



## **A Review on Antioxidant Activity of Coffee and Its Additives**

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### **Authors' contributions**

*This work was carried out in collaboration between both authors. Author DB designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors DB and SB managed the analyses of the study. Author SB managed the literature searches. Both authors read and approved the final manuscript.*

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### **ABSTRACT**

Today, coffee is the most consumed drink all around the world. It has been suggested by many researchers that consumption of coffee is associated with many health-related benefits like increasing the physical performance, lowering the risk of type 1 diabetes, Alzheimer, Parkinson's as well as it is associated with reducing the risk of various types of cancer. It has also been noted that drinking coffee is also linked with the decreased chances of depression which is the major problem for the today's youth. The benefits of coffee and Ganoderma are fascinating. Current study is conducted to review the benefits and the antioxidant activity of coffee and its additives. It has been proven that coffee provides the major amount of antioxidants as compared to other products like dark chocolates, cocoa, wines, fruits and vegetables. Coffee with Ganoderma is reported to have a major amount of anti-tumor as well as anti-oxidative properties as it contains triterpenoids as major bioactive compound.

**Keywords:** Antioxidant; coffee; drink; ganoderma; health care; radical; acid; cancer; cells; compounds.

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## 1. INTRODUCTION

The roasted beans of coffee is the seed of berry obtained from *coffea* species. These coffee roasted beans are utilized to prepare coffee. It is a darkly colored, bitter, mildly acidic drink which are mainly due to its caffeine content, has a relaxing effect on the human body. Currently, India is the manufacturer of 16 distinct coffee products, which mostly come from southern India. *Coffea canephora* and *coffea arabica*, which are widely known as "robusta" and "arabica" respectively, are the two main coffee plant species used to extract the substance. Arabica contributes more than 40-60 percent of the commodity, while robusta contributes more than 20-40 percent to it. Arabica is more common because, relative to the other version, it is less bitter and has more flavor. In the other end, Robusta, which explains its existence in different coffee varieties, is considered to have more caffeine content and a stronger body than arabica. The High Performance Liquid Chromatography (HPLC) coffee study reveals that the existence in roasted coffee residue of phenolic compound such as chlorogenic acids and caffeic acids and nonphenolic compound caffeine, trigonellines, nicotinic acids, and 5-(hydroxymethyl) furfuraldehydes persisted [1]. The health benefits of coffee derive largely from its antioxidants. Most of the coffee constituents' function as antioxidants and, through scavenging free radicals, have been found to decrease the likelihood of many diseases and cell harm [2].

With reference to Fig. 1, the pericarp, or smooth, rough outer skin, of the coffee fruit (also called

berry or cherry) is normally green in unripe fruits but turns red-violet or deep red when ripe (even yellow or orange in particular genotypes). The light yellowish, fibrous, and sweet pulp, also known as the outer mesocarp, is covered by the pericarp. This is accompanied by a mucilage coating that is transparent, colourless, thin, viscous, and heavily hydrated (also called the pectin layer). Then there's a thin endocarp, also known as parchment, that's yellowish in colour. Eventually, each hemisphere of the coffee bean is covered in silverskin (endosperm).

Much focus has been devoted to coffee's antioxidant ability, especially because of the ease of its consumption and its potential health benefits. Several tests have contrasted the potency of coffee antioxidants with that of other drinks and have found that coffee contributes substantially to the consumption of dietary antioxidants. Several experiments have actually demonstrated that coffee (roasted or brewed) is made of antioxidant compounds. Ganoderma coffee is a powdered drink blend that usually includes instant coffee and the powder extracts of *Ganoderma lucidum*, also recognized as "reishi" or "Lingzhi," a medicinal mushroom. Other ingredients can also be used, such as sugar, non-dairy creamer, and herbs. In addition to the caffeine pick-me-up, it is a drink that supporters believe gives a variety of health benefits and is often used by people who wish to limit their coffee consumption but also raise their energy levels. While the positive effects of the *Ganoderma lucidum* mushroom have some scientific evidence, the advantages of Ganoderma coffee have not been tested [3-4].

