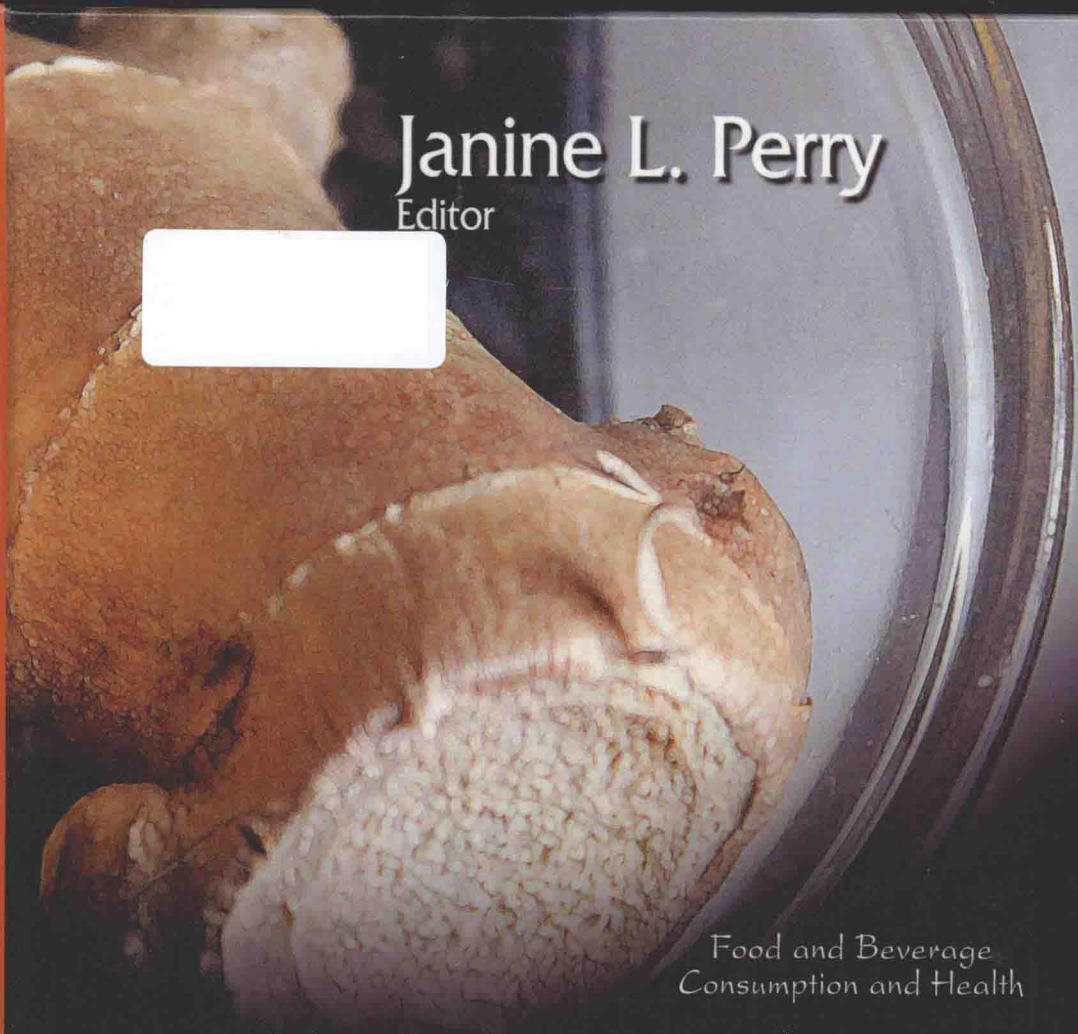

Janine L. Perry
Editor

Food and Beverage Consumption and Health

Ginger

Antioxidant Properties, Functions and Medicinal Benefits

NOVA

FOOD AND BEVERAGE CONSUMPTION AND HEALTH

GINGER

ANTIOXIDANT PROPERTIES, FUNCTIONS AND MEDICINAL BENEFITS

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PREFACE

This book discusses all of the properties, as well as its functions and the medicinal benefits of ginger.

