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Review Article

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Functional Benefits of Green Coffee in Metabolic Syndrome Prevention: A Review Study

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ABSTRACT

Coffee is one of the oldest raw materials known worldwide for containing various bioactive substances. Due to its high consumption and health effects, coffee has aroused the interest of researchers regarding to its chemical compounds and possible benefits available to human health. The present review is based on information collected at National Center for the Prevention of Chronic Diseases and Health Promotion (NCCDPHP), the National Institutes of Health (NIH) in USA, theses, dissertations and scientific papers published in electronic libraries such as Scielo, Science Direct, Scopus and Nature. Descriptors used are coffee, antioxidant, caffeine, chlorogenic acid, chemical compounds, roasted beans and climate. An antioxidant activity present in its beans reported in the literature is confirmed by analytical methods being this activity responsible for coffee health benefits. It is claimed, for example, that cofestol controls or inhibits diabetes and obsesity, deseases that are increasing worldwide at preocupant rates. Studies published on climate change, however, have to be updated since possible climate changes may affect the concentration of its bioactive compounds directly.

Keywords: Green coffee; Health benefits; Chemical compounds; Green coffee

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INTRODUCTION

Coffee is long appreciated by mankind for its sensory attributes and physiological effects [1]. Its use is part of the most traditional cultivated crops of Brazil, Vietnam, Colombia and Indonesia among other countries, providing a panorama large availabilty coffee in the world's market. Due to its high consumption and benefits to the human health, coffee has aroused the interest of researchers; so many studies on green coffee properties were performed [2]. According to Moreira and Babova et al. the most economically important coffee species in the world are Coffea arabica (Arabica), supplying more than 95% of coffee worldwide and Coffea canephora (Robusta), being Arabica considered to be of superior quality due to its organoleptic properties characteristics. This type of coffee is characterized by being more acidulated, fruity and softer, and therefore, has a higher price in the market compared to Robusta coffee [2,3].

The green coffee is characterized by the presence of light grains with a distinct flavor and green color, due to the determinants of the chemical composition of the coffee, particularly the genetic and environmental conditions which are responsible for the concnetrations of chemoprotective compounds present in the green coffe beans, such as the antioxidants. However, when the beans are submitted to roasting process, there is a change in the concentration of its bioactive compounds [4-6].

Coffee beans are a complex plant matrix since it contains several substances that interact with the human body, the antioxidants being among the main foci of epidemiological studies [7]. Researchers have struggled to demonstrating a positive response of coffe in the prevention and treatment of chronic and neurodegenerative diseases [8]. Ludwig et al. for instance, affirm in their study that consuming coffee reduces the risks of contracting certain metabolic disorders and it improves the health state of the individual [9].

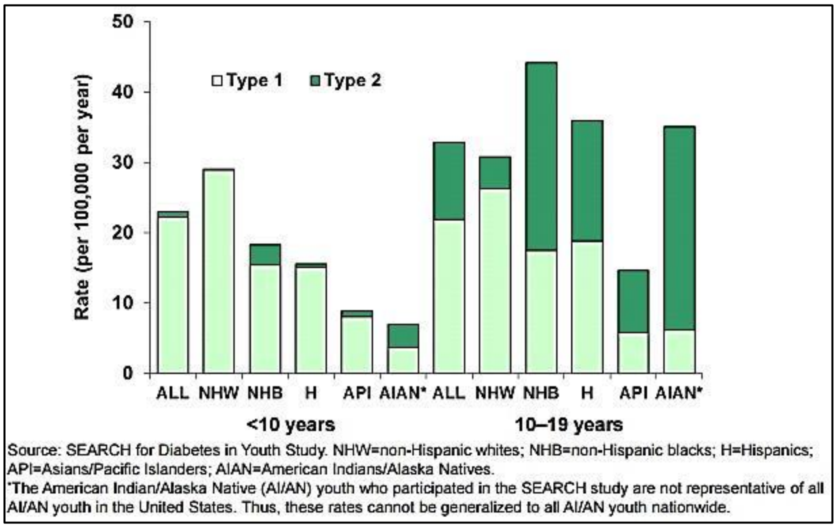
This review study was conducted with the objective of summarizing the information related to the claimed benefits that green coffee provides in suppressing or controling some diseases due to its bioactive compounds, in view of its socioeconomic importance and high consumption. It is restricted to studies published in the literature of recent years and the databases used were Scielo, Science Direct, Scopus and Nature. In addition, criteria data published by the National Center for Chronic Disease Prevention and Health Promotion (NCCDPHP), at the National Institutes of Health (NIH), USA. In addition, theses, dissertations and scientific articles published in English and Portuguese journals and magazines from 2012 to 2017 were consulted. The descriptors used for filtering of scientific documents were green coffee, antioxidant, chlorogenic acid, caffeine, chemical compounds, roasted beans and climate.