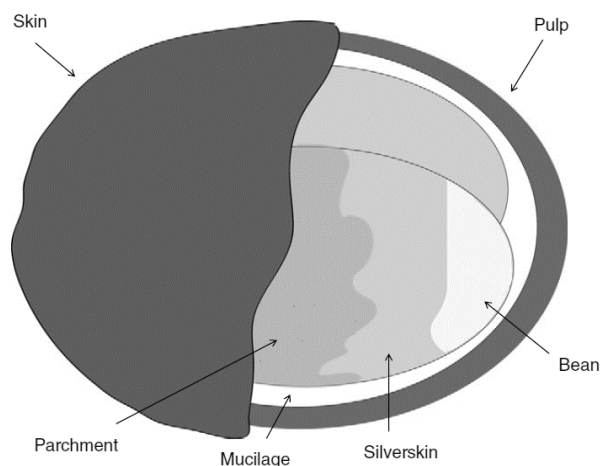


Fig. 1. Illustrating the Different Coffee fruit's layers

## 2. METHOD AND PURPOSE OF THE STUDY

In this study keywords like Antioxidant, Coffee, Activity, Chemicals, *Ganoderma lucidum*, health benefits and extracts were used on the sites like google scholar and NCBI. 12 studies were found from which 5 studies were thoroughly reviewed. Purpose of current study is to identify antioxidant activity of the coffee and their additives.

## 3. REVIEW OF LITERATURE

A review study conducted on some antioxidants like  $\alpha$ -lipoic acid, vitamin E, and the phytochemical present in various herbal, fruits or vegetables. This research was carried out to review the effects of the antioxidants, synthetic or dietary antioxidants, on the normal functioning of age-related and Reactive Oxygen Species (ROS) inducing the changes in the organisms (Humans and animals). The studies reviewed in this article suggested that dietary antioxidants, likely due to ROS threats, play a significant part in avoiding or delaying the development of age-related neurological and behavioural impairments. The differing findings obtained in the different experiments could be attributable to the variation of doses of the different antioxidants utilized, the different types of administration, the variety of procedures used, the scheduling of treatments and, most notably, the fact that only one antioxidant was examined. It was concluded that antioxidant-rich diets can play an important part in the conservation of good wellbeing of human. It is understood that the development and aggregation of free radicals produces catastrophic consequences in the human body when they oxidize the essential components of the cells to neutralize them. The antioxidants that are normally generated are the ones that scavenge certain free radicals, leading in the effects becoming avoided [5].

Another review study conducted on analysing the impacts of free radical, antioxidant and functional food on well-being. This study was conducted to extraction behaviour of the major coffee antioxidants like caffeine, melanoidins and caffeoylquinic acid as well as to study the antioxidant capacity. These extraction behaviours of coffee are studied during the two brew methods i.e., filter and espresso. The studies reviewed for studying the antioxidants capacity was by colorimetric assay which are Folin-Ciocalteu, ABTS (2,2'-azino-bis (3-

ethylbenzothiazoline-6-sulfonic acid)) and DPPH (2,2-diphenyl-1-picrylhydrazyl) and also electron spin resonance spectroscopy methods i.e., Fremy's salt and TEMPO. Various other parameters like turbulences and the interaction period among the water and the coffee on the coffeemaker ground was observed. Later in this study it was concluded that free radicals damage can lead to many chronic diseases like cancer, cataract, cardiovascular as well as inflammatory diseases. It was also suggested in this study to consume dietary and plan-derived antioxidants for a better health [6].

A study conducted on an overview on edible mushrooms with health benefits and applications in the food industry reported that the *Ganoderma lucidum* has many beneficial effects for the human health. There are a lot of researches that have represented that the extracts of *Ganoderma lucidum* have various therapeutic as well as medicinal impacts on the human health. A study also reported that this mushroom is easy to grow from agricultural perspective and can be cultivated in many outdoor geographical locations around the globe. It was also reported that *Ganoderma* holds a high market value as it consists of many bioactive compounds like triterpenoids. *Ganoderma lucidum* is being used for various medicinal purposes in China from the past 2000 years. Few researchers also suggested the consumption of this mushroom in the daily diet in the form of powder or in the coffee. One latest research suggested that *Ganoderma lucidum* majorly improves the antioxidation activities and the levels of bioactive compound for women who are facing the post-menopausal osteoporosis [7].

