1 Introduction

Thomas Hatzold

1.1 COFFEE—A POPULAR BEVERAGE

Billions of cups of coffee are enjoyed every year by consumers around the world. Coffee consumption is common among both younger and older adults, and at all times of the day: early morning upon waking, for breakfast, after a meal, and even in the evening. It is taken at home, at work, and in cafés, bars, and restaurants. The preparation methods range from café ristretto, a special type of espresso containing little water, to large cups of "regular" coffee. It is taken as black coffee or with addition of other food ingredients such as sugar or other sweeteners, milk or nondairy creamer, and in the form of special preparations such as cappuccinos, lattes, or flavored coffees.

Coffee is consumed for its unique aromatic taste and stimulating effects. The pleasant taste originates from the roasting process, where the bitter tasting and the characteristic volatile aroma components are formed [1]. More than 1000 different aroma compounds have been identified in coffee, making it a complex and diverse beverage. Moreover, the effects of coffee can be either stimulating or relaxing, depending on the situation one finds oneself in and how one feels [2].

Consumers may take coffee for emotional reasons because they enjoy it; it may help them relax or improve their mood. Other reasons for drinking coffee may be more rational; it may help one to wake up, be stimulated, have improved concentration, or avoid falling asleep when wakefulness is desired. Coffee is also used for social reasons, which is evident from the 400-year history of coffee houses, where people meet while enjoying their coffee.

Coffee is one of the most popular drinks in Western countries. In many countries, most adults consume this beverage. In the United States, for example, only 22% of adults never drink coffee [3].

1.2 COFFEE FROM A NUTRITIONAL PERSPECTIVE

Coffee is a unique drink and could be regarded as a healthy beverage choice. If taken as black coffee, it is virtually free of saturated fatty acids, sodium, and sugar. Further, it contains an insignificant amount of energy: 2 kcal/178-g serving [4]. However, many consumers add sugar, milk, or cream to their coffee. The amount of calories provided daily by sweetened

Coffee: Emerging Health Effects and Disease Prevention, First Edition. Edited by Yi-Fang Chu.

coffee has been calculated as 130 kcal/day (consumers of this beverage only), which is less than half of the estimated 321 kcal/day obtained from all sweetened beverages (including sodas/colas), based on intake data from the United States [5]. Consumers who want to control their calorie intake or consumption of nonessential nutrients such as sugar or saturated fat may choose to add noncaloric sweeteners and low-fat milk to their beverage.

Certain so-called gourmet coffee beverages should be consumed in moderation. These include cappuccino and lattes that contain ingredients such as cream, full-fat milk, and sugar. These beverages can contain up to 240-kcal/237-mL serving [6], but beverages with significantly lower energy levels are also available. An intake study of college women indicated that gourmet coffee drinkers consumed an additional 206 kcal/day and 32 g sugar/day compared with nonconsumers [7].

Roast coffee produced by traditional roasting processes can be regarded as a natural food or food ingredient. It is a single ingredient product without additives and thus fulfills the criteria for the term “natural” that was established by the UK government, for example [8]. In certain roast coffee products, the only other substances used are packaging gases such as carbon dioxide, an inert gas that preserves the flavor. In other roast coffee products, other technologies such as vacuum packaging may be used for this purpose.

1.3 POTENTIAL BENEFICIAL EFFECTS OF COFFEE

The health aspects of coffee drinking have been subject to many controversial debates. This history is nicely summarized in Ian Bersten’s book *Coffee, Sex & Health, a history of anti-coffee crusaders and sexual hysteria* [9]. As the author points out:

> . . . even though coffee, tea and cocoa all contain caffeine, seemingly the root cause of many problems to do with health, coffee seemed to be the only one of the three that had a health image problem.

Even today, a substantial number of articles about coffee are negative. In the United Kingdom, for example, 51% of media publications on coffee, caffeine, and health are negative, 22% are neutral, and 27% positive [10].

Only recently have scientists begun to document the potential health benefits of coffee drinking, whereas research data on the acute/short-term stimulating properties of coffee due to caffeine are well known. Caffeine is naturally found in about 60 different plants including tea leaves, cocoa beans, guaraná, and kola nut. It is also added to many soft drinks including energy drinks and to medicinal products such as analgesics and cough syrups [11,12].

Acute caffeine effects on the central nervous system have been reviewed extensively [13–15]. Although these effects are not the focus of this book, they are briefly summarized here.

At common consumption levels, the most important acute effect of caffeine and its predominant metabolites (paraxanthine and theophylline) is the blockade of adenosine A_1 and A_{2A} receptors. This leads to activation of a variety of neurotransmitter systems and finally to the well-known effects on improved arousal, vigilance, and attention. There is evidence that caffeine has the potential to improve cognitive functions that are timed such as reaction time, decision-making, or cancellation tasks. Its influence on mood depends on the amount of caffeine consumed, individual differences, and arousal states. In real-life simulations, caffeine appears to improve performance of artificial tasks and simulations of driving and industrial work.

The European Food Safety Authority (EFSA) recently reviewed the science of caffeine effects for the purpose of establishing a health claim, concluding that a cause-and-effect relationship existed between caffeine consumption and increased alertness and attention with at least 75 mg caffeine [16], which is approximately the amount contained in a cup of coffee. Thus, a cup of coffee may well help to start the morning, get through the day when tired, overcome the postlunch slump, or maintain attention at night (e.g., during overnight work). Other effects of caffeine on the nervous system are covered in Chapter 13.

Caffeine is also an ergogenic aid, and thus has the potential to enhance physical performance during prolonged, exhausting exercise in particular and during short-term, high-intensity athletic performance to a lesser degree [17]. Its efficacy has been proven in a variety of endurance sports including cycling, running, swimming, tennis [17,18], and recently even in simulated soccer [19] and rugby playing [20]. The EFSA evaluated these effects, and concluded that a cause-and-effect relationship exists between caffeine intake and increased endurance performance and capacity (at 3 mg/kg body weight) and perceived exertion/effort during exercise (at 4 mg/kg body weight) [21].