CHEMICAL COMPOSITION AND BENEFITS OF GREEN COFFEE

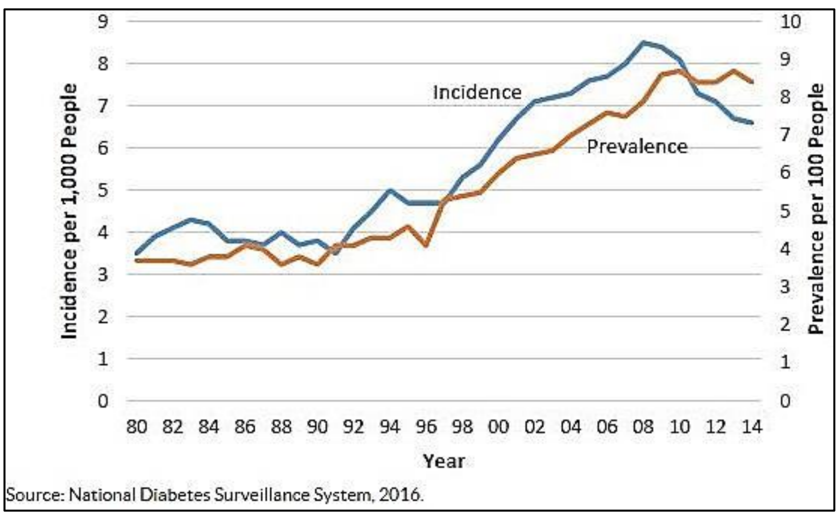
Several authors report that moderate coffee consumption contributes to the reduction of the development of degenerative diseases (Alzheimer's and Parkinson's), type II diabetes (T2DM), cancer, weight reduction, asthma, adjuvant treatment of hypertension, cardiovascular diseases and cirrhosis [5,10].

Coffee beans comprise a set of components complex such as an extensive variety of minerals, amino acids, lipids, sugars, vitamins, and chemical compounds that influence various metabolic processes. The most influential chemical compounds are alkaloids, diterpenes and, in larger quantity, phenolic compounds, such as chlorogenic acids (CGAs), are the main bioactive compounds found in coffee beans. Tannins, lignins and anthocyanins stand out from the phenolic compounds present in the grains in less quantity [10,11]. Trigonellin and caffeine are the most important alkaloids present in grains, but caffeine is the main alkaloid. Caffeine is a methylxanthine and represents 1 to 4% in coffee beans, varying according to cultivars. Robusta has an average of 2.2% caffeine while Arabica has 1.2%. This alkaloid has bitter properties and is known to act in the stimulation of the central nervous system, in the increase of the blood circulation dilating the peripheral vessels, increase of the breathing and it acts also in the metabolism aiding the digestion of the foods in the stomach [12]. In addition to these positive effects on human health due to moderate caffeine consumption, Esquivel, apud Heckman, Weil and González de Mejía, argues that caffeine contributes to physical exercise performance, improves mood and reduces symptoms associated with Parkinson's disease and tremors. Many studies report on the cognitive enhancing effect of caffeine [13] generating a discussion among researchers. Alzheimer's disease has a low incidence in individuals who consume coffee regularly (3-5 cups per day) compared to those who do not drink coffee in their daily lives [14-16]. QI and LI include Parkinson's disease as well. A recent study conducted by Wright et al. with bees aimed at testing the olfactory memory of insects by ingesting tiny amounts with small concentrations of caffeine in the nectar of plants that produce this compound naturally. Among the the plants analyzed were *C. canéfora* and *C. arabica*. Using liquid chromatography-mass spectrometry, the authors observed that the concentration of caffeine in these plants ranged from 0.003-0.253 mM. The results indicated that caffeine had a poor effect on the rate of learning, but had a significant effect with regard to long-term memory of the insects. Within 72 hours, the bees remembered the smell of the plant [17]. Aguiar, citing Farrah, claims that the alkaloid trigonellin is involved in the bioactive effects responsible for inhibiting cancer cells *in vitro* and it provides improved memory due to regeneration of axons and dendrites in animal models. According to Godos et al. and Zhou et al. trigonelin has a hyperlipidemic and hypoclycemic effect [6,18,19]. Studies with animals and humans show reductions in glucose in diabetic and/or obese individuals after administration of trigonelin [17]. Levels of serum cholesterol and triglycerides were observed to be reduced also [19]. The T2DM is the degenative disease that affects the wolrd’s population, corresponding to 90 to 95% of diabetes cases, being obesity and lack of physical exercise risk factors of great importance for the development of the disease [20]. The individual develops a pathophysiological, a metabolic disorder characterized by the resistance to insulin [21]. In the US and other Western countries, obesity and diabetes are the main epidemics today [22]. According to a International Diabetes Federation (IDF) study, "diabesity" - a term used to describe the coexistence of T2DM and obesity - accounts for more than 380 million people, 90% of the diabetes disease, and this number tends to increase due to undiagnosed and unreported cases [23].

