Nutritional value of ginger in sustainable food systems

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ABSTRACT: *Currently, ginger continues to be a subject of major interest in scientific research due to its complex chemical composition and proven beneficial effects on human health. The therapeutic properties and practical uses of ginger provide an integrated perspective on its potential in the health and food industries. This paper analyzes the contribution of ginger to a balanced diet and its role in promoting sustainable diets based on natural ingredients, with a low environmental impact and multiple functional health benefits. In the food industry, ginger can be used to develop innovative products that combine its therapeutic benefits with consumer demands for functional and sustainable foods.*

KEY WORDS: ginger, health, functional, sustainable foods

1. INTRODUCTION

Ginger is known for its chemical complexity, including compounds such as gingerols, shogaols, and sesquiterpenes, which have demonstrated beneficial properties in various studies. It is important to understand the mechanisms by which these substances contribute to the therapeutic effects of ginger, thereby strengthening the scientific basis for its use in various applications [1].

The anti-inflammatory, antioxidant, and gastroprotective properties of ginger, highlighted by the results of clinical and experimental studies, show that they are particularly relevant in the context of preventing and treating chronic conditions such as systemic inflammation, oxidative stress, and digestive disorders.

This approach aims to highlight the potential of ginger as an adjuvant in modern therapies, while also providing insight into the mechanisms by which it can positively influence human health [2]. Another essential aspect of the benefits offered by ginger is the evaluation of its practical uses in various fields, such as traditional medicine, modern medicine, and the food industry.

Modern medicine uses ginger extracts and supplements to prevent and manage chronic diseases such as cardiovascular disease and cancer [3]. In the food industry, ginger is used as a natural flavoring and preservative due to its antimicrobial and antioxidant properties, being included in functional beverages and baked goods. Aromatherapy uses ginger essential oils for relaxation, stress reduction, and migraine relief. In agriculture, ginger is used as an ecological bio-pesticide due to its antimicrobial properties, which help combat pests [12]. The pharmaceutical industry integrates the active compounds in ginger into medicines for the treatment of inflammation, nausea, and pain, thus demonstrating the versatility of this plant in various fields. This wide range of uses highlights the importance of ginger as a multifunctional natural resource.

2. CHEMICAL COMPOSITION OF GINGER

a. The main active compounds in ginger

Ginger (Zingiber officinale) is known for its complex chemical composition, which includes a wide range of bioactive compounds with significant therapeutic properties. The main chemical components of ginger are gingerols, shogaols, and zingerones, which are responsible for its distinctive flavor and pharmacological effects (Fig. 1).

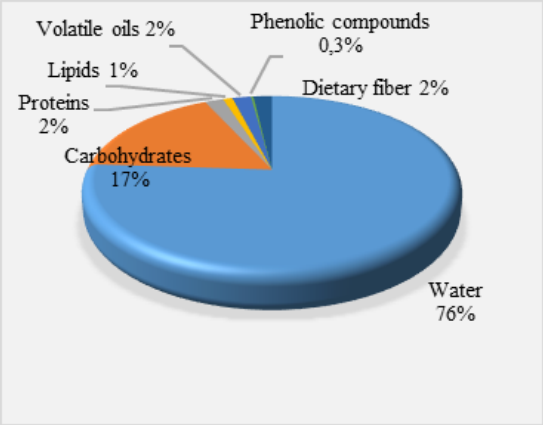

Fig. 1. Chemical composition of ginger per 100 g of fresh product

Gingerols, especially [6]-gingerol, are the major active compounds in fresh ginger, with anti-inflammatory, antioxidant, and analgesic effects. During the drying or cooking process, gingerols are converted into shogaols, which have greater therapeutic potency and are frequently used in treatments for pain and inflammation. A study conducted by Munda and colleagues in 2018 highlighted that ginger essential oils contain terpenes, such as zingiberene and bisabolene, which contribute to its antimicrobial and anti-inflammatory activity. These compounds are concentrated in the ginger rhizome, which is the part used for medicinal and culinary purposes [10,13].