Other potential benefits such as reduced risk for certain diseases, as assessed by observational studies, have become widely known to the scientific community in recent years. For example, the relationship between coffee drinking and diabetes based on epidemiologic studies was first described less than 10 years ago [22], triggering many more observational, human intervention, and mechanistic studies (see Chapter 8).

In fact, when searching for "coffee and health" in the ISI Web of Knowledge, the record count per year increased from 21 to 30 in the years 1996–2001 to 74–107 in the years 2007–2010, demonstrating the significant increase in scientific investigations in this field.

Moreover, some of the diseases that appear to be influenced by coffee drinking are important public health issues. For example, diabetes affects 346 million people worldwide, and the World Health Organization projects that diabetes deaths will double between 2005 and 2030 [23]. Alzheimer's disease is another area in which emerging science indicates that coffee might play a role in risk reduction (see Chapters 4 and 5). Alzheimer's Disease International [24] estimated that 35.6 million people were living with dementia worldwide in 2010; this figure is projected to increase to 65.7 million by 2030 and 115.4 million by 2050. Nearly two-thirds live in low- and middle-income countries, where the sharpest increases in numbers are set to occur. Alzheimer's Disease International calls on governments and other major research funders to act now to increase dementia research funding, including research into prevention, to a level more proportionate to the economic burden of this condition [24].

Other potential beneficial effects of coffee relate to Parkinson's disease (Chapter 6), liver health (Chapter 7), cancers (Chapter 10), overall mortality (Chapter 11), and risk of suicide (Chapter 13).

Even if coffee drinking only slightly reduces the risk of developing some of these diseases, it may add to the effect of already well-known healthy lifestyle recommendations. In this way, this common behavior could be of significant public health importance.

1.4 LIMITATIONS TO THE BENEFICIAL EFFECTS

The potential negative aspects of coffee drinking have been discussed for a longer time. In particular, the International Agency for Research on Cancer in 1991 published the view that coffee "is possibly carcinogenic to the human urinary bladder" (Group 2B carcinogen) [25].

Since then, this concern has largely been dismissed. The World Cancer Research Fund made the following statement in the second expert report [26]:

> The judgments of the previous report on coffee were practically the same as in this Report, except that the previous report judged that drinking more than five cups per day was a possible cause of bladder cancer. The evidence now indicates that coffee is unlikely to have substantial effect on risk of this cancer.

As outlined in Chapter 10, there are some data that link excessive coffee intake with this cancer type; however, epidemiologic studies suggest that coffee consumption is inversely associated with the prevalence of many other cancers.

Although there is little evidence for the overall detrimental health aspects of drinking coffee, some population groups may be negatively affected by coffee or caffeine.

First, coffee is a beverage that is consumed primarily by adults. Although children often consume caffeinated beverages, the contribution of coffee to caffeine intake in childhood is low. According to Canadian Authorities [27], approximately 55% of the caffeine consumed by children aged 1–5 years comes from cola drinks, about 30% from tea, and about 14% from chocolate. The rest comes from other sources including medicines. A review on the subject [28] reported that it is unclear whether caffeine produces serious adverse effects in children. Similarly, a report of an Australian New Zealand expert group concluded that

> [T]he threshold dose for possible behavioral effects in children remains unclear and it is recognized that further studies are needed to elucidate the potential effects of caffeine in children at doses that may be ingested from dietary sources [29].

The EFSA states that consumption of 5 mg/kg body weight could produce transient behavioral changes such as increased arousal, irritability, nervousness, or anxiety in children [16].

In Canada, there is a recommendation to limit the caffeine intake of children (45 mg for children 4–6-year-old; 62.5 mg, 7–9 years; and 85 mg, 10–12 years). For adolescents ($\geq$13 years), Health Canada suggests no more than 2.5 mg/kg body weight. This has been described as a conservative recommendation because older and heavier weight adolescents may be able to consume adult doses of caffeine without having adverse effects [27].

Another area of concern is pregnancy. There are several recommendations by governmental bodies to restrict caffeine intake during pregnancy from 200 to 300 mg/day [30,31]. This issue is discussed in depth in Chapter 14.

Evidence-based advice is limited for individuals with specific health conditions such as elevated blood pressure, diabetes, or cardiac arrhythmias. Regarding arrhythmia, there is advice to counsel:

> [H]igh risk patients to moderate their caffeine intake, but other interventions - e.g., smoking cessation, weight loss, exercise, and a healthy diet, low in saturated and trans fats - yield larger benefits and should come first [32].

This advice is based on blood pressure concerns rather than a causal relationship between coffee drinking and cardiac arrhythmias, for which there is little evidence. In fact, the European Union (EU) Scientific Committee on Foodstuffs stated:

> The evidence from human studies, which have included normal individuals at rest, those undergoing intense exercise and those predisposed to cardiac arrhythmias, have not indicated risks from normal intakes of caffeine alone [30].

Advice regarding the other aforementioned conditions has also been published:

> Although it has not been established whether reducing caffeinated coffee consumption has long-term benefits on blood pressure or glycemic control, individuals with hypertension and type 2 diabetes could try switching from caffeinated to decaffeinated coffee to see whether it improves their condition [33].

Diabetes and cardiovascular diseases will be discussed in more detail in Chapters 8 and 9. Potential mental risks with caffeine intake are discussed in Chapter 17.

Many consumers are not aware of the increasing debate within the scientific community on emerging health benefits of coffee. In the United States, for example, health risks from drinking coffee are the most commonly reported health-related coffee associations. In 2009, 59% of consumers indicated they had heard about the health risks of drinking coffee in the past year, but only 48% indicated that they had heard about health benefits [3]. Of these, 47% stated that coffee improves mental focus and 35% that coffee is good for health.

