



Major component and potential applications of plant essentials oils as natural food preservatives: a short review research results

Philippe Sessou^{1,2}, Souaïbou Farougou^{1*}, Dominique Sohounhloué²

¹Unity of Research in Biotechnology and Animal Health and Production, Polytechnic School of Abomey-Calavi, University of Abomey-Calavi, 01 P.O.B: 2009 Cotonou, Benin

²Laboratory of Study and Research in Applied Chemistry, Polytechnic School of Abomey-Calavi, 01 P.O.B: 2009 Cotonou, Benin

Received: 22 July 2012

Revised: 21 August 2012

Accepted: 22 August 2012

Key words: Spices, volatiles extracts, main compounds, antimicrobial activity, biopreservation.

Abstract

The present review takes in account studies relative to the potential applications as natural food preservatives and major components of essential oils extracted from some aromatic edible herbs and spices *Allium sativum*, *Cinnamomum zeylanicum*, *Cymbopogon citratus*, *Mentha piperita*, *Pimenta racemosa*, *Ocimum gratissimum*, *Syzygium aromaticum*, *Xylopi aethiopica* and *Zingiber officinale*. Therefore, some informations relative to antibacterial and antifungal efficiency of these essential oils on either foods pathogens responsible for humans foodborne diseases and foods deterioration and its poor quality (bacteria: *Escherichia coli*, *Salmonella*, *Listeria monocytogenes*, *Staphylococcus aureus*; more pathogen yeast *Candida albicans* and moulds: *Aspergillus*, *Fusarium* and *Penicillium*) are presented. Furthermore, this short review doesn't occult its main highest elevation which is the presentation of main components and interesting potential applications as food preservatives of these essentials oils. Their application as natural preservatives of traditional cheese Wagashi product in Benin will be tested.

*Corresponding Author: Souaïbou Farougou ✉ souaibou.farougou@uac.bj, farougou@gmail.com

Introduction

Food safety is a fundamental concern of both consumers and the food industry especially as the number of reported cases of food-associated infections continues to increase. Notified cases of foodborne illness in England and Wales now exceed 100 000 a year, this represents only a fraction of the true incidence due to a substantial degree of underreporting (Smith Palmer *et al.*, 2001). Also, it has been estimated that as many as 30% of people in industrialized countries suffer from a food borne disease each year and in 2000 at least two million people died from diarrhoeal disease worldwide (WHO, 2002). Microbial activity is a primary mode of deterioration of foods and many microorganisms are associated with these affections after contributed for the loss of food quality and safety. Antimicrobial chemicals had been largely used as foods preservatives, but unfortunately the uncontrolled concentrations applied increase the risk of toxic residues in the products (Tatsadjieu *et al.*, 2009; Yèhouenou *et al.*, 2010a). Due to the increasing of the negative effects of these chemical synthetic products on human and animal health, the importance of alternative natural products to control foods pathogenic microorganisms is urgently needed (Bankolé, 1997; Burt, 2004; Bajpai *et al.*, 2011). Essential oils (EOs) as antimicrobial agents are recognized as safe natural substances to their user and for the environment and they have been considered at low risk for resistance development by pathogenic microorganisms (Tatsadjieu *et al.*, 2003; Antunes and Cavaco, 2010). The use of essential oils as biopreservatives becomes a matter of great interest for all especially for the food industry since consumers prefer natural additives instead of synthetic ones. That is why many studies have been performed on this subject in the last few years (Lang and Buchbauer, 2012). In fact, many authors such as Asekun and Adeniyi (2004), Burt (2004), Oussou *et al.* (2004), Sasidharan and Menon (2010), Yèhouenou *et al.* (2010a, 2010b), Styczynska, (2011), Noudogbessi *et al.* (2011), Ogundajo *et al.* (2011), Nguefack *et al.* (2004, 2009, 2012) and others have studied for ones the chemical composition of

essential oils from plants and for others the antimicrobial activities and potential biopreservation applications, insecticidal activity, antimycotic activity and antioxidant activity of these EO. It will be better to regroup these informations according to focus.

This paper aims primarily to summarizing the research results on the main components and food preservatives uses of essential oils extracted from edibles herbs and spices *Allium sativum*, *Cinnamomum zeylanicum*, *Cymbopogon citratus*, *Mentha piperita*, *Pimenta racemosa*, *Ocimum gratissimum*, *Syzygium aromaticum*, *Xylopi aethiopica* and *Zingiber officinale*. Indeed, these spices and herbs are at first sight largely distributed or commercialized in the world, consumed by the populations and used in traditional medicine against pains such as dyspepsia, malaria, diabetes, urinary tract infections and respiratory diseases, cough, fever, diarrhea, abdominal pain, conjunctivitis, mouth sores and dental infections, stomachaches, bronchitis, liver disease and dysentery for *Ocimum gratissimum*, *Mentha piperita*, *Xylopi aethiopica*, *Eugenia caryophyllata*, *Pimenta racemosa*, *Cinnamomum zeylanicum* (Chami *et al.*, 2005; Betoni *et al.*, 2006; Nwinyi *et al.*, 2009; Yehouenou *et al.*, 2010b). *Ocimum* species is used against cancer, cardiovascular disease, HIV1 infections (Tomar *et al.*, 2010; Akujobi *et al.*, 2010); treatment of nervous and gastrointestinal disorders. *Cymbopogon citratus* is used against hypertension (Madingou *et al.*, 2012). Informations relative to the major components of EOs which provide them potential antimicrobic effects and their capacity of food biopreserving studied by many researchers deserve to be gathered as data base in order to promote further researches in the sector of food biopreserving.

Essential oils extraction and chemical analysis

Essential oils are products, generally, of rather complex composition comprising the volatile principles contained in the plants, and more or less modified during the preparation process. They are

essentially obtained by hydrodistillation where the plant material is heated in two to three times its weight of water with indirect steam from outside the still. Chemical analysis of essential oils is generally using GC (quantitative analysis) and GC/MS (qualitative analysis). Identification of the main components is carried out by the comparison of both the GC retention times and MS data against those of the reference standards (with known source) (Lahlou, 2004).