Table 1 indicates the chemical composition of ginger, with the corresponding values of the main compounds, per 100g of fresh rhizome [16]. The table summarizes the main categories and types of chemicals present in ginger, relevant to both its nutritional profile and therapeutic benefits.

Table 1. Chemical composition of ginger - main compounds [16]

Component	Quantity (per 100g)	Main compounds
Water	78-80 g	-
Carbohydrates	17-18 g	Starch, sugars, dietary fiber
Proteins	1,8-2,0 g	-
Lipids	0,7-1,0 g	Fatty acids, saturated fats
Volatile oils	1,5-2 g	Zingiberene, bisabolene, zingiberol
Phenolic compounds	0,23-0,25 g	Gingerol, shogaol, paradol, zingerone
Dietary fiber	2 g	-

Table 2 compares the main active compounds in ginger (gingerol, shogaol, and paradol) in terms of chemical structure, organoleptic properties, natural formation, and major biological activity. These substances have important pharmacological activity, contributing to the anti-inflammatory, antidiabetic, and anti-obesity effects of ginger, with variations depending on the preparation and form consumed [13,15].

Table 2. Ginger active compounds comparison: structure, properties, formation, biological activity [13,15].

Characteristic	Gingerol	Shogaol	Paradol
Basic structure	Phenol, alkyl chain	Phenol, alkyl chain	Phenol, alkyl chain
Main functional group	β-hydroxy ketone	Ketone (dehydrated)	Ethyl (hydrogenated)
Taste/smell	Slightly spicy, fresh	Very spicy, hot	Slightly spicy, sweet
Natural formation	Raw rhizome (main)	Thermal dehydration from gingerol	Hydrogenation from shogaol
Thermal stability	Unstable when heated	Heat stable	Heat stable
Antioxidant activity	High	High	Moderate
Main biological activity	Anti-inflammatory, antioxidant, anti-diabetic	Anti-inflammatory, anti-diabetic, anti-obesity	Antidiabetic, anti-obesity
Absorption and bioavailability	Good	Good (metabolized into paradol)	Very good
Concentration in fresh rhizome	Highest	Low/moderate	Very low
Post-processing concentration	Decreases	Increases with heating	Increases through processing

b. Volatile compounds and essential oils

Ginger is a rich source of essential oils, which include volatile compounds such as zingiberene, curcumene, and farnesene. These essential oils are responsible for ginger's intense aroma and play an important role in its antimicrobial and antifungal activity [4]. A report published in Food Chemistry in 2018 showed that ginger essential oils have significant activity against gram-positive and gram-negative bacteria, making them useful in food preservation and infection treatments [2]. Ginger essential oils are also widely used in the cosmetics industry due to their antioxidant properties and ability to stimulate microcirculation.

c. Phenolic compounds and flavonoids

Flavonoids are present in ginger, but occur in much smaller quantities than terpenes or the main phenolic compounds (gingerol, shogaol, paradol). The most common flavonoids identified are quercetin, kaempferol, rutin, and naringenin. The total flavonoid content in fresh ginger root ranges from 1,4 to 3,5 mg/g (0,14 - 0,35% of dry weight).
These compounds play a crucial role in neutralizing free radicals and preventing oxidative stress, which is associated with the development of chronic diseases such as cancer and cardiovascular disease [3].

d. Vitamins and minerals

In addition to bioactive compounds, ginger is an important source of vitamins and minerals, which contribute to its health benefits (Table 3). Ginger contains vitamin C, vitamin B6, magnesium, potassium, and phosphorus, which are essential for optimal body function. Vitamin C, a powerful antioxidant, helps protect cells from damage caused by free radicals, while magnesium and potassium contribute to cardiovascular health by regulating blood pressure [3,15]. A report published by Rahman and his colleagues in 2009 in the Indian Journal of Traditional Knowledge highlighted that ginger is a rich source of micronutrients, which play an important role in supporting the immune system and preventing nutritional deficiencies [11].

