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Family Zingiberaceae Compounds as Functional Antimicrobials, Antioxidants, and Antiradicals

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ABSTRACT

Increasing numbers of reported cases of food-associated infections and health problems associated with synthetic additives have led to a growing interest by consumers in ingredients from natural sources. Some members of the family Zingiberaceae have been extensively used as a condiment for flavoring as well as traditional medicines. These include *Alpinia galanga* (galanga), *Boesenbergia pandurata* (krachai), *Curcuma amada* (mango ginger), *Curcuma longa* (turmeric), *Curcuma zedoria* (zedoary), *Kampferia galanga* (proh hom), *Zingiber officinale* (ginger), and *Zingiber zerumbet* (zerumbet ginger). Their antimicrobial activities against important foodborne pathogens including *Bacillus cereus*, *Campylobacter jejuni*, *Clostridium botulinum*, *Clostridium perfringens*, *Escherichia coli*, *Listeria monocytogenes*, *Salmonella* spp., *Shigella* spp., *Staphylococcus aureus*, *Vibrio* spp., *Yersinia enterocolitica*, Hepatitis A Norwalk virus, *Entamoeba histolytica*, and *Giardia lamblia* are outlined. In addition to the antimicrobial activities against a wide range of microorganisms, their antioxidant activities have been documented. The potential uses of these plant species as food preservatives are discussed.

Keywords: *Alpinia galanga*, antimicrobial activity, antioxidant activity, *Boesenbergia pandurata*, *Curcuma amada*, *Curcuma longa*, *Curcuma zedoria*, food poisoning, food preservation, food spoilage, galangal, ginger, *Kampferia galanga*, krachai, mango ginger, proh hom, turmeric, zedoary, zerumbet ginger, zingiberaceae, *Zingiber officinale*, *Zingiber zerumbet*

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INTRODUCTION

At present, food safety is a fundamental concern to both consumers and food industries as there are increasing numbers of reported cases of food-associated infections. Food-borne illness remains a major problem even in industrialised countries (Gould *et al*. 1995). In addition, lipid oxidation is another issue affecting quality loss in muscle foods. There has been a growing interest in new and effective techniques to reduce the cases of food-borne illness (Otshudi *et al*. 2000). Consumers prefer high quality, nutritious, and long shelf-life food products with no preservative agents. Food preservation, therefore, is the basis of most modern food industries in the world.

A number of botanical supplements have been used for centuries in the ancient Indian system of medicine known as *Ayurveda*. Almost every nation has traditional folk medicines or folk remediation with medicinal plants. The use of herbs and their extracts as functional ingredients in foods is expanding rapidly both for the growing interest of consumers in ingredients from natural sources and also increasing concern about potential health problems associated with synthetic additives (Reische *et al*. 1998). Antimicrobials from natural sources have been used for food safety since antiquity (Alzoreky and Nakahara 2003). There is an increasing interest in the use of plant-derived antimicrobial compounds as natural food preservatives. Natural antimicrobials found in medicinal plants can protect us from infectious diseases caused by bacteria, fungi, and viruses including HIV, the virus that produces AIDS. Interestingly, a new emerging food threat, bird flu virus H5N1, has been claimed to be effectively eliminated using plant extracts such as hypercine

Received: 11 June, 2007. Accepted: 28 September, 2007.

Invited Review

(www.scidev.net/News/index), sambucol (www.nutraingredients.com/news). The secondary metabolites of plants provide humans with numerous biologically active products, which have been used extensively as food additives, flavors, colors, insecticides, drugs, fragrances, and other fine chemicals. These plant secondary metabolites including several classes such as terpenoids, flavonoids, and alkaloids comprise of diverse chemicals and biological activities. In addition, plant derivatives have unique structural diversity. This has led to a renewed interest in bioactive compounds.

The public is using natural products for a wide range of health-related problems. A common need is availability of natural extracts with a pleasant taste or smell combined with a preservative action to avoid both microbial contamination and lipid deterioration. Those undesired phenomena are not an exclusive concern of the food industry but a common risk wherever a pathogen is present. Spoilage microorganisms, lipid oxidation, protein oxidation, and enzymatic oxidation severely affect the shelf-life of many foods in addition to the development of undesirable off-flavours (Farag *et al*. 1990; Hirasa and Takemasa 1998).

In recent years, much attention has been focused on extracts from herbs and spices which have been used traditionally for centuries to improve the sensory characteristics and to extend the shelf-life of foods. Spices and their essential oils have been widely used as natural food preservatives to make processed foodstuff safe for consumers. They are gaining increasing interest because they impart desirable flavors but they may fulfil more than one function to the food when they are added (Nasar-Abbas and Halkman 2004). Spices have been extensively studied by various groups of scientists because of their relatively safe status, their wide acceptance by consumers, and their exploitation for potential multi-purpose functional use (Sawamura 2000; Ormancey *et al*. 2001). Plants produce an array of defensive molecules including antimicrobial proteins and peptides (Xu 1990; Ng and Wang 2000; Wang *et al*. 2000; Ye *et al*. 2000). We reported earlier antibacterial activities of a number of Thai medicinal plants against a wide range of bacteria (Voravuthikunchai *et al*. 2002; Voravuthikunchai and Kitpipit 2003; Voravuthikunchai *et al*. 2004a, 2004b, 2004c; Voravuthikunchai and Kitpipit 2005; Voravuthikunchai *et al*. 2005a, 2005b, 2005c, 2006a, 2006b, 2006c, 2006d; Voravuthikunchai and Limsuwan 2006; Voravuthikunchai *et al*. 2007). In addition, their antimicrobial, antioxidant and radical-scavenging properties by spices and essential oils have been reported (Hirasa and Takemasa 1998) and in some cases, a direct food-related application has been tested. Several antioxidants were used to extend food shelf life. It was anticipated that they might inhibit the oxidation reaction involved in enzymatic browning (Madsen and Bertelson 1995).

Rhizomes of the family Zingiberaceae contain some important aromatic and color-producing spices such as turmeric, ginger, galanga, krachai, cardamom, and grains of paradise. Currently, there is an increasing demand for new ethnic foods. The foods also include the emerging cuisines such as Thai, Vietnamese, Indian, and Moroccan, which have strong flavors and aromas. Some of the popular ingredients for developing these foods include tamarind, cardamon, lemon grass, basil, and galanga (Cousminer and Hartman 1996; Uhl and Mermelstein 1996). Many studies have demonstrated that they contain bioactive compounds that have excellent antimicrobial activities against a diverse group of pathogens. Therefore, they are potential candidates for a preservative substance in food. *Tom-yum*, a well-known Thai traditional seasoning containing galanga and many other herbs, has been shown to possess both antioxidation and antimicrobial effects. *Tom-yum* mix was demonstrated to have a potential as a natural preservative agent for ensuring safe marinated food products (Siripongvutikorn *et al*. 2005).

In tropical countries, many kinds of gingers are cultivated and used not only for spices but also as traditional medicines. This review attempts to gather important scientific information on the family Zingiberaceae in relation to health care concepts as food supplements and preservatives. Particularly, an overview of recent progress reports on the antimicrobial and antioxidant activities of common species of this plant family is substantially highlighted.