Mechanism of antimicrobial action of essential oils

Antifungal action: Antifungal agents such as essential oils kill the fungal cell via binding primarily to ergosterol, the major sterol found in fungal cellular membrane. This binding destroys the osmotic integrity of the membrane, and this is followed by leakage of intracellular potassium, magnesium, sugars, and metabolites and finally by cellular death (Medoff, 1988; Murray et al., 2003). Lipid characteristics of essential oils act via the same mechanism. It has been suggested that oxidative damage due to essential oil may also contribute to its antifungal activity against *Candida* (Murray et al., 2003).

Antibacterial actions: Considering the large number of different groups of chemical compounds present in EOs, it is most likely that their antibacterial activity is not attributable to one specific mechanism but that there are several targets in the cell. An important characteristic of EOs and their components is their hydrophobicity, which enables them to partition in the lipids of the bacterial cell membrane and mitochondria, disturbing the structures and rendering them more permeable. Leakage of ions and other cell contents can then occur and causes the death of bacterial cell (Burt, 2004; Yehouenou et al., 2010b). Generally, the EOs possessing the strongest antibacterial properties against food borne pathogens contain a high percentage of phenolic compounds such as carvacrol, eugenol and thymol (Burt, 2004).

Major components of essential oils

The major component of clove oil is eugenol, a phenolic compound but the proportions vary widely. For example, Raina *et al.* (2001) found in essential oil of *Eugenia caryophyllata* a high percentage of eugenol (94.41%) with 2% β -caryophyllene whereas Prashar et al. (2006) found the content of eugenol to be 78%, with 13% β -caryophyllene. Pawar and Thaker (2006) found that the content of eugenol was 47.64%, with the concentration of benzyl alcohol at 34.10%. Chaeib *et al.* (2007) obtained a high concentration of eugenol (88.58%), eugenyl acetate (5.62%) in essential oil of *Syzygium aromaticum* which contained 79.2% and 85% eugenol (Ranasinghe *et al.*, 2002; Pinto *et al.*, 2009). Essential oil of cinnamon contains high concentration (62.79-65%) of trans-cinnamaldehyde with 8.31% limonene and 7.09% eugenol (Ranasinghe *et al.*, 2002; Simic *et al.*, 2004; Burt, 2004).

Cinnamon essential oil reported by Kamaliroosta et al. (2012) for Tehran specimen contained cinnamic aldehyde (62.09%) as major components whereas data provided by Schmidt *et al.* (2006) on *Cinnamomum zeylanicum* from Sri Lanka where eugenol 74.9%, followed by caryophyllene 4.1%, benzyl benzoate are major components. (E)-cinnamaldehyde (68.95%) was the major component identified from *C. zeylanicum* bark essential oil of Turkey by Unlu et al. (2010) while benzyl benzoate (74.8%) was the main component of cinnamon leaf essential oil from Nigeria (Tira-Picos *et al.*, 2009).

Sahouo *et al.* (2003) found that the predominant components of essential oil of *Ocimum gratissimum* in Ivory Coast were thymol (70.8%). Oussou et al. (2004) identified the chemotype thymol-p-cymene as essential oil of *Ocimum gratissimum* in Ivory Coast. Aquinos Lemos *et al.* (2005) isolated from similar oil in Brazil eugenol (57.82%) and (Z)- α -bisabolene (17.7%) as major components. Madeira *et al.* (2005) underlined in their studies that essential oil of *Ocimum gratissimum* was in majority composed of 1-8 cineole (39.3%) and eugenol (35.5%). Matasyoh (2007) found eugenol (68.81%)

and methyl-eugenol (13.21%) as main components in Kenya. Oussou et al. (2010) identified in this oil thymol (34.6%). Saliu et al. (2011) reported that main components of *Ocimum gratissimum* EOs in Nigeria were eugenol (61.9%) and cis-ocimene (8.2%).

The main constituents identified in *Allium sativum* essential oil were diallyltrisulfide, diallylsulfide, allylmethyltrisulfide (Styczynska, 2011). In the ginger oil, 26 constituents were identified, with 1,8-cineole (10.9%), neral (8.1%), geraniol (14.5%), geranial (9.5%) as major components (Gupta et al., 2011). Major components were zingiberene (23.9%), β -bisabolene (11.4%) and β -sesquiphellandrene (10.9%) according to sacchetti et al. (2005). The chemical compositions of fresh ginger oil and dry ginger oil revealed that zingiberene (28.6-30.3%) was the major components, followed respectively by geranial (8.5%) and arcurcumene (Sasidharan and Menon, 2010).

Essential oil of *Mentha piperita* is in majority composed of menthol (28.3-60%) menthone (15-32%) (Bassolé et al., 2010; Styczynska, 2011). It's chemotype in Benin is menthol-neomenthol (Dahouenon-Ahoussi et al., 2010).

The main components of essential oil of *Pimenta racemosa* investigated by Noudogbessi et al. (2008) in Benin were eugenol (61.9 %-55.7%); chavicol (15.3%-8.0%) et le myrcène (22.3%-12.5%) similar to those identified in the same plant by Jirovetz et al. (2007) and Höferl et al. (2009). In contrary, Ogundajo et al (2011) identified germacrene-D and β -elemene in bay essential oil.

Cymbopogon citratus essential oil is composed in majority of citral (neral + geranial) (Paranagama et al., 2003; Burt, 2004; Nguefack et al., 2004, 2009, 2012). The composition of the oil of *Xylopia aethiopica* is very diverse. The main components of the essential oil of *Xylopia aethiopica* fruit from Benin are: sabinene (9.8-41.8%), terpinen-4-ol (9.2-30.8%) (Noudogbessi et al., 2011). Similar oil from

Ghana showed thirty nine compounds among which germacrene D was the highest (25.1%) in addition to β -pinene (21.6%) (Karioti et al., 2004). Essential oil of *Xylopia aethiopica* fruit from Nigeria studied by Olonisakin et al. (2007) revealed that predominant components are β -pinene (13.78%) and β -phellandrene (12.36%). Noudjou et al. (2007) identified sixty three components in essential oil of *Xylopia aethiopica* from Cameroon. The main constituents were β -phellandrene+1,8-cineole (31.0%). Keita et al. (2003) detected thirty constituents in essential oil of *Xylopia aethiopica* fruit from Mali. The main constituents identified in the EOs were β -pinene (19.1%), γ -terpinene (14.7%). Tatsadjieu et al. (2003) identified in the fruits of *X. aethiopica* the presence of β -pinene (18.3%), terpinen-4-ol (8.9%), sabinene (7.2%), α -phellandrene (7.1%).