1.5 HISTORY

Coffea arabica originated in Ethiopia, where it grew at altitudes between 1300 and 2000 m, whereas *Coffea canephora* (also known as Robusta coffee) was more widely dispersed in tropical Africa at altitudes below 1000 m. According to a legend, coffee drinking began with a goat herdsman who observed that his goats were excited after eating some red berries. When he tasted these berries he was able to stay awake. He took these berries to a local monastery, and the monks used them to keep them awake during prayers [34]. The history of coffee use is summarized in Table 1.1.

Since the introduction of coffee into Western Europe and America, its effect on health has been the subject of major and continuing controversy [9]. However, it is important to take an evidence-based view to understand the actual physiologic effects of coffee.

1.6 COFFEE PRODUCTION WORLDWIDE

The International Coffee Organization [35] regards coffee, which creates US$ 70 billion in retail sales a year, as one of the most valuable primary products in world trade. In 2010, the total world production of green coffee amounted to 134 million 60-kg bags, which corresponds to approximately 8 million tons, and this production has been increasing over the last 5 years. Brazil has the highest production (48 million bags), followed by Vietnam (18 million bags), Indonesia (9.5 million bags), and Colombia (9 million bags). Overall, more than 50 countries produce coffee.

1.7 COFFEE PROCESSING: FORMATION AND FATE OF BIOACTIVE COMPOUNDS

Although coffee is a simple product, its production from the bean to cup is a complex task involving many steps. This process has been the subject of substantial research and attempts to improve technologies to achieve the desired quality, taste, flavor, and physical properties of the

Table 1.1 Key events in coffee history.

Year	Event
600–800	Coffee discovered in Ethiopia.
1000	Arab traders invent coffee beverage by boiling coffee beans.
1000–1600	Coffee exclusively cultivated and roasted in Arabia. First coffee shops opened in Mecca in the Middle Ages.
1475	Coffee on its way to Europe: first coffee shop Kiva Han opens in Constantinople after coffee introduced by Ottoman Turks in 1453.
1607	Introduction of coffee to North America.
1615	Venetian traders first brought coffee to Europe.
1600s	First European coffee houses open: Italy 1645, England 1652, Paris 1672, Vienna 1675, and Berlin 1721.
1675	Habit of refining the brew by filtering out the grounds, sweetening it, and adding a dash of milk born in Vienna.
1700	French and British colonists introduce coffee planting to Central and South America.
1727	Start of Brazilian coffee industry.
1773	The Boston Tea Party makes drinking coffee a patriotic duty in America.
1901	First soluble coffee invented by Japanese–American chemist Satori Kato.
1903	First decaffeinated coffee invented in Germany.
1927	First espresso machine producing foam "crema" introduced.
1946	Cappuccino is born in Italy.
1958	First electric drip filter coffee machine developed.
1990	North American coffee shop phenomenon.
Now	Widespread use of single-serve coffee machines.

Source: Adapted from Kraft Foods 2008: Coffee Antioxidants and Health, Kraft Foods R&D, Inc., Munich, Germany.

final product. The processing methods also influence the presence of bioactive compounds, both qualitatively and quantitatively, and therefore may influence coffee's physiologic effects in the human body (Figure 1.1).

This chapter provides a general overview of the most relevant effects of processing on bioactive compounds. Chapter 2 provides more detailed insight into the chemical composition of coffee and the influence of various processing parameters.

1.7.1 Green bean processing, storage, and transport

Coffee production starts with cultivation and harvesting. The fruits of a coffee tree are known as cherries; they contain the beans with which coffee is made. Common methods for separating the bean are known as dry processing, semidry processing, and wet processing. Controlling or minimizing pesticide usage and their residues in the green bean is important from a health perspective. This is achieved by adhering to good agricultural practices, integrated pest management, or in some cases, organic production. Although maximum limits for pesticides in green beans have been established in several countries, the occurrence of pesticide residues in green coffee beans is insignificant. In a survey conducted in the United States, pesticides were detected in only 4 of 60 green coffee samples at low levels [36]. This issue is discussed in more detail in Chapter 2.

