Potential Roles of Essential Oils on Controlling Plant Pathogenic Bacteria Xanthomonas Species: A Review

Vivek K. Bajpai1, Sora Kang1, Houjuan Xu1,4, Soon-Gu Lee2, Kwang-Hyun Baek1,* and Sun Chul Kang3,*

1School of Biotechnology, Yeungnam University, Gyeongsan, Gyeongbuk 712-749, Korea
2School of Bioresource, Andong National University, Andong 760-749, Korea
3Department of Biotechnology, Daegu University, Gyeongsan, Gyeongbuk 712-714, Korea
4College of Plant Protection, Shandong Agricultural University, Tai-an 271-018, China

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Diseases caused by plant pathogenic bacteria constitute an emerging threat to global food security. Xanthomonas is a large genus of Gram-negative bacteria that cause disease in several host plants leading to considerable losses in productivity and quality of harvests. Despite the ranges of controlling techniques available, the microbiological safety of economically important crops and crop plants including fruits and vegetables continues to be a major concern to the agriculture industry. On the other hand, many of the currently available antimicrobial agents for agriculture are highly toxic, non-biodegradable and cause extended environmental pollution. Besides, the use of antibiotics has provoked an increased resistance among the bacterial pathogens and their pathovars. Thus, novel efficient and safe remedies for controlling plant bacterial diseases are necessary. There has been an increasing interest worldwide on therapeutic values of natural products such as essential oils, hence the purpose of this review is to provide an overview of the published data on the antibacterial efficacy of essential oils that could be considered suitable for application in agriculture as biocontrol measures against plant pathogenic bacteria of Xanthomonas species. The current knowledge on the use of essential oils to control Xanthomonas bacteria in vitro and in vivo models has been discussed. A brief description on the legal aspects on the use of essential oils against bacterial pathogens has also been presented. Through this review, a mode of antibacterial action of essential oils along with their chemical nature and the area for future research have been thoroughly discussed.

Keywords: antibacterial effect, bacteria disease, essential oils, Xanthomonas species

Plants are constantly exposed and threatened by a variety of pathogenic microorganisms present in their environments. Plant diseases caused by pathogenic bacteria significantly contribute to the overall loss in crop yield worldwide (Montesinos, 2007; Savary et al., 2006). In an effort to combat diseases, plants have devised various mechanisms to fend off microbial invaders. Despite the existence of defense mechanisms, a major difficulty encountered is the lack of effective control against some severe diseases. The genus Xanthomonas in the gamma subdivision of the Proteobacteria consists of plant-associated species, many of which cause serious diseases of crops and vegetables including ornamentals. Individual species comprise multiple pathogenic variants (pathovars, pv.). Collectively, members of the genus cause disease on monocot and dicot species, including fruit and nut trees, solanaceous and brassicaceous plants, and cereals by affecting a variety of plant parts including leaves, stems, and fruits (Hayward, 1993). They cause a variety of symptoms including necrosis, cankers, spots, and blight (Leys et al., 1984).

Bacterial diseases caused by Xanthomonas have devastated various host plants, leading to considerable losses in productivity and quality of the harvests (Cavalcanti et al., 2006; Ji et al., 2008). Pathovars of Xanthomonas are reported to have developed resistance to several antibiotics, such as kanamycin, ampicillin, penicillin and streptomycin (Rodriguez et al., 1997). Using metal derivatives for plant protection against pathovars of Xanthomonas serves as a potential threat to environment. Therefore, these limitations seriously hinder the management of diseases of crops and agricultural products (Dekker, 1987). Besides, control of the disease is difficult, often requiring expensive and complex integrated pest managements, which include the use of contamination-free seeds, sanitization practices and the use

*Corresponding author.

KH Baek
Phone) +82-53-810-3029, FAX) +82-53-810-4769
E-mail) khbaek@ynu.ac.kr

SC Kang
Phone) +82-53-850-6553, FAX) +82-53-850-6559
E-mail) sckang@daegu.ac.kr
of chemicals (Araujo et al., 2003). Antibiotics and synthetic pesticides are forbidden in many countries because of their exerting negative impact such as high and acute toxicity, long degradation periods and accumulation in the food chain. Consequently, there is an obvious need to search for alternative natural antimicrobial agents or biopesticides, which can be nontoxic for disease control and nonpolluting environmentally to control plant diseases for agricultural applications and also have activity against pathogenic *Xanthomonas* bacteria that acquire resistance to commercial compounds (Franco et al., 2006).