A study conducted in 2014 by CDC and NIH (National Institutes of Health) evaluated type I (T1DM) and II diabetes in children and adolescents in the United States. Data were collected between 2008 and 2009 and it was estimated that 18,436 individuals under 20 years of age were diagnosed with T1DM and 5,089 with T2DM. When comparing the groups evaluated in the research, it was observed that the group of non-Hispanic children and adolescents had the highest rate for T1DM cases and T2DM cases were higher among people aged 10 to 19 years [24,25] (Graph 1). Between the years of 1980 to 2014, another study, reported in later 2016, was carried out to evaluate the incidence and prevalence of the disease within a group of 20 to 79 years old individuals in the USA. The resulted Graph 2 shows the prevalence of the growth of the disease in the population, which is alarming [24].

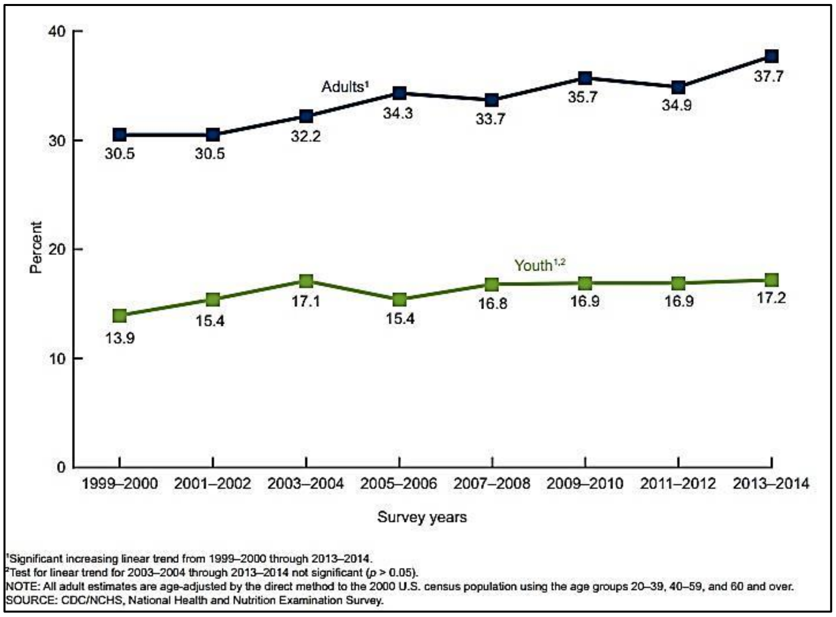


Graph 1: Rate of new cases of type I and type II diabetes among younger people, by age and race/ethnicity, 2008-2009



Graph 2: Trends in the incidence and prevalence of diagnosed diabetes among adults aged 20 to 79 years, United States (USA), 1980-2014

Like diabetes, obesity has become a serious disease worldwide that affects people of all ages, contributed by a high-fat diet [25]. Graph 3 shows, for example, that a significant increase in obesity both in adults (≥ 20 years) and youngsters (<20 years) between the period of 1999-2000 to 2013-2014 in the USA. No change in obsety prevalence among young people was noted between 2011-2012 and 2013-2014 and the observed change in adults was not significant in the same period.



