Coffee–Functional Food and Medicinal Herb

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Coffee *(Coffea arabica)* is the second-largest worldwide commodity, overshadowed only by crude oil. Without question, coffee is the most frequently consumed functional food around the globe: In the United States alone there are 108 million coffee consumers who spend $9.2 billion in the retail sector and $8.7 billion in the foodservice sector each year.[1] And these numbers represent only a fraction of the global population, large numbers of whom incorporate coffee as a staple in their cultural practices.

Coffee also has a rich medical history. The therapeutic benefits of coffee are now supported by a rapidly growing and significant level of scientific validation. The epidemiologic significance of the research in the field of coffee cannot be overstated, considering the prevalence of coffee ingestion among the peoples of the world.

Beyond the cultural and medical ramifications of coffee consumption, the fact is that coffee is big business with huge social, environmental, and economic impacts. The National Coffee Association reported that in 2000 54 percent of the U.S. adult population drank coffee.[2] The average consumption per capita in the United States is approximately 4.4 kg annually at a cost of $164.71 per individual. Among U.S. coffee drinkers the average consumption is 3.1 cups of coffee per day.[2]

These statistics provide compelling motivation to investigate the consequences of such large-scale consumption of this beverage. What follows is a review of some of the most recent research into the active constituents and potential clinical applications of the functional food that is humbly known as the coffee bean.

Coffee-Bean Chemistry

Coffee's bioactive profile contains many of the most important constituents known to exist within functional foods: flavonoids (catechins, anthcyanins); caffeic acid; and ferrulic acid.[3] Additional biologically active components found in coffee include nicotinic acid, trigonelline, quinolinic acid, tannic acid, pyrogallic acid, and caffeine.[4]

A simple chemical analysis of whole green and roasted coffee beans shows their chemical constituents and the metabolic changes that occur during processing, preparation, and ingestion, all of which warrant further investigation.

An illustrative case in point is the significant niacin content that is formed from trigonelline during the roasting process, producing between 2 and 80 mg of niacin per cup of coffee.[5] Thus, although niacin is not abundantly present in the nonroasted bean, processing itself generates spikes in niacin content that depend upon bean quality and the roasting and preparation processes.

This raises the question of what other changes occur during the roasting process that might augment the therapeutic benefits of the coffee bean further.[6] Beyond its phytochemical components, this beverage also provides an array of minerals and other nutrients. A single cup of coffee can provide 8 percent of the daily intake of chromium[7] as well as being a significant source of magnesium.[8]

It has also been reported that the coffee brewing process can help remove toxic metals, such as lead, from contaminated water sources.[9] There is little question that over the next decade the field of coffee research will flourish and yet-to-be-identified biogenic substances and their therapeutic indices will be elucidated.

Analyzing the Analysis of Coffee

The investigation of the therapeutic effects of coffee has endured the same shortcomings that plague most of the whole-plant research paradigm. The concept that "one size fits all" simply does not apply to botanicals in the same manner that it does to isolated drug therapies. The standard scientific model, in its attempt to apply a reductionistic methodology, has generally failed to consider coffee as a whole plant complex that is not divisible into single chemical isolates.

Just as studying the benefits of beta-carotene is not the same as studying the benefits of eating a carrot, studying the benefits (and downfalls) of caffeine is not the same as understanding what it is that makes coffee a useful medicinal plant. Divergent thinking, as opposed to a convergent analysis of medicinal plants, provides the foundation for the discovery of new and synergistic constituent blends that may make an impact on the physiology of human health.

Selected Active Constituents and Classes of Active Constituents in *Coffea arabica*

Agmatine	Magnesium
Anthocyanins	Nicotinic acid
Caffeic acid	Polyphenols
Caffeine	Pyrogallic acid
Catechins	Quinolinic acid
Chlorogenic acid	Serotonin
Chromium	Soluble fiber
Diterpene	Spermidine
Ferrulic acid	Tannic acid
Flavonoids	Trigonelline

This concept is not foreign to the coffee research community, which has had to be introspective as it investigates why, exactly, research findings in the field remain inconsistent and at times lack reproducibility.