Antimicrobial activity of essential oils

The antibacterial activity of different *Eugenia caryophyllata* extracts has been demonstrated against pathogenic bacteria including *Campylobacter jejuni*, *Salmonella enteritidis*, *Escherichia coli* and *Staphylococcus aureus*, *Pseudomonas aeruginosa*, *Klebsiella pneumoniae*, *Listeria monocytogenes*, *Bacillus cereus* (Friedman et al., 2002; Burt and Reinders, 2003; Burt, 2004; Unlu et al., 2010). A recent study reported that the growth rates of *Listeria monocytogenes* strains observed at 15 °C and at 5 °C were significantly reduced by treatment with 1% and 2% clove oil (Mytle et al., 2006) and furthermore, Ogunwande et al. (2005) found that the essential oil of the fruit exhibited strong antibacterial activity against *Staphylococcus aureus*, while the leaf oil strongly inhibited the growth of *Bacillus cereus*. The fungicidal activity of *Eugenia caryophyllata* essential oil has also been reported on several food-borne fungal species (Lopez et al., 2005) and it was observed in a recent study that the essential oil of clove even inhibited the growth of *Aspergillus niger* (Pawar and Thaker, 2006). Studies of Pinto et al. (2009) showed that essential oil of *Syzygium aromaticum* is effective against some species of

Aspergilli (*Aspergillus flavus*, *A. fumigatus*), *Microsporium canis*.
Candida and dermatophytes species such as

Table 1. Major components, susceptible microorganisms and food preserved of selective essential oils.

Common name of - plant	Latin name of plant source	Major components	Approximate % composition	EO active against	Potential biopreservative of	References
Garlic or dehydrated garlic	<i>Allium sativum</i>	Diallyltrisulfide Diallylsulfide Allylmethyltrisulfide	49.2% 37.0% 5.6%	<i>Aspergillus fumigatus</i> , <i>A. niger</i> , <i>S. aureus</i> , <i>Salmonella enteritidis</i> , <i>Penicillium cyclopium</i> , <i>Fusarium oxysporum</i>	-	Benkeblia (2004), Bansod and Rai (2008), Styczynska (2011).
Cinnamon	<i>Cinnamomum zeylanicum</i>	Trans-cinnamaldehyde Limonene Eugenol	62.79-65% 8.31% 7.09-76.9	<i>Aspergillus niger</i> , <i>A. ochraceus</i> , <i>A. versicolor</i> , <i>A. flavus</i> , <i>A. terreus</i> , <i>Penicillium ochrochloron</i> , <i>Fusarium proliferatum</i>	Banana, vegetable, dairy products	Ranasinghe et al. (2002); Burt (2004), Simic et al. (2004), Tira-Picos et al. (2009), Xing et al. (2010), Kamaliroosta et al. (2012), Schmidt et al. (2006)
Lemongrass	<i>Cymbopogon citratus</i>	E-Citral/Geraniol Z-Citral/Neral	37.7 21.2-80	<i>Penicillium expansum</i> , <i>P. verrucosum</i> , <i>A. ochraceus</i> , <i>A. flavus</i> , <i>L. monocytogenes</i> , <i>Salmonella</i>	fruits and vegetables, rice	Burt (2004); Nguefack et al. (2009), Nguefack et al. (2004), Nguefack et al. (2012).
Peppermint tea	<i>Mentha piperita</i>	menthol menthone neomenthol	28.0-46.7%, 25.2-32% 8.26%,	<i>Salmonella enteritidis</i> , <i>E. coli</i> , <i>Streptococcus faecalis</i> ; <i>L. monocytogenes</i> , <i>Staphylococcus epidermidis</i> , <i>A. fumigatus</i> ,	Africa drink, dairy products; fish dishes; vegetables	Burt (2004), Bassolé et al. (2010), Dahouenon-Ahoussi et al. (2010), Styczynska (2010).
Clove basil or African basil/wild basil	<i>Ocimum gratissimum</i>	Thymol p-Cymene γ -terpinène eugenol methyl eugenol cis-ocimene	19.7- 70.8% 23.5-25% 37.4% 53.89-68.8% 13.21% 23.97%	<i>Penicillium expansum</i> , <i>P. verrucosum</i> , <i>Aspergillus ochraceus</i> , <i>S. aureus</i> , <i>E. coli</i> , <i>P.</i>	fruits and vegetables	Nguefack et al. (2004), Matasyoh et al. (2007), Nguefack et al. (2009), Oussou et al. (2010), Saliu et al. (2011),