Graph 3: Trends in obsesity prevalence among adults aged 20 and over (age-adjusted) and youngsters aged 2-19 years

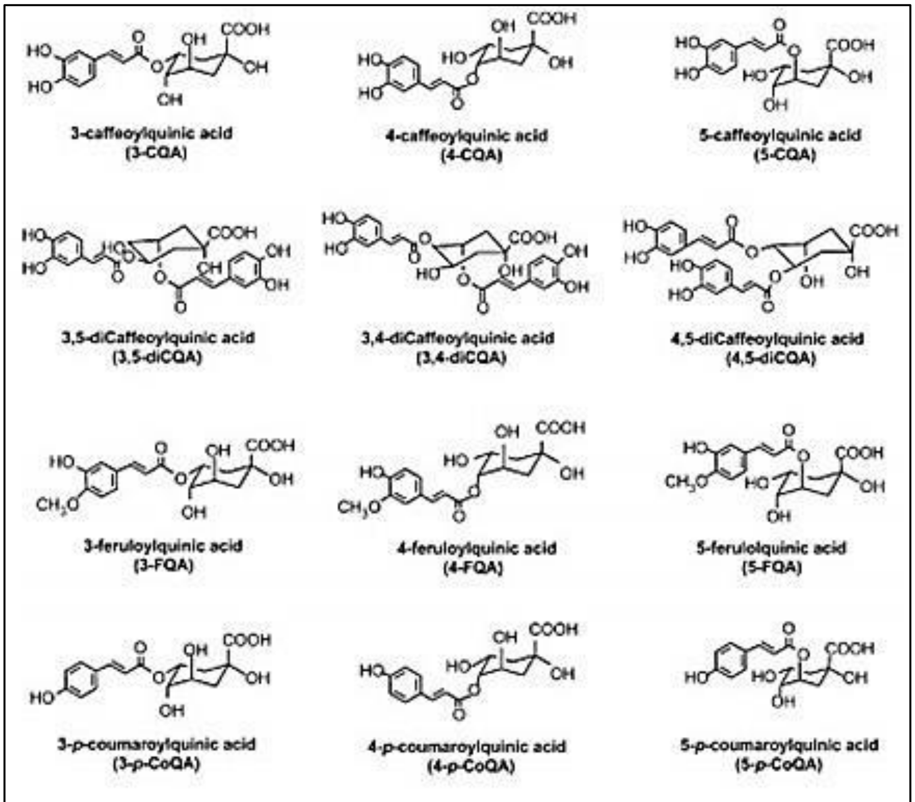
The curiosity of researchers has led to the study of how the metabolites and polyphenols of the coffee act in the body and whether the consumption of the same interferes in the reduction of weight. According to some studies, these coffee components are absorbed in the stomach and small intestine, later absorption occurs in the intestinal microbiota [26]. The main phylotypes of the microbiota are Bacteroidetes and Firmicutes, the latter appears to be related to obesity and fatty foods when in larger percentage. These two phylotypes are present in humans, rats and mice intestins [27].

Recent research by Cowan et al. was performed with rats to determine whether chronic coffee consumption could mitigate the intestinal microbiota induced by a high-fat diet. As a result, they observed that coffee consumption in mice reduce the abundance of Bacteroides/Prevotella and increased decreased the Fermicutes/Bacteroides ratio by increasing the Firmicutes. In addition, it was observed increased fatty acids levels, decreased amino acids levels and systemic insulin resistance, probably due to caffeine. With this, it was hypothesized that the chronic consumption of coffee results in the alteration of the intestinal microbiota, which explains the positive effects on the risks of type II diabetes. It appears, therefore, that diabetes and obesity is an association resulting from the altered profile of the intestinal microbiota [26]. Rustenbeck carried out a study with mice and showed that the doses of caffeine administered to the animals under study with a fat diet reduced the weight gain and consequently improved the tolerance to glucose in the blood [28]. Subsequently, in the study of Choi et al. it was observed that animals that had a high fat diet with CGA at different concentrations (50, 100 and 200 mg/kg) resulted in decreased accumulation of lipids and genes related to body fat composition, evidencing the support of the use of green coffee beans as a supplement to prevent obesity [25]. Consequently, green coffee consumption seems to have a positive effect on reducing the risk of cardiovascular diseases [29,30].