Chapter 1 - *Zingiber officinale* Roscoe (ginger) has been used in popular medicine since ancient times, being explored for its effects anti-inflammatory, antiemetic, anti-microbial and several other properties by both common folk and scientific community. Apart from its well-known folklore uses, there are several more studies that can be found in scientific research which describe many other capabilities of this plant. Also, several investigations have associated ginger with medicinal benefits, as antioxidant, anti-inflammatory and analgesic, antiemetic, anti-diarrheal, anti-ulcer, anti-cancer, anti-cholinesterasic, anti-bacterial, anti-fungal, anti-parasitary and preventing intoxications. So this chapter was prepared with the aim to contribute to the understanding of ginger, its general characteristics, physicochemical properties, pharmacological and toxicological properties as well as elucidating biochemical mechanisms whenever possible. Several beneficial and applicable effects of ginger have already been vastly studied and documented, such as the anti-inflammatory properties. Recent researches demonstrate that ginger possesses still other applications, and it could be useful in the treatment cardiovascular diseases and other metabolic problems. It is important to state that the antioxidant activity of ginger's phenolics is the main property responsible for the majority of the other effects described in this review. Studies published in the few past decades to more recent years will be presented.

Chapter 2 - The use of medicinal plants for developing new medications with therapeutic potential deservedly stands out in research. Numerous medicinal species have been reported in the literature, with promising possibilities of discovery of new drugs and also other products, with different

potential uses. Ginger (*Zingiber officinale* Roscoe 1807) is of particular interest among these species, since it has been known for millennia and has been widely used by the population, mostly in cookery. Research on the chemical composition of ginger has indicated that it has important biological activity such as antimicrobial and antioxidant action, among other forms of activity. Because of these chemical characteristics, ginger has wide-ranging pharmacological use, with action on metabolism activity and use in treating diseases such as obesity (which is a risk factor for cardiovascular diseases), some types of cancer, psychological disorders and diabetes, among others. Studies have shown the worryingly negative aspects of obesity with regard to the population's health. Thus, adding foods that can enhance metabolic activity, as is the case with ginger, has a direct influence on excessive food intake and constitutes a promising strategy. In addition to characteristics relating to pharmacology, other potential uses broaden the functionality of ginger, such as the fact that this species is considered to be a potential insecticide. Plant extracts from ginger have been used in several types of insect pest control. Moreover, results from research have indicated that ginger can be multifunctional for agriculture, with contributions towards management and control of several food production chains, which broadens the diversity of new products used in agriculture, with the aim of integrated management for agricultural production, thus ensuring food quality. This chapter addresses some interesting aspects of research on the use of ginger for the treating various illnesses and also indicates its potential use in controlling and managing sustainable agricultural production. Ginger is a multifunctional medicinal species, with diverse actions and wide-ranging use for development of new products.

Chapter 3 - The rhizome, stem and leaves of ginger (*Zingiber officinale*) exhibit antioxidant activity. However, the bulk of studies was done using the rhizome extract and some were performed using the essential oil. Compounds have been isolated and chemically characterized from ginger. The anti-diabetic, neuroprotective, gastroprotective, nephroprotective, and cardio-protective actions of ginger are related to its antioxidant activity. Ginger has a beneficial effect on male reproduction in rodents and broiler chickens. It ameliorates the toxicity of insecticides. These actions may also be related to its antioxidant activity.

Chapter 4 - Ginger displays protective effects on Alzheimer's disease. It brings about attenuation of neuroinflammation and cognitive deficits. It exhibits anti-inflammatory, anticancer, antihypercholesterolemic, hepato-protective, anti-rheumatoid arthritis, antinociceptive, anti-viral, anti-

schistosomal and insecticidal activities. It inhibits bacterial biofilm formation. It prevents nausea and vomiting, and exerts a protective effect on the metabolic syndrome-associated kidney injury. It decreases the severity of symptoms of premenstrual syndrome.

Chapter 5 - Ginger is a world known food plant which is equally reputed for its food flavoring and medicinal properties. 6-Gingerol is the major phenolic plant secondary metabolite present in the rhizome of ginger. This chapter reports chemical structure, biosynthesis, analytical methods and pharmacology as well as most recent research findings on potential cardiovascular health benefits of 6-gingerol. Qualitative and quantitative analytical techniques for the analysis of 6-gingerol and for the determination of the metabolism and bioavailability of 6-gingerol are discussed. Analytical techniques used for 6-gingerol that are described in this chapter are thin-layer chromatography (TLC), high-performance liquid chromatography (HPLC) combined with various detectors, and nuclear magnetic resonance (NMR) spectroscopy. The potential cardiovascular health effects of 6-gingerol include, anti-atherosclerotic, anti-platelet aggregation and antihypertensive effects as well as fibrinolytic activity.