FACTORS AFFECTING FOOD SAFETY

More than 200 known diseases are transmitted through food. Food-borne illnesses result from ingesting food contaminated with bacteria or toxic substances they produce, yeast, fungi, viruses, prions, parasites, chemicals, and metals. Reactions and the duration of the illness vary according to the type of organism or toxic substance consumed. The symptoms may be mild gastroenteritis and last only a few hours. These usually include diarrhea, malaise, dizziness, nausea, vomiting, headache, and fever. On the other hand, there are more serious, life-threatening infections which last much longer, and require intensive medical treatment, for example, botulism caused by *Clostridium botulinum*, hepatitis A from Hepatitis A virus, and renal syndromes from *Escherichia coli* O157: H7. In specific groups such as children and the elderly, death may encounter.

Food spoilage microorganisms

All food, unless just cooked or sterilised, contains some bacteria. The numbers present will depend on conditions in which the food has been handled and stored. If allowed to grow, some of these bacteria may cause spoilage. Most common organisms include various yeast species such as *Candida albicans*, *Rhodotolura glutinis*, S*chizosaccharomyces pombe*, *Saccharomyces cerevisiae*, and Y*arrowia lypolitica* (Sacchetti *et al*. 2005). Generally, these spoilage organisms are harmless and do not cause illness. However, if spoilage is noticeable, the food should not be consumed.

Food-borne pathogens and food poisoning

Food-borne pathogens continue to cause major public health problems world-wide. These organisms are the leading causes of illness and death in less developed countries, killing approximately 1.8 million people annually (Fratamico *et al*. 2005). Even in developed countries, food-borne pathogens are responsible for millions of cases of infectious gastrointestinal diseases each year, costing billions of dollars in medical care and decreasing productivity. Furthermore, new food-borne diseases are likely to emerge driven by factors such as pathogen evolution, changes in agricultural and food manufacturing practices, and changes to the human host status.

Harmful organisms often do not alter the appearance, taste or smell of food. Because of this, it is impossible to visually determine whether or not food is contaminated. Only a laboratory analysis can verify the presence of these pathogenic microorganisms. Food-borne pathogens cover diverse groups of microorganisms including bacteria, yeast, fungi, enteric viruses, and protozoan parasites. Most common contamination encounters pathogenic bacteria such as *Bacillus cereus*, *Campylobacter jejuni*, *C. botulinum*, *Clostridium perfringens*, *E. coli*, *Listeria monocytogenes*, *Salmonella* spp., *Shigella* spp., *Staphylococcus aureus*, *Vibrio* spp., and *Yersinia enterocolitica*. In addition to bacteria, food may also become contaminated with viruses. Unlike bacteria, viruses cannot multiply in food and do not cause spoilage. They do not cause any change in the appearance, taste or smell of food and cannot be detected by ordinary laboratory tests. Once they get into the human body, however, they can multiply and cause disease. Fortunately, most viruses are destroyed by adequate cooking. Cooking eggs at 160°F (71°C) can kill the avian flu virus (Wiwanitkit 2007). The diseases produced by parasites are varied, and in some countries, they are more important than bacterial food-borne illnesses. Many infected individuals do not show signs of infection, but the symptoms, when they occur, are similar to

Table 1 Major food-borne infections.

Infection	Incubation period	Symptoms	Sources of contamination
Bacterial			
Bacillus cereus	30 min-15 h	abdominal cramps, diarrhea nausea, **vomiting**	cheese, fish, meat, milk, pasta, potatoes, rice, vegetables
Campylobacter jejuni	1-7 d	abdominal cramps, headache, **inflammatory diarrhea**, nausea	raw beef, cake, eggs, unpasteurised milk, poultry, water
Clostridium botulinum	12-72 h	diarrhea, double vision, dry mouth, fatigue, headache, **muscle paralysis**, nausea, respiratory failure, vomiting	bottled garlic, fermented fish, herb-infused oils, low-acid canned foods, meats, sausage
Clostridium perfringens	8-22 h	abdominal cramps, some with dehydration, nausea, **watery diarrhea**	gravy, meat, poultry
Clostridium parvum	2-28 d	watery diarrhea	fruit, unpasteurized milk, vegetables, water
Enterotoxigenic *Escherichia coli*	1-3 d	watery diarrhea	fecal contaminated food or water
Escherichia coli 0157: H7	1-8 d	abdominal cramps, bloody diarrhea, **hemorrhagic colitis**, hemolytic uremic syndrome	egg, ground beef, meat, unpasteurised milk, milk products, poultry
Listeria monocytogenes	2 d to 6 wks	diarrhea, fever, muscle aches, meningitis, nausea, sepsticemia, miscarriage	cheese, hot dogs, meat, milk, seafood, vegetables
Salmonella spp.	12-72 h	abdominal pain, chills, dehydration, diarrhea, fever, headache, **inflammatory diarrhea**, nausea, prostration	dairy products, poultry, raw vegetables, salads
Shigella spp.	12-72 h	abdominal pain, cramps, fever, inflammatory diarrhea, vomiting	fecal contaminated food, salads, water
Staphylococcus aureus	1-6 h	abdominal cramps, diarrhea, **severe vomiting**	cream-filled baked goods, cream sauces, custard, diary, dressing, eggs, gravy, ham, meat, poultry, salads, sandwich fillings
Vibrio spp.	4 h-7 d	abdominal cramps, chills, nausea, diarrhea, fever, headache, nausea, vomiting	infected fish and shellfish
Vibrio parahemolyticus	2-48 h	inflammatory diarrhea	raw shellfish
Yersinia enterocolitica	1-3 d	enterocolitis (may mimic acute appendicitis)	chocolate milk, raw milk, pork, water, raw meats
Fungal			
Cryptosporidium parvum	2-15 d	loss of appetite, mild stomach cramps, nausea, **watery diarrhea**	food, milk, water
Viral			
Hepatitis A virus	15-50 d	abdominal discomfort, fever, malaise, nausea, **hepatitis**, **jaundice**, liver failure	iced drinks, fruits, salads, shellfish, vegetables, water
Norwalk virus	12-48 h	abdominal cramps, diarrhea, nausea, **vomiting**	frosting, fruit, ice, raw oysters, salads, sandwiches, shellfish, water
Enteric virus	10-72 h	watery diarrhea	fecal contaminated food or water
Parasitic			
Cyclospora cayetanensis	1-11 d	watery diarrhea	imported berries, basil
Giardia lamblia	1-2 wks	infection of the small intestine, diarrhea, **loose or watery stool**, stomach cramps	fecal contaminated food or water
Toxoplasma	5-23 d	no symptoms or mild illness (swollen lymph glands, fever, headache, and muscle aches) severe infection for unborn babies, immunocompromised host	raw or undercooked food

Modified from Centers for Disease Control 2006; bold words are the most pronounced symptoms.

those produced by bacteria. Diarrhea is usually the most common symptom. As with viruses, parasites need a host in which to multiply and contaminated food and water act only to transport the parasite from one host to the next. Infections by common pathogens including incubation period, symptoms, and possible causes of contamination are summarised in **Table 1** (http://en.wikipedia.org/wiki/Centers_for_Disease_Control_and_Prevention).