A study conducted on Antioxidants in coffee which consists of a DFT (Density Functional Theory) mechanistic to study the free radical scavenging. In this study researchers evaluated five reaction descriptors (thermodynamic quantities) – BDE (bond dissociation enthalpies), IP (ionization potentials), PA (proton affinities), PDE (proton dissociation enthalpies) and ETE (electron transfer enthalpies). These values are associated to 3 likely antioxidant processes: hydrogen atom transfers (HATs), single-electrons transfers trailed by proton transfers (SET-PTs), and sequential protons loss electron transfers (SPLETs) mechanism. In this researcher used the Polarizable continuum model (PCM) implicit solvation model to simulate water environment for 4 coffee compounds i.e., caffeic acid, 5-O-caffeoylquinic acid, quinine and cafestol.

Researcher obtained the enthalpies for each step of the radical scavenging reactions. Also compounds in coffee without hydroxyl groups are found to have a beneficial effect on the body's existing antioxidant capability (trigonelline, caffeine). Although quinine and cafestol may not be as reactive as chlorogenic and caffeic acids, it is not possible to neglect their effect as antioxidants. The large spectrum of compounds with certain coffee properties and the range of feasible pathways with which they can exercise the operation allows the brew the greatest source of antioxidants present in the daily diet [8].

A study conducted aqueous extracts of coffee on the wound healing. In this study the authors investigated the antioxidant activity and effects of tropical implementation for skin wounds healing of chemicals found in the aqueous extract of coffee bean. In this research authors compared the ability to reduce the wounds of different coffee compounds on animals' models. It was also found that coffee extracts have a large amount of chlorogenic acid and caffeine. In this study they found that the green coffee extracts were better as compared to allantoin, chlorogenic acid, roasted coffee and Carbopol. Authors also reported that the reported that the reactive oxygen species have better potential in wound healing [9].

In previous studies discussion about the Anticarcinogenic Activity, Free Radicals, Mode of action and oxidative stress of coffee and its additives is not discussed together in a single study. This study will help the readers to gain more knowledge about the health benefits and the antioxidant activity associated with the coffee and its additives.

#### 4. ANTICARCINOGENIC ACTIVITY

The association between coffee intake and cancer occurrence at different locations has been researched in a variety of epidemiological studies. Generally speaking, there really is no definitive proof that coffee consumption is a major risk for the growth of human cancer. The World Health Organization/International Body for Investigation on Tumor has released comprehensive reviews on coffee and cancer [10]. No correlation was identified between coffee consumption and the overall cancer risk in a major research carried out in Norway on 42,000 individuals. Many researches, on the other hand, have found an inverse (protective) correlation between the intake of coffee and the occurrence

of some cancers. Colorectal cancers epidemiology offers the most supportive proof of a possible defence based on coffee. A strong inverse correlation was observed amongst coffee intakes and colorectal cancers in a latest meta-analysis of 12 case-control and 5 cohort reports.

Evidence has been presented in a variety of animal experiments supporting the possible chemo-protective effect of coffee. Coffee given at high dietary doses in chronic experiments performed in rats resulted in a decreased occurrence of spontaneous tumors at various organ sites. Several other studies have shown that the constituents of coffee or coffee defend against the activity of well-known carcinogens such as nitrosamines or 1,2 dimethyl hydrazine. Several other experiments have shown that both green and roasted coffee inhibits the production of 7,12-dimethylbenz(a)anthracene (DMBA)-induced carcinogenesis in various laboratory animal cancer models at different tissue sites [11].