Conclusions thus far suggest that variations in the concentration of caffeine and other active constituents, as well as the total volume of fluid consumed, has contributed to the variations in the accuracy of clinical findings. Epidemiologic studies reflect these "discrepancy factors."[10] The scientific literature reports that confounding variables lead to conflicting results in the analysis of the impact of coffee on health.[11] In short, removing culture, diet, and lifestyle from the analyses generates data that are not grounded in the traditional applications of coffee within a given populace, thus diminishing the studies' clinical relevance.

In reviewing the diversity of international coffee consumption, factoring in bean-roasting, brewing, and preferred methods of ingestion are all essential when seeking to determine the therapeutic effects of the coffee bean.[12] In reviewing eight European and U.S. brewing techniques and roasting methods, wide variations were noted. Brewing techniques alone result in differing levels of active constituents, such as diterpene levels, which consequentially have an impact on therapeutic breadth and efficacy.[13]

This article highlights the positive benefits of coffee; yet, as with all herbal products, one size does not fit all. Therefore, those people who have underlying health conditions—such as high blood pressure, fibrocystic breast disease, cardiac arrhythmias, peptic ulcers, anxiety, insomnia, or any other condition that might render one sensitive to the active constituents of coffee—should probably be advised to avoid using coffee as a medicinal food.

And, as with all herbal products, people who want to avail themselves of the benefits of coffee should be advised that working closely with one's health care provider is essential.

Coffee's Antimicrobial Effects

Reports of the use of coffee as folk medicine for treating sore throats, colds, and other ailments abound. These empirical observations are now supported by a growing body of scientific literature suggesting that antibacterial and antiviral properties may be present in coffee.

Namba and Matsuse reported that coffee can lessen the physiologic damage that may arise during viral infections.[14] Antibacterial properties have been reported to arise from caffeic acid, chlorogenic acid, and protocatechnic acid, all of which are present in coffee.[15] Antiadhesive properties have been attributed to roasting-induced molecular changes (e.g., that roasting helps prevent the attachment of bacterial fimbriae to the mucosal membranes).

In one study, antiadhesive properties were associated with a specific influence on *Streptococcus mutans*.[16,17] *S. mutans* is frequently associated with chronic oral pharyngeal infections, including recurrent tonsillitis. Although clinical studies have yet to be conducted, applying the concept of antiadhesive properties by gargling with coffee to decrease virulence and host burden may hold clinical promise.

As a clinical note, when considering the concept of antiadhesive therapeutic interventions, it may be helpful to recall that a prominent mechanism that supports the use of the cranberry in the treatment of bladder infections is the berry's antiadhesive properties.

Further research is needed to elucidate the antimicrobial effects of coffee; this author would also propose investigation into the effects of naturally occurring tannins in coffee on the resistance of mucous membranes to penetration by infectious microbes.

Coffee's Antioxidant Power

It is important to note that there is no such thing as a representative cup of coffee with a specific chemical profile. The origin of the bean; the agricultural practices that grew it; the variations between species; and the handling, processing, brewing, and preferred ingestion practices all serve as confounding variables when trying to perform a chemical analysis on a cup of coffee. However, one important control factor regarding the achievement of maximum antioxidant levels in coffee has been shown to occur from intermediate roasting techniques.[18,19]

Coffee is a rich source of antioxidants, including those derived from the hydroxycinnamic acids family (caffeic, chlorogenic, coumaric, ferrulic, and sinapic acids), flavonoids, and polyphenols.[20]

Beyond the innate antioxidants found in unprocessed coffee beans, processing byproducts have yielded newly formed antioxidants such as the recently discovered "silverskin," which is the innermost skin of the coffee fruit body. Silverskin clings to the dried coffee bean until it is removed by polishing or is liberated during roasting, and represents yet another new, functional ingredient in coffee that contains both soluble fiber and antioxidant activity.[21]

It has been determined that water is the best method for general antioxidant extraction. When four solvents were used—water, methanol, ethanol, and n-hexane—water extracts produced the highest yields of antioxidants and the best lipid-peroxidation protection. The water extract demonstrated a particularly high protective effect against oxidative damage to proteins. The water extract also showed superior free-radical scavenging, generally reducing the ability and capacity to bind ferrous ions thus reflecting its dynamic capacity as both a primary and secondary antioxidant. The

concentration of flavonoids and polyphenolic compounds—both of which are commonly found in coffee—were 8400 and 20,4000 ppm, respectively.[22]