Campylobacter is a pathogen that causes fever, diarrhea, and abdominal cramps. It is the most commonly identified bacterial cause of diarrheal illness in the world. Campylobacter enteritis occurs throughout the world, particularly in the temperate areas during the warmer months. The bacteria may be responsible for some 'traveler's diarrhea'. These bacteria live in the intestines of healthy birds, therefore most raw poultry meat has *Campylobacter* on it. Eating undercooked chicken or other food that has been contaminated with juices dripping from raw chicken is the most frequent source of this infection. Campylobacter enteritis is self limiting and of short duration, with the symptoms lasting from one to four days (Pebody *et al*. 1997; Altekruse *et al*. 1999).

Clostridium perfringens food poisoning is characterised by a sudden onset of abdominal pain and diarrhea. Nausea is common but vomiting and fever are usually absent. This type of food poisoning is mild and usually lasts only one day or less (Eley 1992b).

Escherichia coli O157:H7 is a pathogen that has a reservoir in cattle and other similar animals. Human illness typically follows the consumption of food or water that has been contaminated with cow feces. The illness it causes is often a severe and bloody diarrhea and painful abdominal cramps, without much fever. Hemorrhagic colitis, commonly referred to as 'hamburger disease' or 'barbecue season syndrome', is a recognised type of emerging foodborne illness. The bacteria can produce verocytotoxin which damages the lining of the intestine resulting in diarrhea and pain. While most people recover from this disease within two weeks, in three to five percent of cases, a complication called 'hemolytic uremic syndrome' (HUS) can occur several weeks after the initial symptoms. This illness affects the kidneys and blood. Severe complications include temporary anemia, profuse bleeding, and kidney failure. It is especially dangerous to young children and the elderly. Death can result from either HUS or the intestinal disease (Canada Communicable Disease Report 2000; O'Connor 2002).

Listeriosis is an illness caused by the *Listeria* spp. present in soil and water. Animals such as cattle and sheep can carry it without appearing ill and can contaminate foods of animal origin such as meats and dairy products. About ten per cent of healthy persons may also harmlessly carry this organism in their bowel. Symptoms can be similar to the flu, with fever, muscle aches, and often gastrointestinal symptoms such as nausea or diarrhea. Listeriosis can be deadly if it encounters meningitis, an infection of the fluid around the brain, causing headache, stiff neck, confusion, loss of balance, or seizures (Eley 1992c).

Salmonellosis Salmonella is widespread in the intestines of birds, reptiles, and mammals. It is also found in food such as raw eggs and egg products, meat and meat products, and poultry. The organism can spread to humans via a variety of different foods of animal origin. Illness may occur after individuals eat food or drink water contaminated with faeces. The bacteria multiply in the small intestine and invade the intestinal lining. The illness caused by *Salmonella* typically includes fever, diarrhea, and abdominal cramps. Dehydration, especially among infants, may be severe. In persons with poor underlying health or weakened immune systems, it can invade the bloodstream and cause life-threatening infections (Eley 1992a).

Shigellosis is commonly known as 'bacillary dysentery'. Shigellosis occurs throughout the world and is most often associated with children under ten years. If the disease is not properly treated, it can be fatal. Symptoms such as diarrhea, fever, nausea, vomiting, and cramps are most common. Blood may also be found in the feces (Eley 1992c).

Staphylococcal food poisoning or food intoxication syndrome was first studied in 1894 (Jay 2000). *Staphylococcal gastroenteritis* is caused by the ingestion of enterotoxins produced by some strains of *Staphylococcus aureus* (Vanderzant and Splittstoesser 1992). The toxin is not destroyed by cooking. Although the illness may be of short duration, usually less than two days, it can become very severe. In processed foods in which *S. aureus* should have been destroyed by processing, the reappearance of this particular bacterium can cause damages to food industries as it is a vector of food poisoning. It may be inferred that sanitation or temperature control or both are inadequate. There is no guarantee that foodstuff is safe enough for consumption, although only a trace amount of *S. aureus* is present. Natural preservatives such as spices and plant essential oils can be used as additives instead of chemical preservatives because food remains safe for consumers while *S. aureus* is eliminated (Oonmetta-aree *et al*. 2006).

Hepatitis A is caused by the Hepatitis A virus. Many adults and most children may be infected but have no or very mild symptoms. These symptoms may be followed by jaundice which is the yellowing of the skin and the whites of the eyes. People with symptoms may be ill for a few days, but most people do not feel fully recovered for quite a few weeks. In some rare cases, people are severely ill for several months with liver failure and death occasionally occur (http://www.health.gov.ab.ca/about/about.html).

Norwalk virus is an extremely common cause of foodborne illness, though it is rarely diagnosed, because the laboratory test is not widely available. It causes an acute gastrointestinal illness, usually with more vomiting than diarrhea, that resolves within two days. Outbreaks of Norwalk virus gastroenteritis are often associated with consumption of contaminated oysters (Tian *et al*. 2006). The viruses spread primarily from one infected person to another. Infected kitchen workers can contaminate a salad or sandwich as they prepare it, if they have the virus on their hands. Infected fishermen have contaminated oysters as they harvested them.

Amoebiasis is an intestinal disease caused by the parasite '*Entamoeba histolytica*'. The disease is commonly known as '*amoebic dysentery*' and results when the parasite invades the wall of the large intestine, forming ulcers in the process. Community outbreaks usually involve water supplies contaminated with the cysts of the parasite. Invasive amoebiasis is a potentially fatal condition. It ranks third on a global scale after malaria and schistosomiasis as a cause of death among people with parasitic infections. Infection with has been reported to be an important cause of acute and chronic diarrhea in HIV patients (Arenas-Pinto *et al*. 2003).

Giardiasis caused by the parasite *Giardia lamblia* (syn. *Giardia intestinalis*, *Giardia duodenalis*). The disease occurs world-wide although it is more common in areas with poor sanitation. Children appear to be infected more frequently than adults. The parasite produces cysts which are responsible for the spread of the disease. Feces containing these cysts can contaminate both water and food. Species within this genus cause human giardiasis, which probably constitute the most common causes of protozoal diarrhoea worldwide, leading to significant morbidity and mortality in both developing and developed countries (Cacciò *et al*. 2005).

Lipid oxidation

It is now widely accepted that apart from microbial spoilage, lipid oxidation is the primary process by which quality loss of muscle foods occurs (Buckley *et al*. 1995). Lipid oxidation in muscle foods is initiated in the highly unsaturated phospholipid fraction in subcellular biomembranes (Gray and Pearson 1987). Lipid hydroperoxides formed during the propagation phase of the peroxidation process are unstable and are reductively cleaved in the presence of trace elements to give a range of new free-radicals and other non-radical compounds including alkoxyl and alkyl radicals, aldehydes, ketones, and a range of carboxyl compounds which adversely affect nutritive value, texture, color, flavor, and more seriously, the safety of muscle food (Buckley *et al*. 1995). Oxidative deterioration of fat components in foods is responsible for the rancid odors and flavors which decrease nutritional quality. Undesirable flavors in precooked meats are caused by volatile compounds such as hexanal, pentanal, 2,4-decadienal, 2,3-octanedione, and 2-octenal (St. Angelo *et al*. 1987; Trout and Dale 1990; Kerler and Grosch 1996).