#### 5. FREE RADICALS

Free radicals are produced inside the human body during several metabolic mechanisms, non-enzymatic as well as enzymatic reactions. Free Radicals are produced in the mitochondria, peroxisomes and phagocytotic cells as a result of essential metabolic activities. These are often manufactured within the body as a result of alcohol, cigarettes, and some medications such as halothane and paracetamol use, as well as pollutants, heavy metals, transition metals, synthetic solvents, chemicals, and radiation exposure. Free radicals can be of two species i.e., reactive oxygen species (ROS) or reactive nitrogen species (RNS). Reactive oxygen species is a collective concept that encompasses all oxygen reactive forms, including all oxygen radicals and some non-radical oxidizing agents that are involved in chain reaction initiation and/or dissemination. Hydroxyl radicals, superoxide's anion radicals, hypochlorite, nitric oxide hydrogen peroxides, oxygen singlets, and peroxy nitrite radicals are the most significant ROS in multiple diseases and disorders. As these low-concentration reactive oxygen or nitrogen species are said to be involved in different biochemical pathways inside the body, the function of ROS and RNS can be substantiated as bi-phased, and the increasing amount or aggregation of these radicals contributes to negative impacts [12].

As the free radicals produced in the body are random, in order to neutralize them, they target essential cell components like protein, lipids and nucleic acid, which contribute to proliferation of the chain. An electron is pulled from a molecule by the first free radical that disrupts the molecule and transforms it into a free radical. And the molecule absorbs an electron from another molecule, destabilizes it and converts it into a free radical. The entire cell will ultimately be disturbed and destroyed by this domino effect. And when it is either scavenged by the antioxidants or neutralized by interacting with another free radical or cell part does the termination of a free radical occur. Such reactions contribute to significant cell disruption, contributing to devastating diseases such as cancer, cardiovascular disease, and aging. Compounds called antioxidants are intended to quench or scavenge these free radicals [13].

## 6. EFFECT OF ANTIOXIDANTS

Compounds of several various chemical types are antioxidants, clustered collectively as they both have the ability of countering the influence of extremely reactive, dangerous free radicals that are produced as a result of important food oxidation reactions. An antioxidant can be described as: "any substance which substantially slows or prevents the oxidation of that substrate when produced in reduced concentration likened to that of an oxidizable substrates". To curb the harmful effects of free radicals, the human body has a process by which it synthesizes antioxidants within the organism. In today's environment, dietary changes (tobacco use, smoking) and the effects of different pesticides have contributed to increased manufacture of free radical in the organism. Exogenous forms of antioxidants are very important in the diet in order to scavenge or quench these free radicals [10].

### 6.1 Classification of Antioxidants

As shown in Fig. 2, antioxidants can vaguely be classified as Endogenous and Exogenous on the basis of source of acquirement. The antioxidants produced inside the body, naturally are called endogenous antioxidants whereas the ones acquired from the diet are called exogenous antioxidants. Further, Endogenous antioxidants are classified into non-enzymatic and enzymatic antioxidants where as Exogenous antioxidants are classified into Vitamins, Beta-Carotene, Ubiquinone and Polyphenols [14].

Exogenous antioxidants can be one of the following:

- Natural antioxidants
- High and low molecular weight proteins
- Plant acquired antioxidants.

Our main focus of study is the plant acquired antioxidants as our test sample is coffee. Plant secondary metabolites that act as antioxidants are majorly phenols and are often referred to as "polyphenols" due to the presence of several phenolic hydroxyl substituents. One of the major sources of exogenous antioxidants are vitamins namely vitamin C and vitamin E. Ascorbic acid is a reducing agent and can reduce and thereby neutralize ROS such as hydrogen peroxide. This property of ascorbic acid attributes to all its activities.

### 6.2 Mode of Action

In the presence of several cofactors like the zinc, iron, copper and manganese, antioxidants convert the oxidative product that are assumed as dangerous to hydrogen peroxide ( $H_2O_2$ ) and after that it is converted to water. Antioxidants are reducing agents that oxidise themselves and reduce the free radicals in order to neutralize them. Antioxidants can either prevent the formation of free radicals by scavenging the chain initiators or scavenge the already formed ones by chain breaking mechanism [15].

### 6.3 Oxidative Stress

Oxidative stress is known as the imbalances among the amount of free radical produced as well as the amount of antioxidants present to neutralise or scavenge them, which leads to unfavourable conditions of damage to nucleic acid, proteins and lipids which may even lead to changes in their structure and function.