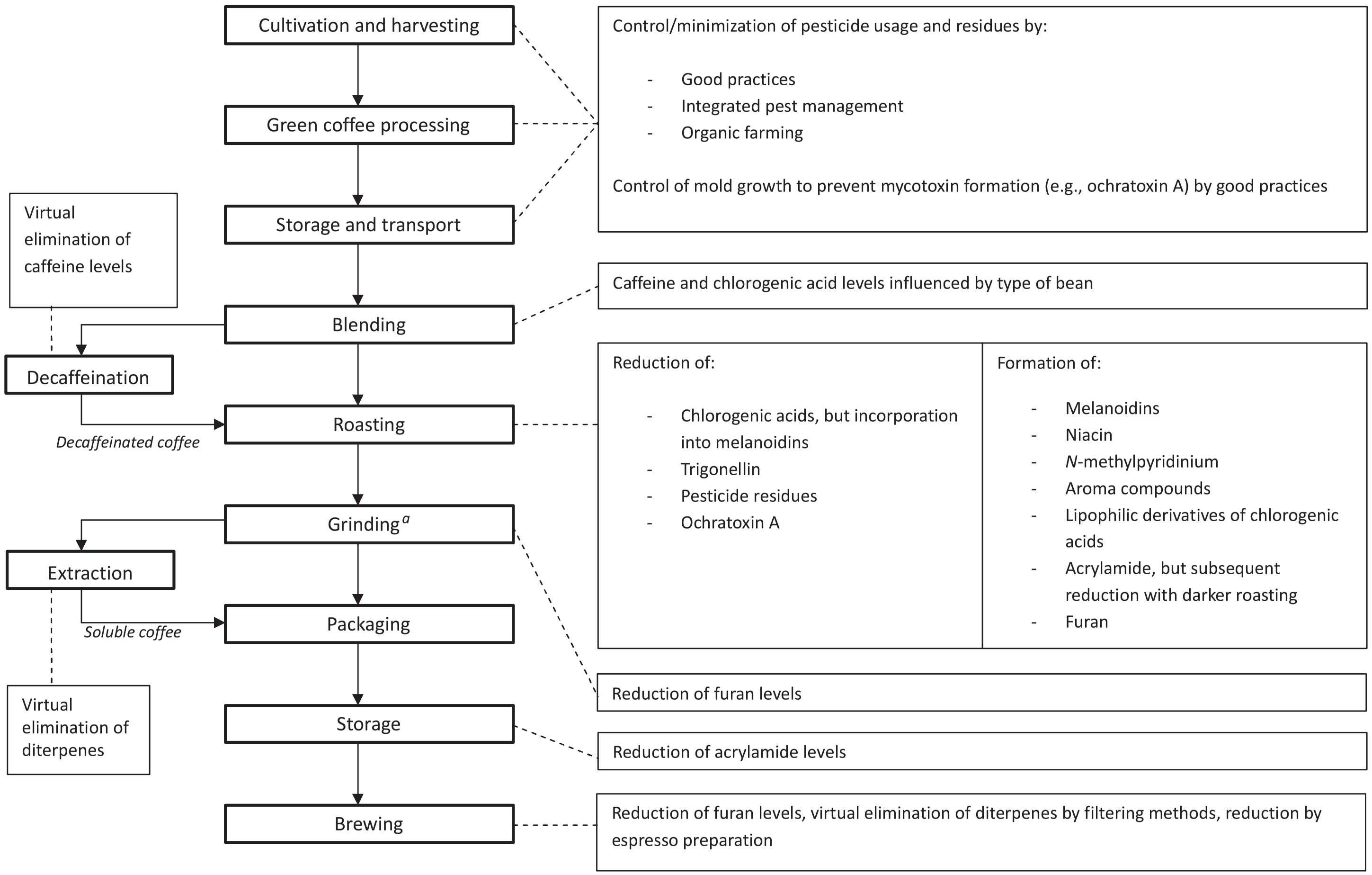

Figure 1.1 Effects of coffee processing on bioactive compounds. [a]Some products are not ground as part of the industrial process but sold as whole bean for subsequent grinding by the consumer.

To minimize the formation of mycotoxins such as ochratoxin A, mold growth should be controlled throughout the coffee production stages including growing, harvesting, processing, storage, and transport. Ochratoxin A levels in green coffee vary considerably depending on the provenience, growing climate, and processing conditions [37,38]. The Codex Alimentarius Commission has established a code of practice to prevent and reduce ochratoxin A contamination in coffee [39].

1.7.2 Blending

The blending of coffee beans is another critical step that influences the chemical composition of the final product. Robusta beans tend to contain higher levels of caffeine and chlorogenic acids than Arabica beans; however, within each species there is considerable variation (see Chapter 2). In addition, there have been attempts to develop varieties of coffee trees [40] that produce a naturally low-caffeine bean without decaffeination for consumers who desire it.

1.7.3 Roasting

Roasting the coffee bean produces the most striking changes in its composition. Although the caffeine level is not affected, other significant chemical changes occur.

First, the characteristic coffee **aroma components** are formed [1]. Aroma compounds in general appear to play an important role in subjective emotions and are used in aromatherapy [41]. The author concluded that there is credible evidence for olfactory effects on mood, physiology, and behavior. Although only a small database exists to support such effects for foods and drinks, there is evidence that the aroma of roasted coffee beans changes the level of antioxidant or antistress-related mRNA and protein expression levels in the rat brain [42]. This research group subsequently demonstrated an olfactory priming effect of coffee aroma on visual selective attention in humans [43].

Other major reactions that occur during roasting are the Maillard reaction and oxidative polymerization or degradation of phenolic compounds [44]. Phenolic compounds in coffee include chlorogenic acids, which exert broad physiologic actions including antioxidative and anti-inflammatory effects. The chemistry of these and other compounds is described in Chapter 2, and their physiologic effects in Chapter 12. Interestingly, some of the reaction products of chlorogenic acid formed during coffee roasting (e.g., 3,4-diferuloyl-1,5-quinolactone) can inhibit the human adenosine transporter with a potency at least equivalent to that of caffeine for blocking adenosine receptors [45]. Further studies are needed to determine whether these substances attenuate the stimulating effect of caffeine when ingested together in roast coffee. For further details, see Chapter 2.

The exact molecular composition of the Maillard reaction products or melanoidins is poorly understood. However, chlorogenic acids probably do not lose their antioxidant and phenolic characteristics after incorporation into coffee melanoidins. Most of these antioxidants formed during roasting are present in the high molecular weight fractions, indicating that the formation of these antioxidants preferentially occurs at specific high molecular weight structures, probably arabinogalactan and/or protein moieties that may be part of the melanoidin complex [46].

Trigonelline, which is the second most important alkaloid of coffee after caffeine, is partially degraded during roasting, producing other bioactive compounds such as niacin and

N-methylpyridinium. Animal trials point to a potential improvement of auditory neuropathy in diabetic mice through trigonelline intake [47]. Other effects of this substance are discussed in Chapter 2.

***N*-Methylpyridinium**, formed from trigonelline during roasting, was identified through activity-guided screening. This compound appears to activate the endogenous antioxidant defense system. Total antioxidant capacity and tocopherol levels were elevated in the plasma of animals fed an *N*-methylpyridinium-containing diet or coffee [48].

Niacin is formed during roasting as a result of trigonelline degradation and is influenced by roasting conditions. Final levels of niacin in the cup range between 1 mg in weak and light roast to 3 mg in strong and dark roast coffees [49]. Lower levels have been described in the type of coffee typically consumed in the United States (0.34 mg/178-g serving) [4]. In the EU, 15% of the recommended dietary allowance (16 mg/100 g food as consumed) would be considered physiologically significant, resulting in a target level of approximately 2.4 mg/100 mL coffee. The EFSA [50,51] reviewed the physiologic effects of niacin and concluded that it provides several health benefits including reduction of tiredness and fatigue as well as contribution to the normal function of the nervous system. EFSA, however, points out that inadequate niacin intake does not occur in the general EU population [50,51].