The addition of antioxidants is required to preserve food quality. Many plants can extend shelf life by slowing oxidation. Rancidity development is an oxidative process that can be blocked by antioxidants, which block formation of free radicals by donating electrons or hydrogen ions to halt the oxidative process. Oxidative damage is thought to be a factor in cardiovascular disease, cancer, neurological disorders, arthritis, and other aging-related degenerative diseases. The benefits of antioxidant are not just limited to food preservation. In the human body, free radicals are initiated by a number of processes such as heat, UV light, radiation, alcohol, and tobacco. Antioxidants prevent damage from reactive oxygen species to tissues throughout the body. Free-radical damage to cells can limit the ability of cells to fight cancer or to limit aging. Numerous studies have indicated that lipid oxidation may be controlled through the use of antioxidants (Gray *et al*. 1996; El-Alim *et al*. 1999; McCarthy *et al*. 2001; Ahn *et al*. 2002; Sanchez-Escalante *et al*. 2003) Synthetic antioxidants from phenolic compounds such as butylated hydroxytoluene (BHT), butylated hydroxyanisole (BHA), tertiary butylhydroquinone (TBHQ), and propyl gallate (PG) have long been used in the food industry, but their use has recently come into dispute to a suspected carcinogenic potential (Chen *et al*. 1992) and the general rejection of synthetic food additives by consumers. BHA was shown to be carcinogenic in animal experiments. At high doses, BHT may cause internal and external hemorrhagic, which contributes to death in some strain of mice and guinea pigs. This effect is due to the ability of BHT to reduce vitamin K-depending blood-clotting factor (Ito *et al*. 1986). Therefore, the importance of replacing synthetic antioxidants by natural ingredients is obvious according to health implications.

Many plants have high antioxidant activity and are used in many food applications (Hirasa and Takemasa 1998).

Table 2 Studies on antimicrobial activities of well-known Zingiberaceae species.

Microorganisms	**Common Zingiberaceae spp.**				
	Alpinia galanga	***Boesenbergia pandurata***	***Curcuma longa***	***Zingiber officinale***	***Zingiber zerumbet***
Aspergillus niger				Konning *et al*. 2004	
Bacillus cereus			Jagannath and Radhika 2006	Alzoreky and Nakahara 2003	
Bacillus subtilis				Konning *et al*. 2004	
Candida albicans	Haraguchi *et al*. 1996; Jantan *et al*. 2003	Jantan *et al*. 2003	Sacchetti *et al*. 2005	Konning *et al*. 2004; Sacchetti *et al*. 2005	
Cryptococcus neoformans	Jantan *et al*. 2003	Jantan *et al*. 2003			
Dengue virus		Kiat *et al*. 2006			
Entamoeba histolytica	Sawangjaroen *et al*. 2006	Sawangjaroen *et al*. 2006		Sohni and Bhatt 1996	Sawangjaroen *et al*. 2006
Escherichia coli			Jagannath and Radhika 2006	Alzoreky and Nakahara 2003, (-)	
Escherichia coli O157: H7				Konning *et al*. 2004; Samy 2005, (-)	
Giarrdia intestinalis	Sawangjaroen *et al*. 2005	Sawangjaroen *et al*. 2005			Sawangjaroen *et al*. 2005
Haemophilus influenza				Akoachere *et al*. 2002	
Helicobacter pylori			Mahady *et al*. 2005	Mahady *et al*. 2005	
Listeria monocytogenes		Thongson *et al*. 2004, 2005	Leal *et al*. 2003; Thongson *et al*. 2004, 2005	Alzoreky and Nakahara. 2003, (-); Leal *et al*. 2003; Thongson *et al*. 2004, 2005	
Mycobacterium tuberculosis	Phongpaichit *et al*. 2006	Phongpaichit *et al*. 2006			
Pseudomonas aeruginosa				Konning *et al*. 2004; Samy 2005, (-)	
Salmonella spp.	Thongson *et al*. 2004, 2005	Thongson *et al*. 2004, 2005	Thongson *et al*. 2004; Jagannath and Radhika 2006	Alzoreky and Nakahara 2003	
Staphylococcus aureus	Oonmetta-aree *et al*. 2006; Voravuthikunchai *et al*. 2005b, 2006d	Voravuthikunchai *et al*. 2005b, 2006d	Jagannath and Radhika 2006	Akoachere *et al*. 2002; Alzoreky and Nakahara 2003, (-); Konning *et al*. 2004; Samy 2005; Voravuthikunchai *et al*. 2005b, 2006d	Voravuthi-kunchai *et al*. 2005b, 2006d
Streptococcus mutans		Hwang *et al*. 2004			
Streptococcus pneumoniae				Akoachere *et al*. 2002	
Streptococcus pyogenes				Akoachere *et al*. 2002	
Trichophyton mentagrophytes		Janssen and Scheffer 1985			

Natural antioxidants have been isolated from various kinds of plant materials such as oilseeds, leaves, roots, spices, herbs, cereal crop, vegetables, and fruits (Ramarathnam *et al*. 1995). A number of studies deal with the antioxidant activity of extracts from herbs and spices (Economou *et al*. 1991; Kikuzaki and Nakatani 1993; Cuvelier *et al*. 1994; Lu and Foo 2001). Among natural antioxidants, plant-derived phenolic compounds are in the forefront as they are widely distributed in the plant kingdom. This may be applicable to such diverse areas as human health and the preservation of food lipids. The antioxidative potential in herbs is related to their redox properties of phenolic compounds. The antioxidant action is similar to synthetic phenolic antioxidants which allow them to act as reducing agents, hydrogen donators and singlet oxygen quenchers (Caragay 1992; Rice-Evans *et al*. 1997).

POPULAR MEMBERS OF FAMILY ZINGIBERACEAE USED IN FOOD PRESERVATION

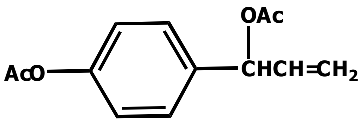
It is a perennial herb with a modified fleshy stem termed the rhizome, which occurs below ground. Some common members of family Zingiberaceae have been extensively used as condiment for flavoring. Many species are frequently prescribed by practitioners of traditional Thai medicine for treating stomach-ache, carminative, diarrhea, and dysentery. Important studies of the antimicrobial activities of important species are presented in **Table 2**. However, results from different laboratories may be varied since antimicrobial properties depends on several factors such as type, composition and concentration of spices, extraction method, and numbers of contaminating microorganisms. In addition to their antimicrobial activities, it has been reported that all tropical ginger extracts have antioxidant activities (Jitoe *et al*. 1992). Moreover, several plants in this family have been used in Thai traditional treatment of allergy and allergic-related diseases (Tewtrakul and Subhadhirasakul 2006). In this communication, the species that provide most of the known benefits to human beings will be reviewed in detail. These include *Alpinia galanga* (galanga), *Boesenbergia pandurata* (krachai), *Curcuma amada* (mango ginger), *Curcuma longa* (turmeric), *Curcuma zedoria* (zedoary), *Kampferia galanga* (proh hom), *Zingiber officinale* (ginger), and *Zingiber zerumbet* (zerumbet ginger). Their potential uses as food preservatives are discussed. Some other species with fewer applications will only be briefly mentioned.

Alpinia galanga (L.) Willd.

Syn. *Alpinia galanga* (Linn); *Languas galanga*. Common names: da liang jiang, el adkham, el galanga, galanga, galanga de l'inde, galanga maior, galanga majeur, galangal, galgant, grand galanga, greater galanga, grober galgant, hang dou kou laos, herbe indienne, java galanga, khaa, lenkuas, naukyo, riêng, siamese galanga, siamese ginger, stor kalanga, ulanjan (**Plate 1**).