When evaluating the antioxidant properties of coffee, higher activity levels appear in vivo, after the coffee has been consumed, because colonic microflora metabolize most of the dietary phenols and therefore significantly increase antioxidant activity.[23]

When reviewing the coffee literature, additional consideration must be taken into account regarding whether the coffee is consumed filtered or unfiltered. Consumption of unfiltered coffee (as in Italy) has been shown to increase plasma glutathione.[24]

As an example of naturally occurring synergy, chlorogenic acid undergoes conjugation with glutathione, increasing the protective mechanism of both of these substances.[25] Revealing more about the unique properties and chemical profile of coffee, research has demonstrated that the melanoidins in coffee produce higher antioxidant activity than the melanoidins present in beer.[26]

This may all be academically interesting but what role might the antioxidant properties of coffee play in maintaining health? It has been concluded by the international scientific community that a Westernized diet is devoid of sufficient antioxidants, in large part the result of inadequate intake of fresh fruits and vegetables. It appears, however, that coffee may help fill this "antioxidant void," serving as a primary source of dietary antioxidants in Germany,[27] Spain,[28] the United States,[29] and probably many other countries.

Coffee, Asthma, and Bronchitis

Asthma and other pulmonary ailments continue to grow in prevalence in the United States. Interestingly, coffee rich in methylxanthines appears to confer a protective effect for maintaining healthy airway function. This is not surprising because another xanthine, theophylline, has been used over the years as a prescription asthma medication.

Studies have shown that regular consumption of coffee reduces symptoms of asthma and lessens the probability of experiencing bronchial asthma.[30] Further pulmonary applications include using coffee to treat both acute and chronic airflow obstructive disease in smokers.[31] Coffee for treating acute and chronic bronchitis may prove to be a worthy area for further clinical investigation.

Coffee and Cardiovascular Disease

In the United States, cardiovascular disease leads to one death every 33 seconds and contributes to 70 percent of total deaths annually. This makes identifying functional foods as potential modifiers of this disease prevalence an invaluable endeavor.

Researchers have investigated whether green coffee bean extract (GCBE), which is rich in chlorogenic acid, may be just such a disease modifier. In one study, two groups were created with 10 people ingesting a green coffee bean extract and 10 ingesting a placebo drink for 4 months. At the end of the study, the treatment group experienced significant decreases in total plasma homocysteine levels and improvements in vasoreactivity.[32] The ability of GCBE to make an impact on these two independent risk factors for cardiovascular disease progression is significant.

Coffee (*Coffea arabica*).

Other studies have shown that regular coffee intake has the potential to decrease the susceptibility of low-density lipoprotein to oxidation and decrease malondialdehyde levels.[33] Further research has examined the ability of caffeine (250 mg two times per day) to lower the incidence of cardiovascular events in patients with type 1 diabetes, demonstrating a positive effect.[34] (For another view of coffee and heart health, see Caffeine and the Heart in News You Use.)

Coffee's Impact on Cognition and Mood

A popular use of coffee—particularly in vogue among college students—is drinking it to enhance one's ability to assimilate vast amounts of knowledge within finite periods of time. According to recent findings, consuming a few cups of coffee can indeed strengthen information processing and enhance the ability to monitor for erroneous outcomes.[35]

The physiologic effects of challenging mental capacity increased catecholamine levels, and coffee drinking increased the concentration of both adrenaline and noradrenaline further, providing "in the moment" clarity. There was also an increased urinary excretion of adrenaline and noradrenaline after the ingestion of a single cup of coffee.[36]

Another study tested the effects of spiking coffee with additional caffeine. The findings demonstrated that caffeine augmentation leads to faster encoding and enhanced information acquisition. Ingesting this high-caffeine coffee improved encoding of new information and counteracted the fatigue that developed over the test session.[37]

The antifatigue properties of caffeine are well-documented among both bus drivers and airline pilots and coffee has been documented to improve safety when discontinuing such activities is not an option.[38,39]

Beyond improving learning and information accessing capacities, there is evidence that drinking coffee can help improve mood as well.[40,41] The findings of at least one study pointed to an inverse correlation between caffeine consumption and suicidal ideation, although coffee is not being suggested as a suicide-intervention technique.