Table 3. Mineral and vitamin content in ginger [16]

Mineral content/100 g fresh ginger	
Potassium	415 mg
Magnesium	43 mg
Iron	0,6 mg
Calcium	16 mg
Phosphorus	34 mg
Zinc	0,34 mg
Sodium	13 mg
Manganese	0,229 mg
Vitamin content/100 g fresh ginger	
Vitamin C	5 mg
Vitamin B6	0,2 mg
Vitamin B3 (niacin)	0,75 mg
Vitamin B2 (riboflavin)	0,034 mg
Vitamin B1 (thiamine)	0,025 mg
Vitamin E	0,26 mg
Vitamin K	0,1 µg

e. Fiber and carbohydrates

Ginger contains dietary fiber and carbohydrates, which contribute to digestive health and maintaining energy levels. The fiber in ginger helps regulate intestinal transit and prevent constipation, while carbohydrates provide a quick source of energy. A study conducted by White and colleagues in 2012, published in the Journal of Clinical Gastroenterology, showed that the fiber in ginger helps reduce intestinal inflammation and improve digestion [14]. These benefits make ginger a valuable ingredient in diets designed for digestive health.

3. PRACTICAL USES OF GINGER

Ginger (Zingiber officinale) is an important aromatic and medicinal plant whose practical applications extend well beyond traditional medicine. It plays a valuable role in the food industry as a natural antioxidant, preservative, and flavor enhancer, contributing to the improvement of shelf life and sensory quality of products. Moreover, its bioactive compounds - such as gingerols and shogaols - support its growing use in the pharmaceutical and cosmetic industries as functional ingredients with antioxidant, anti-inflammatory, and antimicrobial properties [7].

Table 4 presents the multiple areas of use of ginger and its health benefits.

Table 4. Practical uses of ginger (*Zingiber officinale*) [5,6,15].

Field of use	**Form of use**	**Benefits and applications**
Traditional medicine	Decoctions, tinctures, poultices	Treatment of colds, nausea, inflammation, and digestive problems.
Modern medicine	Extracts, capsules, dietary supplements	Reduction of inflammation, pain management, prevention of cardiovascular disease and cancer.
Food industry	Spices, essential oils, functional beverages	Food flavoring, natural preservation, improved digestion.
Cosmetology	Creams, lotions, shampoos, masks	Reducing skin inflammation, stimulating blood circulation, preventing skin aging.
Aromatherapy	Essential oils	Relaxation, stress reduction, migraine relief, and mood improvement.
Agriculture	Natural extracts	Pest control, use as an ecological bio-pesticide.
Pharmaceutical industry	Active ingredients in medicines	Formulation of anti-inflammatory, antiemetic, and analgesic drugs.

THE USE OF GINGER IN THE FOOD INDUSTRY

a. The role of ginger as a natural flavoring agent

Ginger (*Zingiber officinale*) is one of the most widely used spices in the food industry due to its distinctive aroma and functional properties. Its characteristic aroma, which combines spicy and sweet notes, is attributed to volatile compounds such as gingerols, shogaols, and zingerones. These substances not only provide a unique taste but also contribute to improving the sensory profile of food products. A study conducted by Kadam and his colleagues in 2019, published in the International Journal of Chemical Studies, highlighted that ginger is widely used in the preparation of baked goods, soft drinks, and sauces due to its ability to mask unpleasant tastes and intensify natural flavors [6]. Ginger is an essential ingredient in traditional Asian dishes such as curries and soups, but also in modern foods such as energy bars and functional drinks.