Chapter 6 - In this study, a gas chromatography–mass spectrometry method in EI mode is developed for the analysis of dried Korean ginger. Hydro distillation–headspace solvent microextraction with polar and non-polar solvents is used. Forty-nine compounds are separated and identified. Some of the ginger compounds partially or completely were thermally decomposed. Some of these decomposition products likely produced when ginger is used in cooking at high temperatures and subsequently eaten. The major compounds in the rhizome identified are α-zingiberene, curcumene, camphene, β-phellandrene, (E)-citral, α-farnesene, β-bisabolene, β-sesquiphellandrene, zingerone, and [6]-gingerol. This method will be useful for rapid screening purpose of plant samples for finding of high quality ginger under the plant breeding program, genotypes assessment, and also export quality of ginger species.

Chapter 7 - Researchers have for many decades been trying to develop new broad-spectrum antibiotics against the infectious diseases caused by bacteria. Prolonged usage of these broad-spectrum antibiotics has led to the emergence of drug resistance. Resistance to antimicrobial agents has become an increasingly important and pressing global problem. There is a tremendous need for novel antimicrobial agents from different sources.

Plants used in traditional medicine are still understudied, particularly in clinical microbiology. So seeking for the *in vitro* antimicrobial activity of

natural compounds such as polyphenols from ethnomedicinal plants on pathogenic bacteria is a new challenge.

Therefore, the authors investigated the possibility of the plants having the capacity to confront these bacteria.

CONTENTS

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Chapter 1

ZINGIBER OFFICINALE ROSCOE, A PLANT OF MULTIPLE USES: A REVIEW OF PAST AND RECENT RESEARCH

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ABSTRACT

Zingiber officinale Roscoe (ginger) has been used in popular medicine since ancient times, being explored for its effects anti-inflammatory, antiemetic, anti-microbial and several other properties by both common folk and scientific community. Apart from its well-known folklore uses, there are several more studies that can be found in scientific research which describe many other capabilities of this plant. Also, several investigations have associated ginger with medicinal benefits, as antioxidant, anti-inflammatory and analgesic, antiemetic, anti-diarrheal, anti-ulcer, anti-cancer, anti-cholinesterasic, anti-bacterial, anti-fungal, anti-parasitary and preventing intoxications. So this chapter was prepared with the aim to contribute to the understanding of ginger, its general

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characteristics, physicochemical properties, pharmacological and toxicological properties as well as elucidating biochemical mechanisms whenever possible. Several beneficial and applicable effects of ginger have already been vastly studied and documented, such as the anti-inflammatory properties. Recent researches demonstrate that ginger possesses still other applications, and it could be useful in the treatment cardiovascular diseases and other metabolic problems. It is important to state that the antioxidant activity of ginger's phenolics is the main property responsible for the majority of the other effects described in this review. Studies published in the few past decades to more recent years will be presented.

Keywords: Ginger, biological properties, review

INTRODUCTION

Zingiber officinale Roscoe, known popularly as ginger, is a plant belonging to the Zingiberaceae family. Although its most popular use is as a spice, ginger has been used widely in Asian countries for medicinal purposes for centuries. Some of ginger's common uses include: antiemetic, cardiotonic, anti-inflammatory, hypoglycemic, antibacterial, anti-tumor, antifungal and antioxidant. More accurately, the rhizome is the main part used for all of these effects [1].

Increasing search for natural substances with pharmacological actions has given researchers wide field for studies. Population tends to have more acceptances towards natural products, such as herbs and roots.

However, ginger usage must have a cautious approach: even possessing lots of therapeutic uses, ginger can also cause toxic reactions if misused [2], as expected from any other plant.

There are several studies published in the last years that verify ginger`s pharmacological properties, as well as its major components that provide such effects. Literature already contains some reviews concerning ginger [1,3,4], as well as specific reviews that evaluate some of its effects on human health, such as its effects on the cardiovascular system [5], its antiemetic properties [6,7], and its anti-cancer properties [8].