The most influent diterpenes in coffee beans are cafestol and kahweol and are found in higher amounts in unfiltered coffee (6-12 mg). An *in vitro* study utilized small concentrations of cafestol (10^{-10} to 10^{-6} M) which showed a considerable increase in insulin secretion and glucose uptake. As a result, it was noted that the filtered coffee, although having low concentrations of this compound, still can have a preventative action of T2DM [31]. In previous studies, cafestol and kahweol have shown an effective action in modularing multiple enzymes involved in the detoxification process of carcinogens responsible for hepatocellular carcinoma [32].

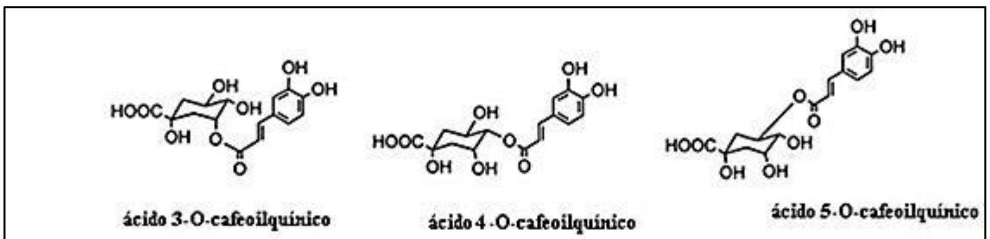
The CGAs are formed by the esterification of transcinamic acids together with quinic acid which can exist in different isomeric forms depending on the position of the ester bond [33]. Among the many CGAs, the most important are caffeine-like acids (CQA), representing about 80% of the total chlorogenic content followed by dicafeoylquinic acids (diCQA), feruloylquinic acids (CFA), p-couaroylquinic acids (p-CoQA) and (CFQA) [6,34] (Figure 1). The association of CGA and caffeic acid has antimutagenic, anticancer, antioxidant and anti-inflammatory properties. In addition to the antioxidant power, CGAs have other important health properties such as hepatoprotective, hypoglycemic and antiviral activities [10]. In the study by Jeska-Skowron et al. CGAs 5-CQA, 4-

CQA and 3-CQA (Figure 2) were estimated by chromatographic analysis and a mean component concentration was observed between arabica and robust coffee of 176 mg /l and 153 mg/l, respectively [35].



Source: LIANG, KITTS, 2005, p. 2.

Figure 1: Chemical structural formulas of the main CGAs



Source: LUDWING et al., 2014, p. 2.

Figure 2: Structural formulas of the main kaeochylinic acids

The residues generated by the coffee industry and natural extracts containing these compounds are also incorporated into formulations of functional foods, nutraceutical products, cosmetics and products for medical use [36]. The cosmetic industry considers the oily raw material obtained from green coffee of great importance because it has emollient properties, softeners, moisturizing and the ability to protect against sunlight, this is because coffee oil is extremely rich in components such as sterols and unsaponifiable compounds [37].

Antioxidant activity

The main contributors to the antioxidant capacity of coffee are the reducing properties present in the phenolic compounds contained in green coffee beans such as CGAs, caffeic, ferulic and n-coumarinic. Ferulic acid is contemplated to have anti-inflammatory, anti-allergic, antibacterial, anti-platelet and antiviral effects [3,4,38]. Some authors have observed antioxidant activity in extracts of green coffee presenting a hypotensive effect in rats [35].

The Yashin study demonstrates the antioxidant activity of green coffee through ORAC (Oxygen Radiation Absorbance Capacity), FRAP (Reduced Antioxidant Potency), TRAP (Total Reactive Antioxidant), TEAC

(Equivalent Antioxidant Capacity) when comparing arabic and robusta coffees submitted to different roasting methods and temperatures. It was observed that the antioxidant activity of the robusta coffee was higher than that of the arabica coffee. However, this difference becomes insignificant after the light roasting and the arabica coffee exceeds the robusta coffee when the degree of roasting is increased [4].