Oxidative stress can lead to diseases like:

- Cardiovascular diseases: All around the planet, cardiovascular inequalities are the major reason of deaths. In the onset and pathogenesis of such diseases, many intrinsic and extrinsic factors play a significant role. In avoiding certain diseases, a small improvement in the eating schedule may be beneficial. As far as coffee is concerned, the controversy about its position in cardiac health continues. In minimizing the incidence of

coronary heart attack, the antioxidants found in coffee are beneficial. Chlorogenic acid increases the body's antioxidant status and lowers degradation of Low-density lipoprotein (LDL).

- Ageing: Gathering of cells and the damage to various functions is the major cause of aging or so-called mechanism of aging [12]. Reducing the amount of free radical or reducing the rate by which they are produced can cause a delay in aging. According to the recent research, claims suggest that free radicals are one of the major contributors to ageing and that antioxidant defence can control the formation or scavenge the already formed ones. It also shows that antioxidant intake in regulated amounts contributes to enhanced quality of life [5]
- Cancer: One of the main causes of cancer is mutagenesis which is caused by radiation. Mutagenesis is caused by DNA damage by OH which is a free radical. Antioxidants therefore are required to quench the free radicals; however, the consumption of exogenous antioxidants

have not shown any evidence of prevention of cancer in vivo. This may be due to the difference in concentration of antioxidants in pure form and those consumed in diet.

- Lipid peroxidation: It is a natural mechanism that is produced in low amount in the organism, mostly initiated by the different ROS. These ROS are responsible for attacking the polyunsaturated fatty acids present in the membranes thus, starting a self-propagating chain reactions and thereby damaging the cell and its components in the process of neutralizing themselves [16].

*Ganoderma lucidum* (Curtis) (Fig. 3) P. Karst. (commonly known as: Reishi, Lingzhi) is a type of Basidiomycete which belongs to Ganodermataceae of Polyporales. A study described numerous kinds of antioxidant from the Ganodermas that might decrease oxidative injury by straight scavenging free radical produced inside the cells. It is known to possess antioxidant activity and antitumor properties [15,17].