This review has as its objective to summarize the uses of ginger and its pharmacological properties present in the scientific literature, including both older and more recent research.

CHEMISTRY

The great number of uses ginger has is due to the large number of chemical compounds it possesses. Although there are several chemical components, most of them can be identified as phenolic structures, such as the gingerols, which are responsible for antioxidant properties [9, 10]. Flavonoids are also included among ginger's chemical components [11].

Volatile terpenoids can also be found, responsible for the characteristic odor of ginger [12].

It is important to note that there aren't academic papers where the authors fully agree on the main chemical components found in ginger's rhizome. This is expected, since compounds present in the rhizome tend to vary greatly according to the precedence of the rhizome, growth and storage conditions, extraction methods and identification methods used.

The most common methods to obtain the chemical components include extraction with solvents [9, 13, 14] and, in some cases, the use of supercritical fluid, such as carbon dioxide – CO_2 [9, 10].

Use of different co-solvents have already been studied, and although different possibilities exist, like ethanol, isopropyl alcohol, acetone, hexane and petroleum ether, each results in ginger extracts with different components [9,14]. Harvest season, drying and storage manner cause alterations in the composition of ginger extracts [15]. Photosynthesis interferes with the production of primary and secondary metabolites, therefore the influence of light and CO_2 can influence the pathways of major chemical components [16, 17]. The different forms of rhizome processing interfere in its composition, as it can be sliced or triturated before extraction [18].

Finally, in the majority of studies, ginger's chemicals are usually analyzed through gas spectrometry coupled to mass spectrometry [13-15], which has been proven a reliable method of analysis of not only ginger extracts, but extracts from other plants as well.

Figure 1 shows the major components of ginger oil and ginger extracts: zingiberene, 6-gingerol and shogaols [9, 10, 15].

As it would be expected, most studies about ginger pharmacological properties involve particularly these compounds.

Of course, these are only the main chemicals, but there is an infinity of other compounds that can be found in ginger in smaller amounts: geranial, neral, geraniol, eucalyptol, canfen, geranyl acetate, ß-bisabolen, ß-felandren, camphor, myrcene, and many others [11, 13, 15].

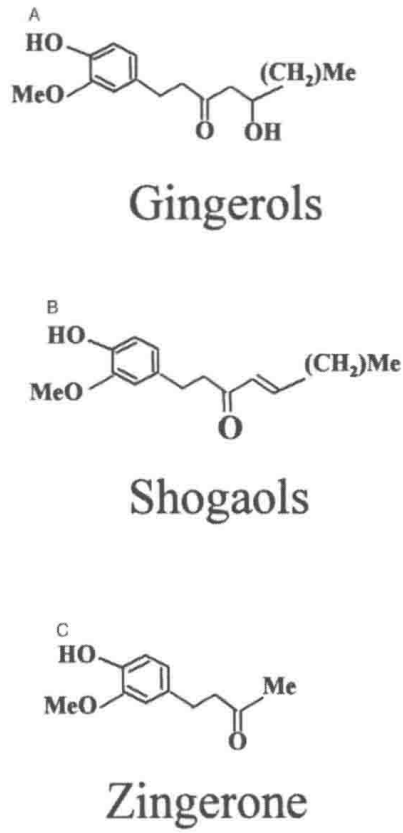

Figure 1. Main chemical compounds found in ginger oil/extracts. A: gingerol basic structure; B: shogaol basic structure; C: zingerone.

PHARMACOLOGICAL PROPERTIES

Antioxidant Property

All phenolic components, from geraniols to shogaols, are responsible to some extension for the antioxidant effects of ginger's rhizome. Researchers had used various methods to show this effect, and the most common methods employed are the DPPH (20-diphenyl-1-picrylhydrazyl), thiobarbituric acid and ferric thiocyanate radical scavenging assays. The antioxidant potential of ginger in these studies is comparable to common synthetic antioxidants, such as BHT (butyl hidroxylated toluene), even surpassing them in some studies [11, 13, 19].

