesticide
In the agricultural industry, rosemary is known to possess insect-repellent and antimicrobial properties which are beneficial in growing and storage of crops. Comparative laboratory studies have been carried out where different herbal powders, including rosemary powder, were dusted on stored grains of wheat and French bean; analysis of the results of these treatments on the pest species *Sitophilus granarius* and *Acanthoscelides obtectus* revealed that grain wheat can be very effectively protected against *S. granarius* by dusting the grain with rosemary powder (Kalinovic *et al.*, 1997). Aphids are also repelled by the odour of rosemary and the mint *Mentha pulegium*. Based on GC–MS analysis, a few components of rosemary oil – i.e. 1,8-cineole, D-1-camphor, α,1-camphor and α-pinene – have been found to be the major principles repelling the aphids (Hori and Komatsu, 1997). The antirepellent property of rosemary oil to *Myzus persiacea* is attributed to 13 compounds; the most important being linalool, D-1-camphor and α-terpineol (Hori, 1998).

Rosemary oil (1 %) is found to reduce the fecundity rate of the predacious mites *Amplyseius zaheri* and *A. barkeri* (Momen and Amer, 1999). The repellent and oviposition-deterring activities of rosemary oil on the spider mites *Tetranychus usticae* and *Eutetranychus orientalis* have also been reported (Amer *et al.*, 2001). Essential oil of rosemary in vapour form is shown to reduce fecundity, decrease egg hatchability, increase neonatal larval mortality and adversely affect offspring emergence of *Acanthoscelides obtectus* (Papachristos and Stomopoulos, 2002).

Essential oil of rosemary has also been reported to have antimicrobial activity against an array of bacterial and fungal species including *Listeria monocytogenes* and *Aspergillus niger* (Baratta *et al.*, 1998; Faliero *et al.*, 1999). Gram-negative bacteria such as *Staphylococcus aureus* and *S. epidermidis* have been found to be more

susceptible to rosemary oil than are other gram-negative bacteria such as *Escherichia coli* and *Pseudomonas aeruginosa* (Pintore *et al.*, 2002). Rosemary leaves themselves are a source of antibacterial molecules; in laboratory studies, an active compound effective against the plant pathogen *Streptomyces scabies* has been isolated from the leaves of rosemary (Takenaka *et al.*, 1997).

25.5 Toxicology and quality control

Rosemary is generally considered safe and devoid of toxic side-effects if taken in recommended doses. However, certain guidelines for its use should be followed. (i) rosemary oil if internally consumed or ingested in excess can trigger convulsions; (ii) pregnant and lactating women are advised not to use rosemary, as are people with epilepsy; (iii) rosemary oil should be used with caution by persons suffering from hypertension, blood pressure or insomnia; (iv) rosemary leaves in excess quantity can cause coma, spasm, vomiting and, in some cases, pulmonary oedema.

There have been occasional reports of allergic reactions such as skin irritation when rosemary has been applied externally. In addition, rosemary essential oil may have epileptogenic properties as a handful of case reports over the past century have linked its use with seizures in otherwise healthy children (Burkhard *et al.* 1999). Rosemary may also interfere with iron absorption; hence it should be avoided by persons with iron deficiency anaemia (Samman *et al.*, 2001).

25.5.1 Adulteration
Rosemary oil can be adulterated with white camphor oil, fractions of eucalyptus oil, Spanish sage oil, oil of turpentine and petroleum. The quality of rosemary oil can be ascertained based on its solubility in alcohol and by using an iodine test. Rosemary oil does not detonate with iodine but just dissolves with heating (Diete and Brannt, 1892).

25.6 Conclusion

Rosemary is emerging as an important herb, being a potential source of anticancer molecules, a functional food, a botanical nutraceutical and a functional pesticide. Despite the multifaceted importance of the herb, it has yet to receive adequate research attention. In many places, it is grown either as a minor herb on marginal lands or still grows wild. Varietal improvement, quality profiling including adulteration detection, toxicology and organic cultivation practices are some areas that require immediate attention, in addition to post-harvest technology.

25.7 References

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