A tropical plant, a member of the ginger family, is native to Southern China, South East Asia, and West Africa. Galanga is a perennial growing up to seven feet tall. The leaves are lanceolate while the flowers are small greenish-white and the fruit is orange-red. Galanga has characteristic fragrance as well as pungency. The rhizome is a hot, sweet, spicy aromatic root-stock like ginger with slightly sour and peppery notes. It is commonly used in stir-fries, curries and soups in the Eastern-Caribbean, and Southeast Asia kitchen. Galanga is commomly used as a flavoring especially in the

Plate 1 ***Alpinia galanga*** **(L.) Willd.**



1'-Acetoxychavicol acetate

Fig. 1 1'-Acetoxychavicol acetate isolated from the rhizomes of *Alpinia galanga* (L.) Willd.

preparation of fresh Thai curry paste and Thai soup (Uhl and Mermelstein 1996; Oonmetta-aree *et al*. 2006). The rhizome is used as a medicine for curing allergy, bad breath, bronchial catarrh, dyspepsia, fever, rheumatism, stomachache, throat infections, toothache, ulcers, and whooping cough in children (Yang and Eilerman 1999; Yoshikawa *et al*. 2004).

With regard to biological activities, it has been shown that essential oils from both fresh and dried rhizomes of galanga exhibit antimicrobial activities against Gram-positive bacteria, fungi, yeast, and parasite (Farnsworth and Bunyapraphatsara 1992). Essential oil from the rhizomes comprised 1,8-cineole, β-pinene, α-terpineol, fenchyl acetate, α-pinene, camphene, guaiol, camphor and β-elemene (Raina *et al*. 2002). In dried galanga, the essential oil has quantitatively different composition than in fresh one. Whereas α-pinene, 1,8-cineol, α-bergamotene, *trans*-β-farnesene and β-bisabolene seem to contribute to the taste of fresh galanga equally, the dried rhizome shows lesser variety in aroma components (cineol and farnesene). The chemical constituents, cineole, camphor, δ-pinene, methyl cinnamate, and volatile essential oil, were reported to be effective against dermatophytes, filamentous fungi, and yeast-like fungi including *C. albicans* and *Cryptococcus neoformans* (Jantan *et al*. 2003). It has been reported that terpinen-4-ol, one of the monoterpenes in the essential oil from fresh galanga rhizomes, contains an antimicrobial activity against *Trichophyton mentagrophytes* (Janssen and Scheffer 1985).

It is well-documented that 1'-acetoxychavicol acetate (ACA) (**Fig. 1**) (Voravuthikunchai *et al*. 2007), the major constituent isolated from an ethanolic extract of dried galanga rhizomes possess antimicrobial activities. This substance is present in some other plants in the Zingiberaceae family. It has been demonstrated to be very active against *S. aureus* (Voravuthikunchai *et al*. 2005b; Oonmetta-aree *et al*. 2006; Voravuthikunchai *et al*. 2006d), *Mycobacterium tuberculosis* (Palittapongarnpim *et al*. 2002), many dermatophyte species (Janssen and Scheffer 1985), *E. histolytica* (Sawangjaroen *et al*. 2006), and *Giarrdia intestinalis* (Sawangjaroen *et al*. 2005). The galanga extract had the greatest inhibitory effect against *S. aureus*, compared to ginger, turmeric, and krachai (Oonmetta-aree *et al*. 2006). As have been mentioned earlier that different results may occur from different laboratories. Khattak *et al*. (2005) have reported a weak inhibition activity of ethanolic extracts of *Bosenbergia pandurata* against *S. aureus* while we found better activity from chloroformic extracts of this plant (Voravuthikunchai *et al*. 2005b, 2006d). The antimicrobial effect of the extract depends on many factors such as extractive solvents, the exposure time and the bacterial cell concentration. It has been demonstrated that the methyl ester penetrated to the hydrophobic regions of the membranes and the carboxyl groups pass through the cell membrane, perturbed internal pH and denatured proteins inside the cell which resulted in coagulation of cell contents (Marquis *et al*. 2003; Oonmetta-aree *et al*. 2006). Furthermore, it disrupted the cytoplasmic membrane function of *S. aureus* cells which resulted in a loss of cytoplasmic constituents and ions. In contrast, the extract could not inhibit the growth of *E. coli* because the extract could not penetrate through the outer membrane which was composed of a lipopolysaccharide monolayer surrounding the cell wall that restricts diffusion of hydrophobic compounds (Burt 2004).

Galanga extract may be a possible additive for meat and meat products. The potent antioxidant activity of curcuminoids isolated from *A. galanga* was reported (Barik *et al*. 1987; Cheah and Abu Hasim 2000; Siripongvutikorn *et al*. 2005). Two phenolic compounds, *p*-hydroxycinnamaldehyde and di-*p*-hydroxy-*cis*-styryl methane, were isolated from the chloroform extract of the rhizomes (Barik *et al*. 1987). Cheah and Abu Hasim (2000) reported the antioxidative effect of galanga in raw and cooked minced beef during storage at 4°C. It was found to delay the induction period of lipid oxidation and affect microbial growth in cooked beef. The application of dried galanga powder and its ethanolic extracts has been demonstrated to enhance oxidative stability of meat. Furthermore, its free radical scavenging activity, superoxide anion radical scavenging activity, Fe^{2+} chelating activity, lipoxygenase inhibitory activity, and reducing power have been documented (Juntachote and Berghofer 2005). Some components found in galagal root are effective in inhibiting tumors in the digestive tract (Murakami *et al*. 1993, 1995). The ability of ACA to act as an antiulcer, antitumor agents as well as an inhibitor of chemically induced carcinogenesis is event (Murakami *et al*. 2000).

Boesenbergia pandurata (Roxb.) Schltr.

Syn. *Boesenbergia pandurata* Holtt; *Boesenbergia pandurata* (Roxb.) Holtt.; *Boesenbergia rotunda* (L.) Mansf.; *Kaempferia pandurata* Roxb. Common names: Chinese ginger, finger root, krachai, temu kunci (**Plate 2**).

B. pandurata, the yellow variety, is a perennial herb found in Southern China and Southeast Asia. A tall ginger has the long tubers sprouting in the same direction from the middle of the rhizome with large beautiful pink-purple flowers. There are culinary applications of its rhizome as a spice in Thai and Indonesian kitchen. 'Thai ginger' or 'Thai krachai' is used for similar purposes as ginger in Thai cuisine. It is one of the plants in the primary health care project of Thailand for medical purposes such as treatment of diarrhea, dyspepsia, inflammation, and wounds.