				<i>aeruginosae</i> , <i>Salmonella</i> <i>typhi</i> , <i>C.</i> <i>albicans</i> , <i>Listeria</i> <i>monocytogenes</i> ,		Nguefack et al. (2012)
Bay	<i>Pimenta</i> <i>racemosa</i>	eugenol chavicol myrcene Germacrene D	61,9 %-55,7% 15,3%-8,0% 22,3%-12,5% 10.6%	<i>E. coli</i> , <i>Pseudomonas</i> <i>aeruginosa</i> , <i>C.</i> <i>albicans</i> , <i>Aspergillus</i> <i>niger</i> , <i>P.</i> <i>verrucosum</i>	Potatoes	Jirovetz et al. (2007) and Höferl et al. (2009), Ogundajo et al. (2011),
Clove (bud)	<i>Syzygium</i> <i>aromaticum</i>	Eugenol Eugenyl acetate	47.64 -94.41 % 8 - 15 %	<i>Listeria</i> <i>monocytogenes</i> , <i>B. cereus</i> , <i>Campylobacter</i> <i>jejuni</i> , <i>Salmonella</i> <i>enteritidis</i> , <i>Aspergillus</i> <i>niger</i> , <i>A. flavus</i> , <i>A. fumigatus</i> , <i>C.</i> <i>albicans</i> , <i>Fusarium.</i> <i>proliferatum</i> , <i>Pseudomonas</i> <i>aeruginosa</i> ,	chicken frankfurters, banana, minced mutton, dairy products	Ranasinghe et al. (2002), Burt et al. (2004), Mytle et al. (2006), Pinto et al. (2009), Unlu et al. (2010).
African pepper, Ethiopian Pepper,	<i>Xylopi</i> <i>aethiopica</i> *	a-sabinene, terpinen-4-ol germacrene D phellandrene	9.8-41,8% 9.2- 30,8% 25% 12.36%	<i>Listeria</i> <i>monocytogenes</i> , <i>Salmonella</i> <i>enteritidis</i> , <i>S.</i> <i>aureus</i> <i>Bacillus subtilis</i> , <i>Pseudomonas E.</i> <i>coli</i> , <i>Aspergillus</i> <i>flavus</i> ,	<i>Sitophilus</i> <i>zeamais</i>	. Noudjou et al. (2007), Yehouenou et al. (2010a) ; Noudogbessi et al. (2011)
Ginger	<i>Zingiber</i> <i>officinale</i>	1,8-cineole neral geraniol geranial zingiberene	10.9% 8.1% 14.5% 9.5% 13.97-23.9%	<i>Bacillus subtilis</i> , <i>Pseudomonas</i> <i>aeruginosa</i> , <i>Aspergillus</i> <i>niger</i> , <i>A.</i> <i>fumigatus</i> , <i>Pencillium</i> spp. <i>Saccharomyces</i> <i>cerevisiae</i> , <i>Fusarium</i> <i>moniliforme</i>	Beverage, drink, types medicinal substances	soft Sacchetti et al. (2005), Singh et al. (2008), Sasidharan and Menon (2010). Gupta et al. (2011)

Many studies have assessed the antibacterial activity of peppermint (Furuhata *et al.*, 2000; Inouye *et al.*, 2001; Iscan *et al.*, 2002; Azuma *et al.*, 2003) and antifungal (Blaszczyk *et al.*, 2000; Edris and Farrag, 2003; Mimica-Dukic *et al.*, 2003; McKay and Blumberg, 2006). For example, mint (*Mentha piperita*) EO was more effective against *Staphylococcus aureus* and *Salmonella enteritidis* (Tassou *et al.*, 2000). Inouye *et al.* (2001) reported the major respiratory tract pathogens, including *Haemophilus influenza*, *Streptococcus pneumonia*, *S. pyogens*, *Staphylococcus aureus* were susceptible to peppermint oil and its components menthol and menthone. Another respiratory tract pathogens, *Legionella pneumophila*, was also found to be susceptible to peppermint (Furuhata *et al.*, 2000). In other study mint oil was effective against *Salmonella enteritidis* compared to *Listeria monocytogenes* (Burt, 2004). Iscan *et al.* (2002) tested peppermint oil and its components menthol and menthone against 21 human and plant pathogens and found moderate inhibitory activity against the human pathogens. The oil showed stronger inhibition against *Pseudomonas* and *Xanthomonas* strains of plant pathogens. Mimica-Dukic *et al.* (2003) reported that *Mentha piperita* essential oil was more effective against a multiresistant strain of *Shigella sonnei* and *Micrococcus flavus* than oils from other *Mentha* species. The fungicidal activity of peppermint oil was demonstrated in 11 of 12 fungi tested by Pattnaik *et al.* (1996) including *Candida albicans*, *Trichophyton mentagrophytes*, *Aspergillus fumigatus* and *Cryptococcus neoformans* (McKay and Blumberg, 2006).

According to Simic *et al.* (2004), essential oil of cinnamon is more effective against filamentous fungi such as *Aspergillus niger*, *A. ochraceus*, *A. flavus*, *A. terreus*, *Penicillium versicolor*, *Fusarium sporotrichoides*. It was reported that Cinnamomum zeylanicum essential oil is active against the postharvest pathogens such as *Rhizopus nigricans*, *Aspergillus flavus* and *Penicillium expansum*, the causal agents of jujube or orange fruit (Xing *et al.*, 2010).

Aurore *et al.* (1998) and Ogundajo *et al.* (2011) reported that essential oil of *Pimenta racemosa* was effective against *Staphylococcus aureus*, *Enterococcus faecium*, *E. coli*, *Pseudomonas aeruginosa* et *Mycobacterium smegmatis*) and fungi (*Candida albicans*, *Aspergillus niger*, *Absidia corymbifera* and *Penicillium verrocsum*).

Asekun and Adeniyi (2004) reported that *Xylopia aethiopica* essential oil from Nigeria inhibited growth of four groups of fungi (*Stellocapella madis*, *Candida albicans*, *Aspergillus flavus*, *A. ochraceus* and *Fusarium oxysporum*). Similar oil from Cameroon inhibited the growth of eight strains of micro-organisms, *E. coli*, *S. aureus*, *Klebsiella pneumoniae*, *Enterococcus faecalis*, *Corynebacterium glutamicum*, *Bacillus cereus*, *B. subtilis* and *Aspergillus flavus* (Tatsadjieu *et al.*, 2003). According to Nwaiwu and Imo (1999), *Xylopia aethiopica* essential oil from Nigeria showed a fungi-toxic activity, at varying degrees, against the mycelial growth of three food-borne fungi (*Aspergillus fumigatus*, *A. nidulans* and *Mucor hiemalis*). Lemongrass essential oil had both antimicrobial activity against many strains such as *Aspergillus flavus*, *Penicillium expansum*, *A. ochraceus*, *P. verrucosum*, *Listeria monocytogenes*, *S. aureus*, *E. coli*, *S. typhimurium* respectively (Burt, 2004; Nguefack *et al.*, 2004, 2009, 2012). Essential oil of *Zingiber officinale* is recognized to have antimicrobial activity against *Bacillus subtilis*, *Pseudomonas aeruginosa*, *Candida albicans*, *Aspergillus niger*, *Penicillium* spp. and *Saccharomyces cerevisiae* (Sasidharan and Menon, 2010).