Researches focused on plant-derived natural bactericides and their possible applications in agriculture to control plant bacterial diseases are being intensified as these are having enormous potential to inspire and influence modern agrochemical research. Naturally occurring and biologically active plant products such as essential oils could be a source of alternative classes of natural bio-pesticides to serve as templates for new and more effective compounds in controlling plant pathogenic microorganisms. Bio-pesticides have also been suggested as effective substitutes for chemical pesticides (Gan-Mor and Matthews, 2003).

Essential oils, the odorous and volatile products of an aromatic plant’s secondary metabolism, normally formed in special cells or groups of cells, are well-known antimicrobial agents that could be used to control plant pathogenic bacteria of *Xanthomonas* species in agriculture (Bajpai et al., 2010a, b; Nguefack et al., 2005). They have long been served as flavouring agents in food and beverages, and due to their versatile content of antimicrobial compounds, they possess potential as natural agents for plant protection in agriculture industry. Chemical analysis of the essential oils has revealed the presence of several ingredients, most of which possess important antimicrobial properties (Bajpai et al., 2007; Bajpai et al., 2010a, b; Nguefack et al., 2005). Several references on the antimicrobial efficiency of essential oils are available in the literature (Burt and Reinders, 2003; Cox et al., 2000; Delaquis et al., 2002; Gyorgyi et al., 2004; Mejholm and Dalgard, 2002; Nguefack et al., 2005). More particularly, essential oils and their components are known to be active against a wide variety of microorganisms, including Gram-negative (Helander et al., 1998) and Gram-positive bacteria (Kim et al., 1995). Although, a small number of essential oils are commercially available, very few studies of the activity of essential oils against *Xanthomonas* bacteria have been published. Moreover, it has been established that, certain essential oils stand out as better antibacterial agents than the commonly used chemical antibacterial agents against plant pathogenic bacteria of *Xanthomonas* species (Bajpai et al., 2010a, b; Gyorgyi et al., 2004; Nguefack et al., 2005). Applications of several essential oils in agriculture have been found effective in inhibiting the growth of *Xanthomonas* bacteria (Bajpai et al., 2010a, b; Gyorgyi et al., 2004; Nguefack et al., 2005). Hence, to reduce health hazards and economic losses due to plant pathogenic *Xanthomonas* bacteria, the use of essential oils as natural antibacterial compounds seem to be an interesting way to control the presence of plant pathogenic bacteria in agriculture.

The antimicrobial activity of essential oils is assigned to a number of small terpenoids and phenolic compounds (thymol, carvacrol, eugenol), which also in pure forms were demonstrated to have high antibacterial activity (Conner, 1993; Didry et al., 1993; Gyorgyi et al., 2004). A number of essential oil constituents exhibit significant antimicrobial properties when tested separately (Gyorgyi et al., 2004; Kim et al., 1995; Lambert et al., 2001). However, there are evidences that essential oils are more strongly antimicrobial than are accounted for by the additive effect of their major antimicrobial components; minor components appear, therefore, to play a significant role (Paster et al., 1995). There are often large differences in the reported antimicrobial activity of essential oils from the same plant sources. The reasons of this variability can be traced back to the differences in the plant origins for the oils by geographical distributions, the harvesting seasons, the genotypes, the drying procedure and the distilled parts of the plant. All of this variability can influence the chemical composition and the relative concentration of each constituent in the essential oils (Salgueiro et al., 1997).

Recently, there has been a considerable interest in essential oils from common culinary herbs, spices and aromatic plants characterized by a notable antimicrobial activity (Gyorgyi et al., 2004; Nguefack et al., 2005; Tobias et al., 2007). Such oils can be used to inhibit the growth of plant pathogenic bacteria in an agricultural system (Bajpai et al., 2010a, b). This growing interest is emphasized by the fact that diseases caused by plant pathogenic bacteria of *Xanthomonas* species are still a major problem in the world, even in well developed countries (MacManus et al., 2002). In such context, plant essential oils are well known to exhibit a wide range of biological activities as well as they tend to have low mammalian toxicity, less environmental detrimental effects and wide public acceptance (Paranagama et al., 2003). Hence, they form the basis of many applications in food and agriculture industries to control plant pathogenic bacteria of *Xanthomonas* species.

**Pathogen Biology**

The taxonomy of plant pathogenic bacteria is currently in flux based on recent advances on how bacteria are classified. Most plant pathogenic bacteria belong to the following genera: *Pectobacterium*, *Pantoea*, *Agrobacterium*, *Pseudo-