The level of bioactive compounds in coffee can thus be influenced by the type of roasting, with light roast coffees containing higher levels of chlorogenic acids than dark roast coffees. On the other hand, dark roast coffees contain higher levels of other bioactive compounds such as melanoidins, *N*-methylpyridinium, and possibly niacin.

Undesirable substances are also affected by roasting. Any **pesticides residues** present in the green bean are degraded (72%–98%) [52] and reduced further by subsequent brewing (33%–99%).

Similarly, **ochratoxin A** levels are reduced by 69%–96% during roasting [53]. In the EU, maximum limits for ochratoxin A have been established for roast coffee (5 μg/kg) and soluble coffee (10 μg/kg) [54].

In addition, some so-called process-related contaminants are formed. **Acrylamide** is generated at the beginning of the roasting process, but partially broken down later [55]. Details of this process are discussed in Chapter 15.

Acrylamide is considered to be both genotoxic and carcinogenic in laboratory animals as well as neurotoxic (see Chapter 15). However, given that its occurrence in coffee is largely unavoidable, like many other naturally occurring food substances, the effect of coffee as a whole should be considered. As outlined in Chapters 4, 5, and 10, scientific data indicate that coffee exerts neuroprotective and anticarcinogenic effects (or at least neutral effects on cancer development), which may outweigh any theoretical harm caused by acrylamide. In fact, DNA oxidative damage was shown to be reduced after coffee drinking in humans [56], which suggests a protective role of coffee despite the presence of acrylamide. Further studies are needed to substantiate this hypothesis.

The situation is similar with **furan**, which is also formed during roasting and is part of the volatile aroma fraction of coffee [57]. This substance is considered cytotoxic, and the liver is the primary target organ of furan after ingestion (see Chapter 18). However, coffee appears to exert a protective effect on the liver (see Chapter 7).

Taken together, these findings show that although minimizing contaminants in processing is important, the physiologic effects of coffee should be considered for coffee as a whole rather than its individual components.

P1: SFK/UKS P2: SFK
BLBK402-c01 BLBK402-Chu November 17, 2011 11:8 244mm×172mm

1.7.4 Grinding

Grinding is the next stage in coffee production. Loss of volatile aroma compounds (including furan) occurs during grinding, depending on the process conditions. Smaller grind sizes increase furan losses [57] (see Chapter 18).

1.7.5 Packaging and storage

Packaging and storage of coffee, the final stages of the process, generally produce only small effects on bioactive components. However, the acrylamide levels of roasted beans decrease during storage (Chapter 15).

1.7.6 Decaffeination

Decaffeinated coffee is produced by extracting caffeine from the green beans before roasting. This product is preferred by consumers who do not desire the stimulating effect of caffeine. Caffeine ingestion may make them feel nervous or agitated, especially in the afternoon or evening, when it may affect the ability to fall asleep. Pregnancy or certain diseases and health conditions are other reasons that decaffeinated coffee may be preferred. The three main methods for extraction: use organic solvents (dichloromethane or methyl acetate), water, or supercritical carbon dioxide. These technologies have been reviewed in detail [58]. European regulations state that the level of caffeine in the final product must not exceed 1 g/kg roast coffee or 3 g/kg coffee extract (dry matter). In contrast, the standard in the United States is based on absolute reduction of caffeine in the bean; the final product may contain no more than 3% of the original caffeine content of the coffee bean (i.e., 97% caffeine free).

1.7.7 Soluble coffee production

Soluble coffee (instant coffee) is a convenience product that requires only the addition of hot water before drinking. The production of soluble coffee has been reviewed in detail [59]. In the EU, only water can be used for extraction. By definition, extraction methods used to produce soluble coffee increase the concentration of soluble compounds in the final product. However, the consumer uses a smaller amount of soluble product to prepare a cup of the beverage, compared with the amount of roast coffee used; therefore, the concentrations of bioactive compounds in the final preparation are similar to that of a filtered coffee.

The separation methods applied during processing largely eliminate coffee oils and the compounds cafestol and kahweol, resulting in final concentrations similar to that of filtered coffee (see Section "Coffee Preparation").

1.8 NEW PROCESSES TO OPTIMIZE THE HEALTH BENEFITS OF COFFEE

The roles of the individual compounds on the physiologic effects of coffee are not yet well characterized. More detailed research in this area could enable coffee producers to selectively enhance some of the beneficial compounds through processing. Several attempts to optimize the health benefits of coffee in this way have been described in the literature and underpinned by human intervention trials.

1.8.1 Enhancement with mannooligosaccharides

Mannooligosaccharides (MOS) are naturally present in coffee beans but are not extracted into the beverage to a significant degree under standard preparation methods. However, they can be obtained by a secondary high-temperature extraction of spent grounds during commercial soluble coffee production and then combined with the original extract. Coffee with enhanced MOS content exerts prebiotic effects in animals [60] and humans [61–63]. This coffee appears to decrease fat absorption [64] and reduce abdominal fat in humans, as demonstrated by a clinical study in a Japanese population [65]. A subsequent study in an American population provided some evidence for this effect in men but not in women. Men consuming a MOS-enriched beverage showed a greater change in total body volume ($P = 0.043$) than the placebo group, and appeared to have greater percent change in subcutaneous fat ($P = 0.069$) and total adipose tissue ($P = 0.098$). However, no significant effect on visceral adipose tissue was observed [66].