Antimicrobial activity of Essential oils in food systems.

Spices and herbs can be used as an alternative preservative and pathogen-control method in food materials. Indeed, according to studies of Burt (2004), Dahouenon-Ahoussi *et al.* (2010), essential oil of *Mentha piperita* had been recognized as biopreservatives for Africa drink, low-fat yoghurt (dairy products), fish dishes and vegetables. The

same report was for essential oils of clove and cinnamon on vegetable and dairy products. The main active essential oil was clove oil (Burt, 2004). According to Ranasinghe *et al.* (2002), cinnamon and clove essential oils could be used as antifungal agents to manage post fungal diseases of banana. *Xylopi aethiopica* fruit had a great potential to control *Sitophilus zeamais*, and therefore it could be used in the protection of maize grain from storage pest. Pesticidal properties of *Xylopi aethiopica* seem to be related to β -pinene and terpinene-4-ol concentrations (Kouninki *et al.*, 2007). Lemongrass essential oil had potential to preserve food such as rice, vegetable (Burt, 2004).

With reference to the Table 1, all the essential oils selected possess antimicrobial efficiency against both bacteria and fungi at different degree. Certain oils such as *Syzygium aromaticum*, *Cinnamomum zeylanicum*, *Ocimum gratissimum* have large spectrum activity due to their composition in phenolic compound. They constitute the more potential biopreservatives of food among these nine plants. Essential oils of *Syzygium aromaticum* seems to be the most effective essential oil which is more active against the majority of bacteria and moulds which affect the quality of foods. Its activity is due to high concentration in eugenol, a phenolic component recognize to be active against more pathogens.

Application of EOs of plant-origin antimicrobials such as leaves of *Allium sativum*, *Ocimum gratissimum*, *Zingiber officinale*, *Syzygium aromaticum*, *Pimenta racemosa*, *Cinnamomum zeylanicum*, *Xylopi aethiopica*, *Cymbopogon citratus* and *Mentha piperita* could be a potential alternative to synthetic preservatives for reasons that they have large spectrum activity against Gram negative bacteria, Gram positive bacteria and fungi which are known to be the main factor of food deterioration. Further studies are necessary to prove their potentiality in foods preserving including traditional cheese Wagashi manufactured in Benin.

Acknowledgements

The authors are grateful to University Council of Development (CUD) for financial assistance.

References

Akujobi CO, Ogbulie JN, Njoku HO. 2010. The extract of *Ocimum gratissimum* on the dehydrogenase activities to clinical isolates of *Escherichia coli* and *Staphylococcus aureus*. *Journal of Agricultural Technology* 6(1), 57-65.

Antunes MDC, Cavaco AM. 2010. The use of essential oils for postharvest decay control. A review. *Flavour and Fragrance Journal* 25(5), 351-366.

Aquino Lemos J, Passos XS, Fatima Lisboa FO, de Paula JR, Ferri PH, de Souza LKH, de Aquino Lemos L, de Rosario Rodrigues Silva M. 2005. Antifungal activity from *Ocimum gratissimum* L. towards *Cryptococcus neoformans*. *Memórias do Instituto Oswaldo Cruz* 100(1), 55-58.

Asekun OT, Adeniyi BA. 2004. Antimicrobial and cytotoxic activities of the fruit essential oil of *Xylopi aethiopica* from Nigeria. *Fitoterapia* 75, 368-370.

Aurore GS, Abaul J, Bourgeois P. 1998. Antibacterial and antifungal activities of the essential oils of *Pimenta racemosa* var. *racemosa* P. Miller (J.W. Morre) (Myrtaceae). *Journal of Essential Oil Research* 10, 161-164.

Azuma K, Ito H, Ippoushi K, Higashio H. 2003. In vitro antibacterial activity of extracts from four Labiatae herbs against *Helicobacter pylori* and *Streptococcus mutans*. *Bulletin of National Institute of Vegetal Tea Science* 2, 83-91.

Bajpai VK, Baek KH, Kang SC. 2011. Control of *Salmonella* in foods by using essential oils: A review. *Food Research International* article in press.

Bankolé SA. 1997. Effect of essential oil from Nigerian medicinal plants (*Azadirachta indica* and

Mrinda lucida) on growth and aflatoxin B₁ production in maize grain by toxigenic *Aspergillus flavus*. Letters in Applied Microbiology **24**, 190-192.

Bansod S, Mahendra R. 2008. Antifungal activity of essential oils from Indian medicinal plants against human pathogenic *Aspergillus fumigatus* and *A. niger*. World Journal of Medicinal Science **3**(2), 81-88.

Bassolé IHN, Lamien-Meda A, Bayala B, Tiogo S, Franz C, Novak J, Nebié RC, Dicko MH. 2010. Composition and Antimicrobial Activities of *Lippia multiflora* Moldenke, *Mentha x piperita* L. and *Ocimum basilicum* L. Essential Oils and Their Major Monoterpene Alcohols Alone and in Combination. Molecules **15**, 7825-7839.

Benkeblia N. 2004. Antimicrobial activity of essential oil extracts of various onions (*Allium cepa*) and garlic (*Allium sativum*). LWT Food Science and Technology **37**, 263-268.

Betoni JEC, Mantovani RP, Barbosa LN, Di Stasi LC, Junior AF. 2006. Synergism between plant extract and antimicrobial drugs used on *Staphylococcus aureus* diseases. Memórias do Instituto Oswaldo Cruz **101**(4), 387-390.

Burt S. 2004. Essential oils: Their antibacterial properties and potential applications in foods-a review. International Journal of Food Microbiology **94**, 223-253.

Burt SA, Reinders RD. 2003. Antibacterial activity of selected plant essential oils against *Escherichia coli* O157:H7. Letters in Applied Microbiology **36**, 162-167.