Coffee and Diabetes

As early as the 1970s, research has documented a link between increased coffee consumption and reduced plasma glucose levels.[42] A study conducted in Japan demonstrated an inverse association between coffee drinking and the prevalence of fasting hyperglycemia.[43] More recent studies have shown that coffee consumption protects women from the development of diabetes[44] and further studies have shown that there is a statistically lower risk of developing type 2 diabetes with long-term coffee consumption.[45]

Several studies have shown that coffee consumption can decrease the incidence or risk of Parkinson's disease.

Studies conducted in Sweden showed that coffee consumption improved insulin sensitivity in elderly nondiabetic men[46] and reduced the risk of both type 2 diabetes and impaired glucose tolerance in men and women who drank 5 or more cups per day.[47]

What is especially interesting is the investigation into the role of coffee as a potential modulator of the expression of genetic factors that might impart a tendency toward developing diabetes. Twin studies have shown that, if one twin consumes moderate amounts of coffee while the other twin consumes low levels, the twin consuming more coffee has a higher level of protection against developing diabetes.[48]

Maintaining lean body mass is an important clinical factor in helping individuals with diabetes control glucose levels and helping patients with prediabetes gain control over otherwise-precarious blood sugar levels.

Coffee, in addition to its other protective properties, has been found to increase metabolic rates in both obese and nonobese individuals, with significant metabolic increases in both groups.[49] A study of lean women demonstrated that coffee consumption increases thermogenesis and lipid oxidation.[50] There is also evidence of increased metabolic rates when coffee is consumed with the first morning meal.[51]

Yet another study has identified an increase in skin temperature and caloric expenditure with coffee consumption.[52] When coffee and exercise are combined, there is a higher lipolytic response compared to exercise alone.[53] There is also growing evidence in the literature demonstrating the ability of both caffeine and methylxanthine to make a positive impact on cellular metabolic rates.[54]

These findings have been applied broadly in the weight-loss-supplement industry and are likely to become applied increasingly as other popular herbal thermogenic substances have been removed from the market.

Coffee and Gastrointestinal and Liver Health

The effects of coffee on the gastrointestinal (GI) tract, the liver, and the biliary tract are well-documented and have been attributed to the effects of caffeine and chlorogenic and caffeic acids.

The effects of coffee as a laxative and digestive aid within the GI tract are triggered either directly or indirectly by the release of gastrin and other GI hormones.[55] Maintaining regular bowel movements is itself protective against GI disease; in addition, specific studies have demonstrated other potential protective effects of coffee for reducing the risk of serious overt disease processes, such as alcohol-induced pancreatitis.[56] Another clinically significant application for coffee appears to arise from its ability to help inhibit both alcoholic and nonalcoholic liver cirrhosis.[57,58]

Because of the unique relationship between caffeine and the hepatic microsomes that metabolize it, it has been proposed that fasting plasma caffeine concentration may serve as a guide to measuring the physiologic impairment arising from chronic liver disease.[59] By inducing phase 1 detoxification, caffeine can provide, via hepatic detoxification testing, information on whether an imbalance between phase 1 and phase 2 detoxification pathways are present.

The unique physiologic impact of caffeine in the liver has also led to research on the relationship between serum γ-glutamyltransferase—a measure of liver damage—and smoking that suggests coffee may help mitigate some of the damage associated with smoking.[60] What also supports this trend is an observation of an increase in γ-glutamyltransferase in women from Norway who decreased their consumption of boiled coffee.