Plate 2 ***Boesenbergia pandurata*** **(Roxb.) Schltr.**

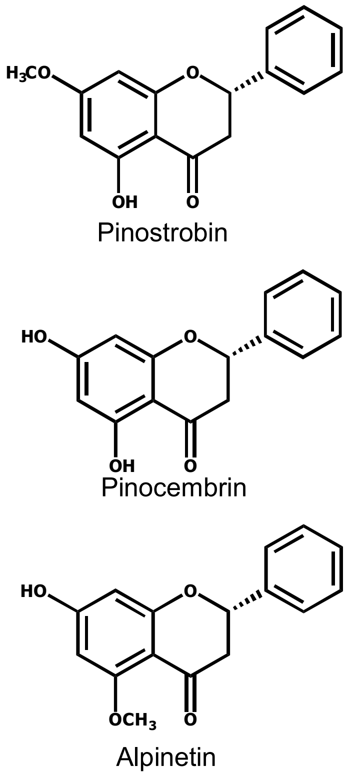


Fig. 2 Main chemical constituents isolated from the rhizomes of ***Boesenbergia pandurata*** **Holtt.**

Regarding the chemical constituents of *B. pandurata*, there are many reports on chalcones (Trakoontivakorn *et al.* 2001), flavonols (Jaipetch *et al.* 1983), flavones (Jaipetch *et al.* 1982), and essential oil (Pandji *et al.* 1993). Flavonoids such as boesenbergin A, boesenbergin B, panduratin A, panduratin B, cardomin, cardamonin, pinostrobin, pinocembrin, alpinitin, 5-hydroxy-7-dimethoxyflavanone (Jaipetch *et al.* 1982; Jaipetch *et al.* 1983; Pancharoen *et al.* 1987; Pandji *et al.* 1993), and 1,8-cineole are recognised as the bioactive compounds (Pancharoen *et al.* 1987). Main chemical constituents isolated from the rhizomes of *B. pandurata* are presented in **Fig. 2** (Voravuthikunchai *et al.* 2007).

A broad range of biological activities have been attributed to *B. pandurata*. These include antibacterial (Palittapongarnpim *et al.* 2002; Voravuthikunchai *et al.* 2005b, 2006d) and anti-giardial (Sawangjaroen *et al.* 2005) activities. Finger root contains 1-3% of essential oil. Several aroma components from its rhizomes contained high levels of 1-8 cineol, camphor, δ-borneol, methyl cinnamate, geraniol, and camphene being the most important. Trace components are δ-pinene, zingiberene, zingiberone, curcumin, and zedoarin. The oil of *Boesenbergia pandurata* rhizomes has been reported to be effective against dermatophytes, filamentous fungi and yeast-like fungi including *C. albicans* and *C. neoformans* (Jantan *et al.* 2003). Its activities against *S. mutans* (Hwang *et al.* 2004), *L. monocytogenes* and *S.* Typhimurium have been reported (Thongson *et al.* 2005). In our series of studies, we found that among the three flavonoids, alpinetin, pinocembrin, and pinostrobin, isolated from methanolic extract of *B. pandurata*, pinocembrin was the most potent antimicrobial compound. It exhibited activity against *S. aureus* (MIC 256 μg/ml) (Voravuthikunchai *et al.* 2006d), *E. histolytica* (MIC 125 μg/ml) (Sawangjaroen *et al.* 2006) *M. tuberculosis* (MIC 25 μg/ml (Phongpaichit *et al.* 2006), and *M. gypseum* (MIC 32 μg/ml) (Phongpaichit *et al.* 2005). However, it showed no effect on *C. albicans* (Phongpaichit *et al.* 2005).

Moreover, this plant also displayed antimutagenic (Trakoontivakorn *et al.* 2001), antitumor (Murakami *et al.* 1993, 1995), anti-hepatocarcinogenic (Tiwawech *et al.* 2000), anti-inflammatory, analgesic, and antipyretic activities (Pathong *et al.* 1989). Both natural and synthetic chalcones are known to exhibit immunostimulatory activities (Barfod *et al.* 2002), anti-inflammatory (Tuchinda *et al.* 2002), anticancer (Saydam *et al.* 2003), and anti-tuberculosis (Lin *et al.* 2002). Panduratin A, sakuranetin, pinostrobin, pinocembrin, and dihydro-5,6-dehydrokawain from chloroform extracts of the rhizomes were reported to be responsible for the anti-inflammatory effect (Tuchinda *et al.* 2002). In addition, the chloroform and methanol extracts of *B. pandurata* have been reported to have HIV-1 protease inhibitory activity (Trakoontivakorn *et al.* 2001).

It is obvious that this plant may have a high potency to be used as a food additive since it possesses appreciable antibacterial activities. Its safety is also supported by a previous report on the low toxicity and lack of mortality in rats after 7 days of treatment (Pathong *et al.* 1989).

Curcuma amada Roxb.

Common names: amada, amba haldi, mango ginger (**Plate 3**).

The main use of *C. amada*, or mango ginger rhizome is in the manufacture of pickles. It has a morphological and phylogenic resemblance with ginger but imparts a mango (*Mangifera indica*) flavor. Themango flavor is mainly attributed to car-3-ene and *cis*-ocimene among the 68 volatile aroma components present in the essential oil of mango ginger rhizome (Singh *et al.* 2002, 2003). The mango ginger rhizome has been extensively used as an appetizer, alexteric, antipyretic, aphrodisiac, and laxative. In Ayurveda, it has been applied to cure biliousness, itching, skin diseases, bronchitis, asthma, hiccough and inflammation as a result of injuries (Warrier *et al.* 1994). High antibacterial activity of difurocumenonol, a new antimicrobial compound from mango ginger against a wide range of bacteria has been recently demonstrated (Policegoudra *et al.* 2006). Difurocumenonol possesses four-hydroxyl, six-methyl and one-carbonyl groups along with two furan rings. Difurocumenonol by virtue of possessing two furan rings, which are aromatic in nature, thus possesses units, which are capable of exhibiting

Plate 3 ***Curcuma amada*** **Roxb.**

Plate 4 ***Curcuma longa*** **L.**

delocalization of electrons, a feature that has been proposed to be responsible for increased antibacterial activity (Ultee *et al*. 2002). These may account for the enhanced activity of difurocumenonol compared with its source extract. The bioactivity of difurocumenonol may be similar to several other compounds like curcumin, capsaicin, caffeic acid, carvacrol, eugenol and menthol (Apisariyakul *et al*. 1995; Cichewicz and Thorpe 1996; Ali-Shtayeh *et al*. 1997; Cowan 1999). In addition, the presence of hydroxyl groups in plant derivatives has been associated with many biological activities (Phillipson 1995; Halliwell *et al*. 1995; Tess *et al*. 1999; Laurence *et al*. 2001; Tegos *et al*. 2002; Adewole *et al*. 2004; Burt 2004). The hydroxyl group may be actively responsible for depletion of ATP-dependent metabolic functions, ultimately leading to cell death (Ultee *et al*. 2002). Further, the presence of oxygen function in the framework of the compound increases the antibacterial properties (Naigre *et al*. 1996).

Curcuma longa L.

Common names: curcuma, cucurmin, geelwortel, huldi, gelbwurz haldi, Indian safran, kakoenji, koenir, koenjet, koenjit, kondin, kurkuma, kunir, kunyit, oendre, rame, renet, safrandes indes, temu, temu kuning, tius tumeric, turmeric, ukon goeratji (**Plate 4**).

This perennial plant is native to Indonesia, India, South and Southeast Asia. When the roots of *Curcuma longa* are dried and ground, the result is a yellowish-orange powder called 'turmeric' (Indian saffron). Turmeric is an ancient spice and a traditional remedy that has been used as a medicine, condiment and flavoring. There is also a vegetable which has all the properties of the true saffron, as well as the color, and yet it is not really saffron. From thousand of years turmeric has been used with no side effects. Curcumin is the active ingredient in turmeric which has been shown to have a wide range of therapeutic effects and can be used as natural preservative. Powdered turmeric, or its extract, is found in numerous commercially available botanical supplements. Studies have also shown that curcumin even in large quantities does not produce any known side effects in humans. The FDA classifies turmeric as GRAS (General Recognized as Safe).