Chaieb K, Hajlaoui H, Zmantar T, Nakbi KAB, Rouabhia M, Mahdouani K, Bakhrouf A. 2007. The chemical composition and biological activity of essential oil, *Eugenia caryophyllata* (*Syzygium aromaticum* L. Myrtaceae): a short review. Phytotherapy Research **21**(6), 501-506.

Chami F, Chami N, Bennis S, Bouchikhi T, Remmal A. 2005. Oregano and clove essential oils induce surface alteration of *Saccharomyces cerevisiae*. Phytotherapy Research **19**, 405-408.

Dahouénon-Ahoussi E, Sessou P, Wotto DV, Yèhouénou B, Kinsoudé, E, Kpatinvoh B, Soumanou M, Sohounhloué D. 2010. Mise au point d'une technologie de production d'une boisson locale Africa drink a base d'huiles essentielles de menthes verte et poivrée. Bulletin d'Information de la Société Ouest Africaine de Chimie **7**, 39-53.

Edris AE, Farrag ES. 2003. Antifungal activity of peppermint and sweet basil essential oils and their major aroma constituents on some plant pathogenic fungi from the vapor phase. Nahrung **47**, 117-121.

Friedman M, Henika PR, Mandrell RE. 2002. Bactericidal activities of plant essential oils and some of their isolated constituents against *Campylobacter jejuni*, *Escherichia coli*, *Listeria monocytogenes*, and *Salmonella enterica*. Journal of Food Protection **65**, 1545-1560.

Furuhata K, Dogasaki C, Hara M, Fukuyama M. 2000. Antibacterial activities of several herbs on *Legionella pneumophila*. Journal of Azabu University **1/2**, 15-20.

Gupta S, Pandotra P, Ram G, Anand R, Gupta AP, Husain K, Bedi YS, Mallavarapu GR. 2011. Composition of a monoterpenoid-rich essential oil from the rhizome of *Zingiber officinale* from north western Himalayas. Natural Product Communications **6**(1), 93-96.

Höferl M, Buchbauer G, Jirovetz L, Schmidt E, Denkova ASZ, Slavchev A, Geissler M. 2009. Correlation of Antimicrobial Activities of Various Essential Oils and Their Main Aromatic Volatile Constituents. Journal of Essential Oil Research **21**(5), 459-463.

Inouye S, Yamaguchi H, Takizawa T. 2001. Screening of the antibacterial effects of a variety of essential oils on respiratory tract pathogens, using a modified dilution assay method. *Journal of Infection and Chemotherapy* **7**, 251-254.

Iscan G, Kirimer N, Kurkcuglu M, Husnu Can Baser K, Demirci F. 2002. Antimicrobial screening of *Mentha piperita* essential oils. *Journal of Agriculture and Food Chemistry* **50**, 3943-3946.

Jirovetz L, Buchbauer G, Stoilova I, Krastanov A, Stoyanova A, Schmidt E. 2007. Spice plants: Chemical composition and antioxidant properties of *Pimenta Lindl.* essential oils, part 2: *Pimenta racemosa* (Mill.) J.W. Moore leaf oil from Jamaica. *Ernährung/Nutrition*. **31/NR. 7/8**, 293-300.

Kamaliroosta L, Gharachorloo M, Kamaliroosta Z, Alimohammad Zadeh KH. 2012. Extraction of cinnamon essential oil and identification of its chemical compounds *Journal of Medicinal Plants Research* **6(4)**, 609-614.

Karioti A, Hadjipavoulou-Litinna D, Merlin LK, Theophilus CF, Skaltsa H. 2004. Composition and Antioxidant Activity of Essential oils of *Xylopia aethiopica* (Dun) A. Rich. (Annonaceae) Leaves, Stems, Bark, Root Bark, Fresh and dried Fruits Growing in Ghana. *Agricultural and Food Chemistry* **52**, 8094-8098.

Keita B, Sidibe L, Figueredo G, Chalchat J. 2003. Chemical Composition of the Essential oil of *Xylopia aethiopica* (Dunal) A. Rich. from Mali. *Journal of Essential Oil Research* **15**, 267-269.

Kouninki H, Haubruge E, Noudjou FE, Lognay G, Malaisse F, Ngassoum MB, Goudoum A, Mapongmetsem PM, Ngamo LS, Hance T. 2007. Toxicity of some terpenoids of essential oils of *Xylopia aethiopica* from Cameroon against *Sitophilus zeamais* Motsch. *Journal of applied Entomology* **131**, 269-274.

Lahlou M. 2004. Methods to study the phytochemistry and bioactivity of essential oils. *Phytotherapy Research* **18**, 435-448.

Lang G, Buchbauer G. 2012. A review on recent research results (2008–2010) on essential oils as antimicrobials and antifungals. A review. *Flavour and Fragrance Journal* **27(1)**, 13-39.

Lopez P, Sanchez C, Batlle R, Nerin C. 2005. Solid- and vapor-phase antimicrobial activities of six essential oils: susceptibility of selected foodborne bacterial and fungal strains. *Journal of Agricultural and Food Chemistry* **53**, 6939-6946.

Madeira SVF, Rabelo M, Soares PMG. 2005. Temporal variation of chemical composition and relaxant action of the essential oil of *Ocimum gratissimum* L. (Labiatae) on guinea-pig ileum. *Phytomedicine* **12**, 506-509.

Madingou KNO, Souza A, Lamidi M, Mengome LE, Eyele MMC, Bayissi B, Mavoungou J, Traore AS. 2012. Study of medicinal plants used in the management of cardiovascular diseases at Libreville (Gabon): an ethnopharmacological approach. *International Journal of Pharmaceutical Science and Research* **3(1)**, 111-119.

Matasyoh GL, Matasyoh JC, Wachira FN, Kinyua MG, Thairu Muigai WA, Mukiyama TK. 2007. Chemical composition and antimicrobial activity of the essential oil of *Ocimum gratissimum* L. growing in Eastern Kenya. *African Journal of Biotechnology* **6(6)**, 760-765.

McKay DL, Blumberg JB. 2006. A review of the bioactivity and potential health benefits of peppermint tea (*Mentha piperita* L.). *Phytotherapy Research* **20(8)**, 619-33.