1.8.2 Use of green bean extracts

The effect of a coffee product containing 35% green coffee water extract and 65% roasted coffee water extract was also evaluated in humans [67]. The chlorogenic acid content of the product was increased by extraction of water-soluble material from the green (unroasted) beans. The antioxidant effect of this product was significantly higher than that of the control. In particular, urinary 8-iso-prostaglandin F2α levels declined by 15.3%, and 3-nitrotyrosine declined by 16.1%. DNA migration due to oxidized purines and pyrimidines was however not significantly reduced in lymphocytes.

Consumption of green coffee extract has recently been suggested for weight management. Although caffeine and other constituents may stimulate weight loss [68], the existing data from epidemiologic studies are not sufficient to support a significant weight loss effect of green coffee extract. However, green coffee contains more chlorogenic acid than roasted coffee, and chlorogenic acid appears to exert an antagonistic effect on glucose transport [69]. A review and meta-analysis of human studies indicate that green coffee extract may promote weight loss. A significant difference in body weight was observed between participants who consumed green coffee extract compared to those who consumed placebo (mean difference: −2.47 kg; 95% confidence interval: −4.23, −0.72). However, the magnitude of this effect was judged to be moderate, and significant heterogeneity among the studies was observed. The authors conclude that although these results are promising, the studies were of poor methodological quality. Thus, more rigorous trials were suggested [70].

1.8.3 After-roast blending for enhanced antioxidative properties

A blend of light roast and dark roast beans may optimize the antioxidant properties of coffee. Researchers have demonstrated differential antioxidant activities of light, medium, and dark roasted coffee extracts. This difference was attributed primarily to the original constituents of the beans (particularly chlorogenic acids and trigonelline in light roasts) and thermal degradation products (in dark roasts) [71]. The researchers subsequently demonstrated that DNA oxidative damage was decreased in subjects who consumed a coffee blend rich in both original constituents and thermal degradation products [72].

1.8.4 Stomach-friendly coffee

So-called "stomach-friendly" coffees may be better tolerated by sensitive individuals, but more rigorous human intervention studies are needed to prove a beneficial effect. This subject is discussed in more detail in Chapter 16.

1.9 COFFEE PREPARATION

A variety of coffee preparation methods are used across countries and regions, ranging from traditional simple household methods to sophisticated extraction methods carried out with modern equipment. These methods have been described in detail [73]. The preparation method, coffee/water ratio, brewing temperature, contact time, and grind size determine the type and amount of the substances extracted into the beverage. Overall, extraction yields range from 24.2% (espresso) to 31.4% (moka). Caffeine is extracted into the brew with most methods, with yields between 89% and 100%. This may be different for espresso-type coffees, in which the yield may reach only 75%–85% due to the short contact time.

The most important differences between brewing methods with regard to coffee's physiologic effects are seen with lipids (e.g., diterpenes, cafestol, and kahweol). These substances appear to play a dual role. Although cafestol and kahweol are primarily known for increasing total cholesterol and low-density lipoprotein [74], animal experiments provide evidence for a hepatoprotective role against damage induced by carcinogens [75–77].

These substances do not easily pass through filter paper and are therefore not present at a significant level in filtered coffee, including soluble coffee and brews prepared from coffee pads in a single-serve machine. The cholesterol-raising effect of these brews is therefore negligible, whereas boiled coffees and cafetière coffees have demonstrated a cholesterol-raising effect in human intervention trials. This subject has been extensively reviewed by Urgert et al. [74]. A summary of the literature regarding diterpene levels in different coffee brews is provided in Table 1.2. Although no paper filter is used in its preparation, espresso contains diterpene levels between the two extremes. This is probably due to the short contact time.

Table 1.2 Diterpene contents in different coffee brews.

	Cafestol (mg/cup)			Kahweol (mg/cup)		
Coffee type	[78]	[79]	[80]	[78]	[79]	[80]
Paper-filtered	0.1	<0.1	0.09–0.12	0.1	<0.1	0.09–0.15
Instant	0.2	0.2	–	0.2	0.2	–
Pads (from a single-serve machine)	–	–	0.1–0.12	–	–	0.12–0.14
Percolator	0.3	–	–	0.3	–	–
Moka	1.1	2.3	–	1.4	2.3	–
Espresso	1.5	1.0	–	1.8	1.0	–
Cafetière	3.5	–	–	4.4	–	–
Turkish	3.9	5.3	–	3.9	5.4	–
Boiled	3.0	7.2	7.3–14.5	3.9	7.2	6.8–14.7

Levels were calculated for 150-mL cup size for pads and filtered, instant, cafetière, and boiled coffees, 60-mL cup for Turkish and moka coffees, and 25-mL cup for espresso coffees, as suggested by Urgert et al. [74].

Another effect of brewing is the loss of volatile compounds including furan [57], which is described further in Chapter 18.

Although detailed descriptions of the different brewing methods have been previously published [34,73,81], a short summary is provided here.

1.9.1 Boiled coffee

Boiled coffee was an early preparation method in which the coffee/water mixture is boiled for up to 10 minutes. Alternatively, hot or boiling water can be poured into a cup containing coffee. While the coffee cools, the grounds sink to the bottom, and the beverage can then be consumed. Variations on this method include Turkish coffee, Greek coffee, and Arabic coffee.

1.9.2 Cafetière or French press coffee

For cafetière and French press coffee, hot or boiling water is poured into a cylinder containing coffee. This mixture is stirred and then left to steep. After a few minutes, a plunger is pushed down to separate the grounds from the liquid.

1.9.3 Filter coffee

To prepare filter coffee, hot/boiling water is poured into a filter containing coffee. The grounds remain in the filter, and the coffee beverage is obtained as a filtrate.

1.9.4 Espresso

Espresso coffee is prepared with a specialized machine. The extraction takes place under high pressure for a short time to produce a shot of espresso coffee with a distinctive cream layer on top.

1.9.5 Moka (mocha)

Boiling water is forced through coffee in a special device called a moka pot. The water at the bottom of the device is boiled and then filters through the coffee grounds into the upper section of the pot where the coffee is brewed.