Finally, gallstone formation may be modified by coffee consumption according to a study of 46,008 men, ages 40–75, in which those who consumed 2–3 cups of coffee per day had a lower risk of forming gallstones.[61] It is noteworthy that all brewing techniques produced a reduction in incidence of stone formation, as long as the coffee had not been decaffeinated. It has also been shown that drinking caffeinated coffee decreases the risk of symptomatic gallstones in women but this has not been demonstrated in men.[62]

Coffee, Parkinson's Disease, and Other Neurologic Conditions

Several studies have shown that coffee consumption can decrease the incidence or risk of Parkinson's disease. Indeed, evidence exists for protection against the incidence of Parkinson's disease in Asian-Americans[63] as well as in the general population in the United States,[64] Italy,[65] and China.[66] Additional studies support findings that coffee consumption lowers the risk of Parkinson's disease.[67]

With an ever-increasing number of cases of Alzheimer's disease being diagnosed, interest in ways to mitigate this devastating illness is quite high. It appears that coffee might very well be the beverage of choice in this instance as well, as it has been asso-

ciated with a reduced risk of Alzheimer's disease.[68,69] However, currently, there is a lack of evidence that coffee slows nonspecific, age-related mental decline.

There appears to be a synergistic effect between coffee and anticonvulsant therapy, when used together, that results in a reduction of sleep seizures.[70] However, this is not advisable for all patients with seizure disorders, because individual tolerences vary.

Coffee and Sexual Activity

A healthy sexual response is achieved when proper neurologic, cardiovascular, hormonal, and mental health is maintained. Common hormonal denominators for both men and women relative to sexual desire and response are total- and free-testosterone levels. It has been reported that total testosterone is positively associated with coffee consumption in men[71] and that drinking at least 1 cup of coffee per day increases sexual activity in elderly women and higher potency has also been reported in elderly men.

Miscellaneous Biogenic Amines

The variability seen in the chemical profiles of coffee, depending on the amount of roasting and the brewing technique used, cannot be overemphasized. As researchers continue to investigate the bioactive substances in coffee, these investigators have brought to the forefront a series of biogenic amines that become particularly prominent during the roasting process, such as serotonin, spermidine, and agmatine.[12] The efficacies and therapeutic applications of these biogenic amines have not yet been explored thoroughly but may lead to an entirely renewed appreciation of coffee's transcultural appeal to humanity as a whole.

Caffeine

No discussion on coffee would be complete without at least a brief review of caffeine. Until recent years, the word coffee was synonymous with caffeine. The scientific literature has attributed to caffeine coffee's ability to enhance mental alertness, reduce fatigue, and enhance wakefulness.[72] This review of the benefits of coffee has not focused on the benefits of caffeine specifically simply because an entire separate treatise would be necessary to do justice to the topic.

It is important to realize that because caffeine is a well-known and documented biomarker in coffee research, the frequent large variations in levels of caffeine in prepared coffee serves as a point for consideration. The typical caffeine content in coffee ranges from 58 to 259 mg per dose.

In one study, the mean caffeine content for a 16-ounce cup of coffee was 188 mg per dL.[73] There is an equally high variance in caffeine content reflected in a more recent study that shows a caffeine concentration range of 259–564 mg per dose in the same coffee beverage obtained from the same outlet on 6 consecutive days.[74] Thus, the question must be posed: What other active constituents varied within those same samples?

We know that consistent dosing provides a level of clinical predictability, whether this involves standard drug therapies, nutritional interventions, botanicals, or functional foods. If we are to encourage the use of functional foods as tools in overall diet and lifestyle modifications, attempts must be made to provide consistent quality and therapeutic bioactivity.

Conclusions

Coffee is important for helping to sustain human health. Yet, if we are to prescribe coffee as a therapeutic intervention, it is essential that we understand its dynamic constituent profile better. It is even more important to note that, because current scientific research has yet to determine the best across-the-board method to achieve maximum therapeutic efficacy, coffee remains a food best consumed in its purest, most natural form.

The epidemiologic studies that identify the most effective mix of coffee, diet, and lifestyle are providing us—as clinicians—with the most useful information as we seek to modify disease expression in our patients.

There is a tremendous movement to help make the production of coffee a sustainable industry, and proposed guidelines for this endeavor seek to encourage the consumption of coffee that is shade-grown, organic, and fairly traded. To use coffee actively as medicine is to adhere to the guidance of Hippocrates, who stated in 400 BC: "May your food be your medicine and your medicine be your food." □

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