Medoff G. 1988. The mechanism of action of amphotericin B, p.161-164. In H. Van den Bossche

(ed.), International Symposium on Aspergillus and Aspergillosis. Plenum Press New York, N.Y.

Mimica-Dukic N, Bozin B, Sokovic M, Mihajlovic B, Matavulj M. 2003. Antimicrobial and antioxidant activities of three *Mentha* species essential oils. *Planta Medica* **69**(5), 413-419.

Murray R, Patrick Baron JE, Jorgensen James H, Pfaller Yolken RH. 2003. Manual of Clinical Microbiology (8è Ed.), volume 2, p. 1859-1879.

Mytle N, Anderson GL, Doyle MP, Smith MA. 2006. Antimicrobial activity of clove (*Syzygium aromaticum*) oil in inhibiting *Listeria monocytogenes* on chicken frankfurters. *Food Control* **17**, 102-107.

Nguefack J, Budde BB, Jakobsen M. 2004. Five essential oils from aromatic plants of Cameroon: their antibacterial activity and ability to permeabilize the cytoplasmic membrane of *Listeria innocua* examined by flow cytometry. *Letters in Applied Microbiology* **39**, 395-400.

Nguefack J, Lekagne Dongmo JB, Dakole CD, Leth V, Vismer HF, Torp J, Guemdjom EFN, Mbeffo M, Tamgue O, Fotio D, Amvam Zollo PH, Nkengfack AE. 2009. Food preservative potential of essential oils and fractions from *Cymbopogon citratus*, *Ocimum gratissimum* and *Thymus vulgaris* against mycotoxigenic fungi. *International Journal of Food Microbiology* **131**, 151-156.

Nguefack J, Tamgue O, Lekagne JB, Dongmo CD, Dakole V, Leth HF, Vismer PH, Zollo A, Nkengfack AE. 2012. Synergistic action between fractions of essential oils from *Cymbopogon citratus*, *Ocimum gratissimum* and *Thymus vulgaris* against *Penicillium expansum*. *Food Control* **23**, 377-383.

Noudjou F, Kouninki H, Hance T, Haubruge E, Leonard ST, Pierre MM, Ngassoum M, Malaisse F, Marlier M, Lognay G 2007.

Composition of *Xylopia aethiopica* (Dun) A. Rich. Essential oils from Cameroon and Identification of a Minor Diterpen: ent-13-epimanoyl oxide. *Biotechnology Agronomy Society Environment* **11**, 193-199.

Noudoghessi JP, Kossou D, Sohounhloué D. 2008. Chemical compositions and physico-chemical properties of essential oils of *Pimenta racemosa* (Miller) and *Chromolaena odorata* (L. Robinson) collected in Benin. *Journal de la Société Oust Africaine de Chimie* **26**, 11-19

Noudoghessi JP, Natta AK, Avlessi F, Sohounhloué DCK, Figueredo G, Chalchat JC. 2011. Chemical Composition of the Essential Oils Extracted from Two Annonaceae Required in Beninese Pharmacopeia. *Australian Journal of Basic and Applied Science* **5**(2), 34-40.

Nwaiwu MY, Imo EO. 1999. Control of food-borne fungi by essential oils from local spices in Nigeria. *Acta Phytopathologica et Entomologica Hungarica* **34**, 91-97.

Nwinyi OC, Chinedu NS, Ajani OO, Ikpo CO, Ogunniran KO. 2009. Antibacterial effects of extracts of *Ocimum gratissimum* and piper guineense on *Escherichia coli* and *Staphylococcus aureus*. *African Journal of Food Science* **3**(1), 22-25.

Ogundajo LA, Owolabi SM, Oladosu AI, Ogunwande AI, Flamini G and Yusuff OK. 2011. Volatiles constituents and Potatoes Tuber Sprout Supressant Activity of *Pimenta racemosa* (Mill) J.W. Moore. *African Journal of Basic and Applied Science* **3**(3), 92-97.

Ogunwande IA, Olawore NO, Ekundayo O, Walker TM, Schmidt JM, Setzer WN. 2005. Studies on the essential oils composition, antibacterial and cytotoxicity of *Eugenia uniflora* L. *International Journal of Aromatherapy* **15**, 147-152.

Olonisakin AM, Oladimeji O, Lajide L. 2007. Composition and Antibacterial Activity of Steam Distilled Oils of *Xylopia aethiopica* and *Syzygium aromaticum*. *Journal of Engineering and Applied Science* **2**, 236-240.

Oussou KR, Kanko C, Guessend N, Yolou S, Koukoua G, Dosso M, N'guessan YT, Figueredo G, Chalchat JC. 2004. Activités antibactériennes des huiles essentielles de trois plantes de Côte d'Ivoire. *Comptes Rendus de Chimie* **7**, 1081-1086.

Oussou KR, Yolou SF, Tue Bi B, Kanko C, Boti JB, Ahibo C, Casanova J. 2010. Etude chimique bio-guidée de l'huile essentielle de *Ocimum gratissimum* (Lamiaceae). *European Journal of Scientific Research* **40(1)**, 50-59.

Paranagama PA, Abeysekera KHT, Abeywickrama K and Nugaliyadde L. 2003. Fungicidal and anti-aflatoxigenic effects of the essential oil of *Cymbopogon citratus* (DC.) Stapf. (lemongrass) against *Aspergillus flavus* Link. isolated from stored rice. *Letters in Applied Microbiology* **37**, 86-90.

Pawar VC, Thaker VS. 2006. *In vitro* efficacy of 75 essential oils against *Aspergillus niger*. *Mycoses* **49**, 316-323.

Pinto E, Silva LV, Cavaleiro C, Salueiro L. 2009. Antifungal activity of the clove essential oil from *Syzygium aromaticum* on *Candida*, *Aspergillus* and dermatophyte species. *Journal of Medical Microbiology* **58(11)**, 1454-1462.

Prashar A, Locke IC, Evans CS. 2006. Cytotoxicity of clove (*Syzygium aromaticum*) oil and its major components to human skin cells. *Cell Proliferation* **39**, 241-248.