1.9.6 Percolated coffee

To prepare percolated coffee, water and then the coffee brew is recirculated in a percolator until the desired strength is reached.

1.9.7 Soluble coffee

Soluble coffee powder is prepared by dissolving in hot (or cold) water.

1.9.8 Liquid coffee

No preparation is necessary; it is ready to drink. However, concentrated liquid coffee extracts require dilution with hot water before drinking.

1.9.9 Single-serve coffee machines

Single-serve coffee machines force hot water through a filtering pad or capsule containing coffee.

Unfiltered/boiled coffee is the traditional preparation method, but this has been replaced in many countries by other methods. However, it is still very common in Central and Eastern European countries and in the Middle East and North Africa. Typical cup sizes for all coffees range from 20 to 35 mL in Italy (espresso) to 120 to 190 mL in other countries. Typical roast and ground coffee usage ranges from 5 to 10 g/cup. For soluble coffee, 1.5–3 g are used per cup, which corresponds to approximately 4–8 g of the original coffee powder.

1.10 COFFEE BEVERAGES AND SPECIALTIES

Coffee can be consumed as black coffee or after adding other ingredients. The ingredients most commonly used are milk and sugar or other sweetener, but cream or coffee whiteners are often added, as well as flavoring ingredients such as vanilla, chocolate, or hazelnut. Gourmet coffees include special preparations such as cappuccino or latte macchiato. Coffee is sometimes combined with alcoholic beverages such as whisky, cognac, or amaretto. In the Middle East, spices (e.g., cardamom, nutmeg, and cinnamon) are common ingredients. Chicory and figs are used primarily in France and the United Kingdom, respectively.

In the United States, the consumption of black coffee without other ingredients appears to be increasing. In 2008, 27% of consumers who started with brewed or instant black coffee did not add other ingredients. This figure increased to 34% in 2009; 20% of consumers used creamer only, 13% used sweetener only (sugar or other sweetener), 24% used both sweetener and creamer, and 9% used something else in 2009 [3].

A relatively recent trend in coffee is the consumption of ecologically responsible/organic coffee or coffee certified for social responsibility and sustainability, driven by consumer concerns about poverty, social injustice, and environmental degradation [82].

The International Trade Centre estimates the trade volume of organic coffee to approximately 1.7 million bags in 2009, which corresponds to about 1.3% of total coffee production. For certified sustainable coffees, the percentage is estimated at approximately 8% of the total coffee market, but the current growth rate is considerable, and 20%–25% of the global market has been projected for 2015 [82].

Other specialty coffees refer to specific origins or blends that confer unique flavor characteristics due to soil, altitude, climatic conditions, or variety of beans.

1.11 COFFEE CONSUMPTION

Figure 1.2 provides an overview of the per capita coffee consumption by country. These data are based on the country population and total consumption; therefore, the coffee intake of the coffee consumers alone is higher. However, the data reveal differences in coffee consumption between countries.

Europeans tend to drink more coffee than North Americans, and consumption is even lower in other regions of the world. Among Europeans, people living in Nordic countries drink the most coffee, with the highest consumption in Finland. Southern European countries

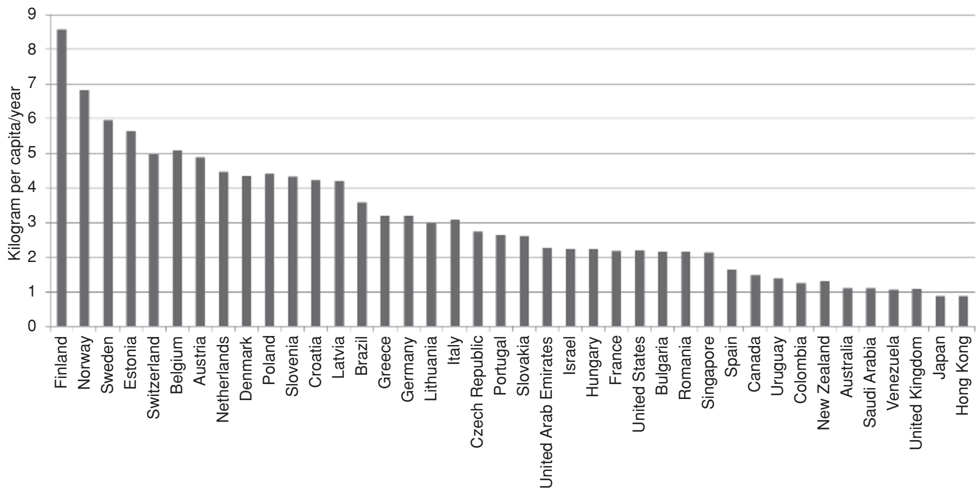

Figure 1.2 Coffee consumption by country 2010: 40 countries with the highest consumption. (Data from Datamonitor 2011, London, United Kingdom. The facts of this report are believed to be correct at the time of publication but cannot be guaranteed. Please note that the findings, conclusions, and recommendations that Datamonitor delivers will be based on information gathered in good faith from both primary and secondary sources, whose accuracy we are not always in a position to guarantee. As such, Datamonitor can accept no liability whatever for actions taken based on any information that may subsequently prove to be incorrect.)

tend to consume less coffee. However, the United Kingdom and Ireland, although located in northern Europe, are an exception to this trend with relatively low coffee consumption and high levels of tea consumption.

It is interesting to note that coffee consumption is higher in countries where Arabica is almost exclusively used (e.g., Nordic countries), whereas countries that consume more Robusta tend to consume less coffee (per capita). This finding may be due to the difference in caffeine content [81] between species; Robusta contains almost twice the amount of Arabica (see Chapter 2).