Many intoxications and diseases are associated with free oxygen radicals. As ginger helps nullifying them, it is no surprise that many problems related to free radicals can be attenuated by ginger's extract. For example, studies demonstrated that cisplatin induces nephropathy by depleting the antioxidant renal systems by lowering reduced glutathione levels. Ginger extracts can scavenge the free radicals generated by cisplatin, maintaining the glutathione levels tolerable and preventing renal damage [20]. Acetaminophen induces hepatotoxicity by the same way, ginger extracts prevent the depletion of reduced glutathione and improve the antioxidant status of the liver, keeping the damage to a minimum [21]. In gastric ulcer models, the gastrointestinal damage causes increase in the levels of enzymes xanthine oxidase and myeloperoxidase, administration of ginger extracts can attenuate the increase in enzyme activity caused by oxidative distress generated by neutrophils and lipid peroxidation [22]. Generation of free radicals caused in arthritis conditions also increases superoxide dismutase and catalase levels and decreases the concentration of reduced gluthatione, ginger extracts are capable of stabilizing the activity of such enzymes and also of restoring the reduced glutathione levels [23].

Most studies found in the literature were performed with ginger extracts, but some show research done with isolated ginger compounds, in order to find a specific chemical with the most antioxidant capability. Several components have been obtained as derivates from zingiberene, one major ginger component. Studies with such derivates elucidated that the number and position of hydroxyl groups attached to the main aromatic structure are critical to the antioxidant activity of zingiberene. Since zingiberene is one of the phenolics present in ginger, it is suggested that other phenolics should work the same way [24]. Another substance, 6-gingerol, is a compound frequently studied, it is a potent inhibitor of oxidation caused by nitric oxide and its derivates, and it also prevents DNA damage caused by the formation of peroxynitrite.

In HepG2 cells subjected to radiation at LD50 doses, pre-treatments with 6-gingerol are capable of reducing cell death and regulating the activity of enzymes catalase and superoxide dismutase. Since nitric oxide synthesis and formation of radicals rely on reactions involving oxygen and superoxides, and that the activity of the enzymes superoxide dismutase and catalase are related directly to the intensity of oxidative distress, the activities of 6-gingerol reinforce the fact that ginger's polyphenols are strong antioxidants [25, 26].

Although the majority of studies performed with ginger made use only of the rhizomes, leaves and stem also have radical scavenging properties.

Even if the exact components and their proportions vary depending on the part of the plant, polyphenols can always be encountered in the whole plant, and not only in the rhizome. Rhizome and leaves have almost the same antioxidant capacity. The stem, however, exhibits only half the antioxidant potential shown by the other plant parts [11].

Anti-Inflammatory and Analgesic Properties

One of ginger's most common uses is as an analgesic, due to its anti-inflammatory properties. It is known that the inflammatory response that generates pain is mediated by a lot of factors, and ginger is capable of interfering with the inflammatory response through many of these factors. Scientific literature even has reviews dedicated to this matter alone [27].

Anti-inflammatory action of ginger comes from the inhibition of inflammatory prostaglandins. This happens because most of ginger's phenolic compounds, mainly 6-gingerol, are capable of inhibiting COX-2, thus preventing inflammatory prostaglandins, like PGE2, from being synthesized; 5-LIPOX is also inhibited, preventing leukotriene synthesis. A study demonstrated that not only 6-gingerol, but also 10-gingerol, 12-gingerol, 8-shogaol, 10-shogaol, 6-gingerdione, 8-gingerdione, 10-gingerdione, 6-paradol and 8-paradol are all capable of inhibiting COX-2; 10-gingerol, 8-shogaol and 10-shogaol are also receptor-specific, capable of inhibiting COX-2 without interacting with COX-1. Even though this inhibition is not very strong, it certainly demonstrates that ginger's chemicals show potential as base structures for future development of anti-inflammatory drugs [28].

Studies performed with rodents which employed induced skin edema, acetic acid induced writhing, induced arthirtis and hot-plate models of induced inflammation, demonstrated preeminent value of ginger anti-inflammatory properties. In these studies, ginger-treated animals developed less skin edema, took more time to writhe and lick the forepaws, and paws exhibited less redness and swelling when compared to non-treated animals [23, 29-32]. In one of these studies, the prevention of inflammation effects caused by adjuvant arthritis was shown to be directly linked to COX-2 inhibition by ginger [32].

Another study using the rat skin edema model again demonstrated that inflammation can be attenuated by a ginger extract, however, the authors induced the inflammatory process for more than 4 hours, and at this point, no longer is the inflammation modulated by eicosanoids. Instead, it is regulated by serotonin, released by degranulation of mast cells. This study suggests that