Raina VK, Srivastava SK, Aggarwal KK, Symasundar KV, Kumar S. 2001. Essential oil composition of *Syzygium aromaticum* leaf from

Little Andaman, India. *Flavour and Fragrance Journal* **16**, 334-336.

Ranasinghe L, Jayawardena B, Abeywickrama K. 2002. Fungicidal activity of essential oils of *Cinnamomum zeylanicum* (L.) and *Syzygium aromaticum* (L.) Merr et L.M.Perry against crown rot and anthracnose pathogens isolated from banana. *Letters in Applied Microbiology* **35**, 208-211.

Sacchetti G, Maietti S, Muzzoli M, Scaglianti M, Manfredini S, Radice M, Bruni R. 2005. Comparative evaluation of 11 essential oils of different origin as functional antioxidants, antiradicals and antimicrobials in foods. *Food Chemistry* **91**, 621-632.

Sahouo BG, Tonzibo ZF, Boti B, Chopard C, Mahy JP, N'guessan YT. 2003. Anti-inflammatory and analgesic activities: chemical constituents of essential oils of *Ocimum gratissimum*, *Eucalyptus citriodora* and *Cymbopogon giganteus* inhibited lipoxygenase L-1 and cyclooxygenase of PGHS. *Bulletin of the Chemical Society of Ethiopia* **17(2)**, 191-197.

Saliu BK, Usman LA, Sani A, Muhammad NO, Akolade JO. 2011. Chemical composition and antibacterial (oral isolates) activity of leaf essential oil of *Ocimum gratissimum* L. grown in north central Nigeria. *International Journal of Current Research* **33**, 22-28.

Sasidharan I, Menon N. 2010. Comparative chemical composition and antimicrobial activity fresh & dry ginger oils (*Zingiber officinale* roscoe). *International Journal of Current Pharmacy Research* **2**, 40-43.

Schmidt E, Jirovetz L, Buchbauer G, Eller A, Stoilova I, Krastanov A, Stoyanova A, Geissler M. 2006. Composition and Antioxidant Activities of the Essential Oil of Cinnamon (*Cinnamomum zeylanicum* Blume) Leaves from Sri

Lanka. Journal of Essential Oil of Bearing Plants **9(2)**, 170-182.

Simic A, Sokovic DM, Ristic M, Grujic-Jovanovic S, Vukojevic M. 2004. The chemical composition of some Lauraceae essential oils and their antifungal activities. *Phytotherapy Research* **18**, 713-717.

Singh G, Kapoor IPS, Singh P, de Heluani C S, de Lampasona M P, Catalan C AN. 2008. Chemistry, antioxidant and antimicrobial investigations on essential oil and oleoresins of *Zingiber officinale*. *Food Chemistry and Toxicology* **46**, 3295-3302.

Smith-Palmer A, Stewart J, Fyfe L. 2001. The potential application of plant essential oils as natural food preservatives in soft cheese. *Food Microbiology* **18**, 463-470.

Styczynska KA. 2011. Activity of essential oils against food-spoiling yeast. A review. *Flavour and Fragrance Journal* **26**, 326-328.

Tassou C, Koutsoumanis K, Nychas GJE. 2000. Inhibition of *Salmonella enteritidis* and *Staphylococcus aureus* in nutrient broth by mint essential oil. *Food Research International* **33**, 273-280.

Tatsadjieu NL, Dongmo Jazet PM, Ngassoum MB, Etoa FX, Mbofung CMF. 2009. Investigations on the essential oil of *Lippia rugosa* from Cameroun for its potential use as antifungal agent against *Aspergillus flavus* Link ex Fries. *Food Control* **20**, 161-166.

Tatsadjieu NL, Essia Nganga JJ, Ngassouma MB, Etoa F. 2003. Antibacterial and antifungal activity of *Xylopia aethiopica*, *Monodora myristica*, *Zanthoxylum xanthoxyloides* and *Zanthoxylum leprieurii* from Cameroon. *Fitoterapy* **74**, 469-472.

Tira-Picos V, Gbolade AA, Noguera JMF, Ajibesin KK. 2009. Analysis of leaf essential oil

constituents of *Cinnamomum zeylanicum* grown in Nigeria. *Journal of Essential Oil Bearing Plants*, **12(1)**, 76-80.

Tomar US, Daniel V, Shrivastava K, Panwar MS, Pant P. 2010. Comparative evaluation and antimicrobial activity of *ocimum basilicum* linn. (labiateae). *Journal Global Pharma Technology* **2(5)**, 49-53.

Unlu M, Ergene E, Unlu VG, Zeytinoglu SH, Vural N. 2010. Composition, antimicrobial activity and in vitro cytotoxicity of essential oil from *Cinnamomum zeylanicum* Blume (Lauraceae). *Food Chemistry and Toxicology* **48**, 3274-3280.

WHO. 2002. Food safety and Food-borne illness, World Health Organization Fact Sheet 237 revised January, Geneva.

Xing Y, Li X, Xu Q, Yun J, Yaqing L. 2010. Original article: Antifungal activities of cinnamon oil against *Rhizopus nigricans*, *Aspergillus flavus* and *Penicillium expansum* in vitro and in vivo fruit test. *International Journal of Food Science and Technology* **45(9)**, 1837-1842.

Yèhouenou B, Noudogbèssi JP, Sessou P, Avlessi F, Sohounhloué D. 2010b. Etude chimique et activités antimicrobiennes d'extraits volatils des feuilles et fruits de *Xylopia aethiopica* (DUNAL) A. Richard contre les pathogènes des denrées alimentaires. *Journal de la Société Ouest Africaine de Chimie* **29**, 19-27.

Yèhouenou B, Wotto V, Bankolé L, Sessou P, Noudogbèssi JP, Sohounhloué D. 2010a. Chemical study and antimicrobial activities of volatile extracts from fresh leaves of *Crassocephalum rubens* (Juss & Jack) S.Moore against food-borne pathogens. *Scientific Study Research* **11(3)**, 343-351.