b. Using ginger as a natural preservative

In addition to its role as a flavoring agent, ginger is recognized for its antimicrobial and antioxidant properties, which make it an effective natural preservative. Bioactive compounds in ginger, such as gingerols and shogaols, inhibit the growth of pathogenic microorganisms, thereby extending the shelf life of food products [8]. A study published by Islam and his colleagues in 2012 in the Bangladesh Journal of Agricultural Research demonstrated that ginger extracts can significantly reduce bacterial contamination in meat and fish products without affecting their organoleptic quality [5]. These findings have led to the use of ginger in the production of processed foods, such as sausages and canned foods, as an alternative to chemical preservatives.

c. The use of ginger in drinks and functional products

The beverage industry has embraced ginger as a key ingredient in the development of functional products due to its health benefits and the growing demand for natural alternatives. Ginger-based beverages, such as ginger beer, teas, and juices, are popular not only for their taste but also for their beneficial effects on digestion and immunity. A report published in Food Chemistry in 2018 highlighted that functional beverages containing ginger extracts are preferred by consumers due to their perception as healthy and natural [2]. Ginger is also used in the production of energy drinks and dietary supplements due to its ability to boost metabolism and reduce fatigue.

d. The use of ginger in baked goods and sweets

Ginger is an essential ingredient in baked goods and sweets, where it is used for both its flavor and its functional properties. Products such as gingerbread, ginger cookies, and ginger biscuits are popular around the world due to their combination of taste and health benefits. A study by Mathew and his colleagues in 2018, published in Economic Oils, showed that ginger is widely used in the production of sweets and candies due to its ability to improve texture and extend the shelf life of products. Ginger is used in combination with other spices, such as cinnamon and cloves, to create complex and appealing flavors [9].

Table 5 presents a synthetic situation of functional foods containing ginger or its bioactive compounds.

Table 5. The synthetic situation of functional foods containing ginger or its bioactive compounds.

Product category	Example products	Functional role of ginger	Form of use / Main active compound	Product category
Functional beverages	Herbal teas, detox juices, infused water	Improves digestion, antioxidant and anti-inflammatory effect	Natural or synthetic ginger extract (6-gingerol)	Functional beverages
Dairy and fermented products	Probiotic yogurt with ginger, flavored kefir	Improves gut microbiota, reduces inflammation	Microencapsulated gingerol extract	Dairy and fermented products
Bakery and cereal products	Whole-grain biscuits, granola, ginger energy bars	Natural antioxidant, digestive stimulant, metabolism booster	Ginger powder or synthetic extract	Bakery and cereal products
Dietary supplements	Anti-inflammatory capsules, antioxidant complexes	Supports immune system, regulates glucose and body weight	Purified gingerol / 6-shogaol	Dietary supplements
Functional confectionery	Dark chocolate, candies, herbal lozenges	Tonic and stress-reducing effect through antioxidant action	Standardized ginger oleoresin	Functional confectionery
Ready-to-drink products	Smoothies and natural soft drinks	Thermogenic and metabolism-enhancing effect	Nanoencapsulated ginger extract	Ready-to-drink products

4. CONCLUSIONS

In the food industry, ginger is used both as a culinary ingredient and as a natural additive for food preservation due to its antimicrobial activity. Ginger can also be used as a dietary supplement for the prevention of cardiovascular and metabolic diseases, due to its ability to reduce serum cholesterol and glucose levels. Ginger is a plant with remarkable therapeutic and practical potential, which deserves greater attention from researchers, healthcare practitioners, and the food industry. Through the responsible and informed use of ginger, it is possible to contribute to improving quality of life and promoting natural therapies and sustainable food systems.

Recent research highlights the effectiveness of ginger's bioactive compounds - particularly gingerols, shogaols, and zingerone - in inhibiting the growth of foodborne pathogens such as *E. coli*, *S. aureus*, and *Salmonella typhi*, suggesting its promising role as a natural food preservative. Moreover, the integration of ginger extracts or essential oils into functional foods and clean-label formulations supports the transition toward safer, eco-friendly, and value-added products. Continued scientific investigation into its molecular mechanisms and optimal extraction

methods will further enhance its applications in both the food and pharmaceutical industries.

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