The polysaccharides present in the green coffee beans, besides having an important role with respect to the organoleptic characteristics in coffee beverage, researchers have found that these components have a prebiotic potential and antioxidant activity and activities are satisfactory when a molecular modification occurs [39]. Arabica coffee presents 6% to 9% of sugars while robusta, 3% to 7%. In this study, the modified polysaccharides showed excellent antioxidant activity. The evaluation of the antioxidant activity was determined by *in vitro* methods using Saccharomyces cerevisiae yeast as a model of living cells. *In vitro* methods are classified in hydrogen transfer (HAT) and electron transfer (ET) assays. The ORAC assay is performed in HAT, a competitive scheme between the antioxidant and the substrate and the ET includes DPPH and ABTS assays of radical trap capacity and the FRAP assay. Liang performed an analysis of the antioxidant activity between green coffee and roasted coffee and used the ORAC and ATBS assays also. The antioxidant values varied depending on the chemical essay employed and the result between the two types of coffee were similar. CGAs are the only compounds that demonstrated a positive response to intracellular antioxidant activity measured in intestinal Caco-2 cells [40]. Thus, Liang concludes that intracellular antioxidant activity responds positively to CGAs, providing coffee health benefits. Wolska et al. evaluated the antioxidant activity by infusing the green coffee beans through the spectrophotometric method using synthetic DDPH radicals and the Agilent 8453UV spectrophotometer apparatus. They observed a high antioxidant activity (71.97-83.21%) with variation depending on the coffee species used for infusion. It has been shown to depend on the method of coffee brewing that there is interference in the antioxidant potential of the infusions.

FACTORS THAT ALTER THE CHEMICAL COMPOSITION OF COFFEE

Drying and Roasting

The drying and roasting processes cause changes in the composition of the coffee beans, since some compounds are degraded or modified. The tradicional method of drying is the sun dry. The negative aspect of this method is that coffee beans are subject to the weather conditions. The other method is machine drying with constant warm air flow and that depends on the fuel used in the air heater. If wood is used, it is possible that the beans acquire the taste of the wood, changing the beans organoleptic properties. In the roasting process, the beans are exposed to temperatures up to 300°C and this step is critical also, because the organoleptic characteristics of the beans again may be influenced, affecting the quality of the product. The complexity of the process promotes a series of physical, physicochemical and chemical changes involving volatile compounds (phenols, aldehydes, ketones, alcohols, ethers, hydrocarbons, organic acids, anhydrides, esters, lactones, amines and compounds containing sulfur atoms) and non volatile compounds (caffeine, trigonelline, chlorogenic acids, lipids, polysaccharides and proteins) that give aroma and flavor characteristic of the coffee [41,42]. The volatile compounds of the coffee are generated during the roasting process. According to some scholars, approximately a thousand volatile compounds have been identified in processed coffee, making their synthesis difficult [43-45].

In order to avoid the loss of some coffee compounds that have beneficial health effects, it is possible to extract the beans compounds with alcohol, hot water or amixture, the so called "green coffee extract" prior to roasting. The extract has been investigated for its antioxidant, antihypertensive properties and for controlling body weight, besides reducing blood pressure and possessing antibacterial activity [11].

Climate Factors

The chemical and organoleptic characteristics of the coffee beans are directly affected by the climatic characteristics and therefore, the places where the plants can be cultivated is limited [46]. Climate change in tropical and subtropical regions threatens farmers with insect pests, reduced water availability, and other events that may reduce crop yields [47].

Altitude and Temperature

The altitude must be taken into account due to its relation with the change of temperature and the exposure of solar radiation, as the intensity of UV rays increase with altitude. The exposure of the plant under high solar radiation, especially high UV flux, results in the modification of the hormones and species characteristics [46].

Arabica coffee grows in equatorial regions with altitudes between 1000 and 2100 m with average temperatures of 18 to 22°C and in partial shading whereas the robusta coffee requires a hotter and humid climate for its growth and has

a better development in altitude ranging from 100 to 1000 m and average temperature range of 22 to 26°C in the presence of sun [46,48].
Bertrand et al. state that previous studies performed by Villarreal et al. and Joët et al. demonstrated that the chemical composition responsible for the aroma of the coffee undergo changes due to the temperature of the crop. They also conducted a study on the microclimatic conditions and sensorial perception of the coffee beverage and its volatile compounds and verified that these compounds change depending on the development of coffee seeds and that warm climates favor the accumulation of volatile compounds, concluding that microclimate onditions interfere directly in the quality of the product.

CONCLUSION

Because coffee is one of the most consumed raw materials worldwide and its economic value, it is of great importance to study its chemical components and to know their benefits to human health. In particular, the phenolic compounds present in the green coffee beans are very important because they are rich in antioxidant components responsible for the beneficial properties of the coffee. It is claimed, for instance, that cafestol appears to control obesity and diabetes, deseases that are increasing worldwide at alarming rates. However, since the chemical compounds are directly affected by the climatic conditions, identification of the appropriate microclimatic conditions for cultivation is deserved and future studies have to be performed in order to evaluate the possible effects of climate change over different cultivars.

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