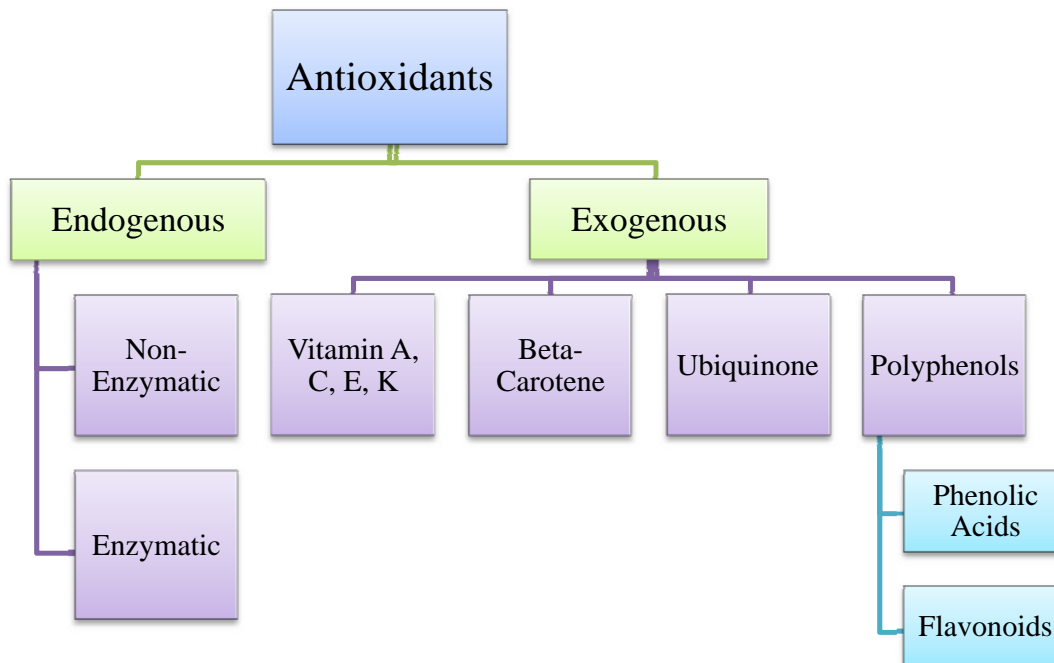


Fig. 2. Flowchart representing the classification of antioxidants



**Fig. 3. (A) *Ganoderma lucidum* mushrooms (B) Coffee prepared by the mushrooms of *Ganoderma lucidum***

The bioactive consistency of *Ganoderma* constitutes of non-volatile components of 1.8% ash, 26–28% carbohydrates, 3–5% crude fats, 59% crude fibres, and 7–8% crude proteins. *Ganoderma* is proven to have dose dependent antioxidative effect and also a cardioprotective effect. Ginger and its compounds like gingerol are proved to have medicinal and antioxidant properties and are very effective in quenching the free radicals from the system [18,19]. It also possesses the properties of anti-inflammatory and anti-oxidation which controls the aging. The following study intends to have a comparative analysis of the antioxidant properties of four different kinds of coffee samples as mentioned above. The essence of the study is the antioxidant effect of coffee and the “claimed” antioxidant effect of the infusions. The study aims to have a comparative analysis of all the four samples and their antioxidant activities with respect to the presence or absence of infusions and derive a conclusion of the same [20].

## 7. LIMITATIONS OF THE STUDY

In this study, limited number of additives are studied. In further studies more additives can be used with coffee to study more health benefits associated with the consumption of coffee with different types of additives.

## 8. CONCLUSION

Coffee, relative to numerous other widely eaten sources such as tea, dark chocolates, wines and vegetable/fruit, is among the primary source of antioxidant among the various sources of

antioxidants. Coffee is also considered to contain numerous micronutrients such as vitamin B2, vitamin B3 etc., in addition to being a rich source of antioxidants and also one of the most consumed drinks worldwide. The antioxidant property of coffee is attributed to its scavenging activity of free radicals. Both phenolic and non-phenolic compounds compose coffee, which may be responsible for its antioxidant effects. As the bioactive portion, phenolic compounds such as chlorogenic acid, caffeic acid, and non-phenolic compounds such as caffeine. For physiological functions such as cell apoptosis, free radicals generated in the body are necessary, but when accumulated, they can cause damage to cell components such as proteins and nucleic acids and can contribute to serious conditions such as cancer. The human body ideally maintains an equilibrium between the induced free radicals and the antioxidants formed naturally. Oxidative stress may result from some alteration or interruption of this equilibrium due to different lifestyle behaviours such as smoking and pesticide and radiation effects. In order to scavenge free radicals by reducing and neutralizing them and thus decreasing oxidative stress, exogenous sources of antioxidants such as coffee come into the image. The research briefly explains the antioxidant effect of any compound found in all coffee samples that has a “polyphenol” form. The antioxidant property is calculated by using Ascorbic acid as the standard in terms of Ascorbic Acid Equivalents.

Ascorbic acid is an important nutrient that is required for the preservation of connective tissue and bone in human diets. Its biologically active

form, vitamin C, functions in many metabolic pathways as a reducing agent and coenzyme. It is known as an antioxidant. In this analysis, because of its declining potential and its prevalence in the human body, ascorbic acid is used as a reference for the measurement of Ascorbic acid equivalents. Various other criteria can also be used, such as Gallic acid. In our case, because of its abundance and economic viability, ascorbic acid is chosen. The nature of the analysis is the presence in the coffee samples of infusions like Ganoderma and ginger and its effect on the total number of equivalents of Ascorbic acid.

Ganoderma has been found to have antioxidant and anti-tumor effects related to its bioactive ingredients, such as triterpenoids. In contrast to instant coffee, the infusion of coffee with Ganoderma extracts reveals a larger number of Ascorbic acid equivalents. This indicates that Ganoderma's bioactive portion that is responsible for its antioxidant action has a structure of polyphenol. Various studies have reported several beneficial effects of the coffee consumption on the human health and reducing the risk of various chronic diseases by consuming the coffee with different additives. These health promoting effects of the coffee consumption are associated with the antioxidants present in the coffee.

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#### COMPETING INTERESTS

Authors have declared that no competing interests exist.

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