The presence of carotenoids is responsible for its lemon yellow color. It has a bitterish, slightly acrid taste and a peculiar fragrant odor. It is one of the principle ingredients of curry powder. It is also used in pickles, relishes, and mustards as a coloring and flavoring agent. Turmeric has found application in canned beverages, baked products, dairy products, ice cream, yogurts, yellow cakes, biscuits, popcorn-color, sweets, cake icings, cereals, sauces, gelatines, direct compression tablets, etc. In combination with Annatto (E160b) it has been used to color cheeses, dry mixes, salad dressings, winter butter, and margarine. Interestingly, γ–irradiation showed no effect on the color of turmeric (Chatterjee *et al*. 1998).

In Ayurvedic medicine, turmeric, the powdered rhizome of the herb has traditionally been used as a treatment for epilepsy, bleeding disorders, skin diseases, fevers, diarrhea, urinary disorders, poisoning, cough, lactation problems as well as inflammation, wounds and tumors (Ammon and Wahl 1991). The rhizome of *C. longa* has long been used in Thai traditional medicine for treatment of itching and other skin diseases (Tewtrakul and Subhadhirasakul 2006). The Chinese use turmeric to improve digestion, reduce gas, and to stimulate bile production in the liver. The rhizome are crushed fresh and the juice was mixed with water and used as a treatment for ear infections, cleaning the nasal passages. Herbalists recommend it for many health disorders like digestive disorders, irritable bowel syndrome, colitis, Crohn's disease, diarrhea, and post-salmonella infection, skin diseases, wound healing, eye disorder, atherosclerosis, and liver problems. It improves beneficial intestinal microbiota, while inhibiting certain harmful bacteria.

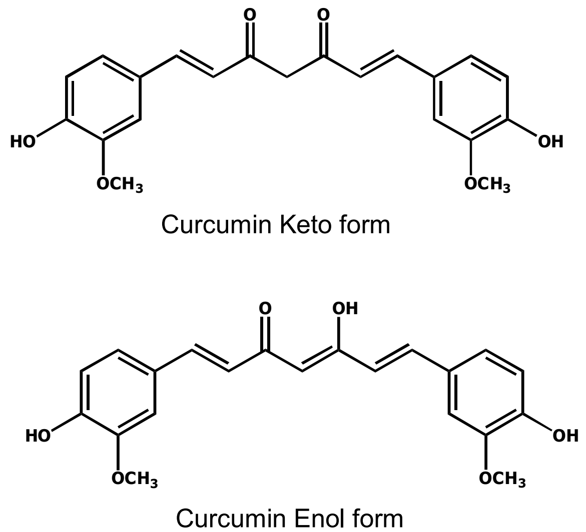


Fig. 3 Curcumin from the rhizomes of *Curcuma longa* L.

Curcumin (**Fig. 3**) (http://en.wikipedia.org/wiki) is known for its antimicrobial (Martins *et al*. 2001), anti-inflammatory, antioxidant (Nakatani 2000), anticancer (Surh 1999), and anti-allergic (Yano *et al*. 2000) properties. The active components of turmeric are the curcuminoids (Xu *et al*. 2006). Interestingly, the rhizome has liver protection properties. This juice is taken one spoon for children and one to two for adults, once a day for l0 to l5 consecutive days for hepatitis. In preclinical animal studies, turmeric has shown anti-inflammatory (Araújo and Leon 2001), cancer-chemopreventive and antineoplastic properties (Kelloff *et al*. 1996). Curcumin appears to be able to act at multiple sites to reduce inflammation (Aggarwal *et al*. 2003; Lantz *et al*. 2005). Turmeric has proven to decrease blood lipid peroxides in humans (Ramirez-Bosca *et al*. 1995, 1997) and prevent ulcers (Prucksunand *et al*. 2001). It also protects the liver from chemical injury (Sohni and Bhatt 1996; Song *et al*. 2001), and alleviate pain from arthritis (Kulkarni *et al*. 1991). A recent study showed that turmeric dramatically lowers blood fibrinogen levels (Dean 2000). Fibrinogen is a substance in the blood that is responsible for the final step in the blood clotting cascade. The formation of blood clots may cause heart attacks or strokes (Olajide 1999). High fibrinogen levels have been shown to be an even more significant risk factor for heart disease and stroke than cholesterol.

Curcuma zedoaria (Christm.) Roscoe

Common name: white turmeric, zedoary, zedoary root (**Plate 5**).

It is found in the East Indies and Cochin-China. There are two kinds of zedoary, the long and the round, distinguished by the names of *radix zedoaria longae* (Curcuma Zerumbet, the Long Zedoary of the shops) and *radix zedoaria rotundae*. The long is in slices, or oval fingers; the round in transverse, rounded sections, twisted and wrinkled, greyish-brown in color, hairy, rough, and with few root scars. The odor is camphoraceous, and the taste warm, aromatic, and slightly bitter, resembling ginger. The powder is colored brown-red by alkalis and boric acid. The zerumbet has been erroneously confused with the round zedoary. The main chemical components are curzerenone 22.3%, 1-8 cineole 15.9%, germacrone 9% (Purkayastha *et al*. 2006). *Curcuma zedoaria* has been used as a substitute for *Curcuma longa*. It is used in flatulent colic and debility of the digestive organs. It is used as an ingredient in antiperiodic pills and antiperiodic tincture. It has recently been reported to show anti-allergic activity (Matsuda *et al*. 2004).

Plate 5 *Curcuma zedoaria* (Christm.) Roscoe.

Kaempferia galanga

Common name: Proh hom (**Plate 6**).

Plate 6 *Kaempferia galanga*.

It is an acaulescent perennial that grows in Southern China, Indochina, Malaysia and India. Essential oils from its rhizomes have been used in Thai traditional medicine for indigestion, cold, pectoral and abdominal pains, headache and toothache urticaria and allergy. The rhizomes have been used in Chinese medicine as an aromatic stomachic. Its alcoholic maceration has also been applied as liniment for rheumatism (Keys 1976).

The constituents of this rhizome consist of cineol, borneol, 3-carene, camphene, kaempferol, kaempferide, cinnamaldehyde, *p*-methoxycinnamic acid, ethyl cinnamate, and ethyl *p*-methoxycinnamate. Ethyl *p*-methoxycinnamate was reported to inhibit monoamine oxidase (Noro *et al*. 1983). The rhizome extract of *K. galanga* exhibited inhibitory activity against Epstein-Barr virus (EBV) (Vimala *et al*. 1999). The methanolic extract of *K. galanga*, which identified as ethyl cinnamate, ethyl *p*-methoxycinnamate and *p*-methoxycinnamic acid, showed larvicidal activity against *Toxocara canis* (dog roundworm) (Kiuchi *et al*. 1988). *K. galanga* extract possessed effective amoebicidal activities for *Acanthamoeba culbertsoni*, *Acanthamoeba castellanii*, and *Acanthamoeba polyphaga*, the causative agents of granulomatous amoebic encephalitis and amoebic keratitis (Chu *et al*. 1998). Pitasawat *et al*. (1998) demonstrated significant larvicidal activity of this plant species against *Culex quinquefasciatus*.

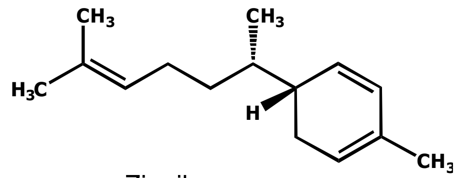
Zingiber officinale

The genus *Zingiber* has about 85 species of aromatic herbs mostly distributed in East Asia and tropical Australia (Mabberley 1990). The term '*Zingiber*' is derived from the Sanskrit word '*shringavera*', owing to their 'horn-shaped' rhizomes (Sabulal *et al*. 2006). *Zingiber* species are rich in volatile oils and are used in traditional medicine and as spices. Ginger is on the GRAS list from FDA, however, like other herbs, ginger may be harmful because it may interact with other medications, such as warfarin.

Even though ginger is native to Southeast Asia, it is widely used in both western and oriental dishes. Oleoresin from ginger roots can be found in ginger ale, gingerbread, gingersnap cookies, ginger tea, ginger wine, cordials and candies, as well as a number of great Chinese, Indian, and Jamaican dishes. It has been used in Indian traditional medicine for relief from arthritis, rheumatism, sprains, muscular aches and pains, congestion, coughs, sinusitis, sore throats, diarrhoea, cramps, indigestion, loss of appetite, motion sickness, fever, flu, chills, etc. (Varier 1996). In addition to its aromatic contribution to a food, ginger tea is often used to improve circulation, aid digestion, and treat nausea from motion sickness, pregnancy or chemotherapy. Medical research has shown that ginger root is an effective treatment for nausea caused by motion sickness or other illness (Ernst and Pittler 2000).

Organic compounds present in ginger include zingiberol, zingiberene (**Fig. 4**), bisabolene, α-curcumene, linalool, cineole, gingerol, and gingerone (Xu 1990). Volatile oils from the rhizomes of *Z. officinale* (**Plate 7**) have been characterised (Pino *et al*. 2004). The volatile oil of ginger contains zingiberene, α-curcumene and farnesene, while the pungent taste is due to gingeroles and zingerone. Zingiberene and α-curcumene, the major constituents in most of the rhizome oils of *Z. officinale*, are known for insecticidal, repellent and insect feeding deterrent activities (Sakamura *et al*. 1986; Millar 1998; Pino *et al*. 2004).

The ethnomedical and pharmacological activities of *Z. officinale* have been reviewed by various authors (Afzal *et al*. 2001). In addition to its antioxidant (Nakatani 2000) and antimicrobial activities (Martins *et al*. 2001; Wang and Ng. 2005), ginger is most noted for its actions to safely relieve nausea from many causes including morning sickness, labyrinthitis, and motion sickness (Ernst and Pittler 2000) improve digestion (Gupta and Sharma 2001) lower cholesterol (Bhandari *et al*. 1998) and prevent seizures (Minami *et al*. 2000). It has been used as anti-asthmatic agent in Thai traditional medicine (Wutthithamavet 1997). It can prevent cancer (Surh 1999) and the formation of blood clots which



Zingiberene

Fig. 4 Zingiberene from the rhizomes of *Zingiber officinale*.

Plate 7 *Zingiber officinale*.

may cause heart attacks or strokes (Olajide 1999; Koo *et al*. 2001). It also protects the liver from chemical injury (Sohni and Bhatt 1996; Song *et al*. 2001) and alleviate pain from arthritis (Kulkarni *et al*. 1991; Altman and Marcussen 2001).

Zingiber zerumbet (L.) Roscoe ex Sm.

Common names: broad-leaved ginger, pinecone ginger, pine-cone ginger, shampoo ginger, wild ginger, zerumbet ginger (**Plate 8**).

Z. zerumbet is native to Southeast Asia but has been widely cultivated in tropical and subtropical areas around the world. It grows to about seven feet tall with long narrow leaves arranged oppositely along the stem. In mid to late summer, separate stalks grow out of the ground with green cone-shaped bracts that resemble pinecones. The green cone turns red over a couple of weeks and then small creamy yellow flowers appear on the cone. In some locales, this plant is known as the 'pinecone ginger', but it is most widely known as the 'shampoo ginger' for the creamy liquid substance in the cones.

The rhizomes are mashed with salt and used to treat headaches. It has been used as against tooth and stomachache, antiflatulant, and anti-inflammatory agent (Wutthithamavet 1997). Chemical composition of the volatile oils from different parts of *Z. zerumbet* have been characterised (Chane-Ming *et al*. 2003). Zerumbone is the major component in rhizome oils of *Z. zerumbet* (Chane-Ming *et al*.

Plate 8 ***Zingiber zerumbet*** **(L.) Roscoe ex Sm.**

2003; Nakamura *et al*. 2004). It shows potential insecticidal (Chane-Ming *et al*. 2003) antibacterial (Kitayama *et al*. 2001) and chemopreventive (Murakami *et al*. 2002; Kirana *et al*. 2003) activities.

The ginger family also houses many other members which are less common such as *Kaempferia parviflora*. Its rhizome is used for the treatment of allergy and gastrointestinal disorders as well as an aphrodisiac (Pengcharoen 2002).

Zingiber nimmonii (J. Graham) Dalzell, an endemic species from the Western Ghats in South India, grows both at low and high altitudes, in moist areas under the shades of trees (Sabu. 2003). Its rhizomes are fleshy with a yellowish cross-section and an occasional purple tinge. The antibacterial and antifungal activities of the rhizome oil of *Z. nimmonii* have been reported (Sabulal *et al*. 2006).

Zingiber mioga Roscoe (Myoga) appears in Japanese cuisine; the flower buds are the part eaten.

Zingiber montanum (Koening) Link ex Dietr. (Syn. *Zingiber cassumunar* Roxb.) (Phlai) It is used for the treatment of inflammation and skin disease (Wutthithamavet 1997). Cardamom, whose sweet, aromatic seeds contain about 8% essential oil and a number of the previously mentioned compounds. In the past, cardamom was used as an aromatic in pomanders, and as an aphrodisiac. It is an essential part of Arabic coffee, and is also used in meat and rice dishes.

Properties of rhizome oils from many other Zingiber species such as *Zingiber cassumunar* (Bordoloi *et al*. 1999; Tewtrakul and Subhadhirasakul 2006), *Zingiber ottensii* (Thubthimthed *et al*. 2005), *Zingiber wrayi* var. *halabala* (Chairgulprasert *et al*. 2005) have been studied.

CONCLUDING REMARKS

The literature outlines different approaches within this trend and both the biological screening of new natural products from family Zingiberaceae and the evaluation of new properties. For manufacturing processes of food products, quality, safety, long-term adverse effects, and toxicity are primary concerns. To establish food product safety and efficacy, extensive safety studies including toxicity studies, supplementary studies in animals, and clinical trials in humans are necessary. The safety assessment of chemical preservatives in food and food supplements is complicated. Detailed scientific studies on the members of family Zingiberaceae should lead to effective application of the plant extracts as natural food preservative agents to control spoilage organisms and food-borne pathogens in food industry.

ACKNOWLEDGEMENTS

Research work on Family Zigiberaceae was funded by Thai Government Budget, Fiscal year 2001-2003 and the Thailand Research Fund, Fiscal year 2005-2008.

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www.nutraingredients.com/news
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