Because the data do not differentiate among individuals who are heavy consumers, occasional consumers, and nonconsumers, more specific data are needed. In the United States, for example, 54% of the adult population drink coffee daily, 63% drink coffee at least once per week, 77% at least once per year, and 22% of the population state that they never drink coffee [3]. The actual coffee consumption of heavy coffee drinkers therefore is probably considerably higher than the mean consumption. Older data from 1987 to 1989 [11] provide caffeine consumption data from coffee for all ages, with mean consumption of 2.30–3.66 mg/kg body weight and 90th percentile as 5.10–8.09 mg/kg body weight in the United States. These data indicate that a heavy coffee drinker in the United States drinks slightly more than twice the coffee consumed by the average consumer. The data indicated similar intake for the United Kingdom (mean: 2.19 mg/kg body weight; 90th percentile: 5.25 mg/kg body weight) but higher intakes for Denmark (mean: 8.1 mg/kg body weight; 90th percentile: 15.8 mg/kg body weight/day).

Some individuals consume even higher amounts of coffee. There are some anecdotal reports about heavy coffee drinkers in history. For example, Voltaire is said to have needed 72 cups of coffee per day. Beethoven liked his coffee very strong, with "sixty beans per cup."

The mean overall caffeine consumption in the United States from all sources including coffee, tea, caffeinated soft drinks, and chocolate were collected in the National Health and Nutrition Examination Survey database [83]. These data show that mean caffeine consumption increases with age, peaks at 273.4 mg/day for men and 207 mg/day for women (50–59 years), and then declines. Thus, men tend to consume more caffeine than women.

Data from 1995 show an overall mean daily caffeine consumption of 16 mg/day in China, 169 mg/day in Japan, and a range in Western countries from 168 mg/day in the United States to 390 mg/day in Denmark [12].

Although no clear evidence-based upper limit for caffeine consumption exists, Health Canada advises healthy adults to limit caffeine intake to 400 mg/day to avoid potential adverse effects [27], which the previously mentioned data indicate is complied with by most coffee drinkers globally. Future studies may clarify the putative benefits of coffee consumption and suggest an upper recommended intake level.

In 2009, total coffee consumption in the United States was 1.76 cups/person/day and 3.3 cups among coffee drinkers [3].

Interestingly, according to the German Coffee Association, coffee is the number one beverage in Germany in terms of total amount consumed (150 L/year), ranking before mineral waters (131 L/year) and beer (109 L/year) [84].

In the United States, regular coffee is the most commonly consumed coffee (1.23 cups/person/day). Other types of coffee are consumed less: 0.20 cups/day soluble coffee, 0.28 cups/day decaffeinated coffee, and 0.32 cups/day gourmet coffee beverages including espresso, cappuccino, and premium coffees [3]. Most coffee is consumed at breakfast; 91% of coffee drinkers drink it for breakfast, 20% between breakfast and lunch, 13% at lunch, 10% in the afternoon, 13% at dinner, and 8% in the evening [3]. This consumption pattern varies considerably across the world.

1.12 CONCLUSIONS

Science is only beginning to understand the relationship between coffee drinking and health and well-being. Previously, most scientific research focused on caffeine, for which there is now significant evidence describing its mild stimulating effect. However, there are many compounds in coffee that appear to exert bioactive actions.

The other chapters of this book will provide additional details of the current status of coffee science. This information will help scientists design studies to further evaluate these putative benefits, elucidate the mechanisms of bioactive substances, and differentiate populations that may benefit from coffee drinking from those that might not.

Consumers can be broadly divided into coffee drinkers and noncoffee drinkers. Coffee drinkers tend to drink the beverage daily and may do this over decades. Therefore, coffee may be the ideal carrier for health benefits of its bioactive constituents. Few foods and drinks are consumed as consistently as coffee. For individuals sensitive to the effects of caffeine, decaffeinated or caffeine-reduced products may serve as alternatives.

ACKNOWLEDGMENTS

The author wishes to thank Claire Williams and Daniel Steffen for editorial assistance.

REFERENCES

1. Grosch, W. Chemistry III: Volatile compounds. In: *Coffee, Recent Developments*. Clarke, R. J., Vitzthum, O. G., eds. Oxford, London, Edinburgh, Malden: Blackwell Publishing Ltd., 2001, pp. 68–89.
2. Snel, J. *Permission to enjoy*. Utrecht, the Netherlands: Kosmos-Z&K Publishers; 1998, 60.
3. The National Coffee Association. National coffee drinking trends 2009. New York, 2010.
4. U.S. Department of Agriculture, Agricultural Research Services. Nutrient data laboratory. re. 2011. http://www.nal.usda.gov/fnic/foodcomp/search/index.html (accessed May 11, 2011).
5. Duffey, K. J., Popkin, B. M., Shifts in patterns and consumption of beverages between 1965 and 2002. *Obesity (Silver Spring)*. 2007, **15**, 2739–2747.
6. Popkin, B. M., Armstrong, L. E., Bray, G. M., Caballero, B., Frei, B., Willett, W. C. A new proposed guidance system for beverage consumption in the United States. *Am. J. Clin. Nutr.* 2006, **83**, 529–542.
7. Shields, D. H., Corrales, K. M., Metallinos-Katsaras, E. Gourmet coffee beverage consumption among college women. *J. Am. Diet. Assoc*. 2004, **104**, 650–653.
8. UK Food Standards Agency. An Investigation of the use of terms such as natural, fresh etc. in food labelling. 2004. http://www.food.gov.uk/multimedia/pdfs/labeltermsreport0204.pdf (accessed May 11, 2011).
9. Bersten, I. *Coffee, Sex & Health*. Sydney, Australia: Helian Books; 1999.
10. European Coffee Federation. European Coffee Report 2009. Rijswik, The Netherlands, 2010.
11. Barone, J. J., Roberts, H. R. Caffeine consumption. *Food Chem. Toxicol*. 1996, **34**, 119–129.
12. Heckman, M. A., Weil, J., de Mejia, E. G. Caffeine (1, 3, 7-trimethylxanthine) in Foods: A comprehensive review on consumption, functionality, safety, and regulatory matters. *J. Food Sci*. 2010, **75**, R77–R87.
13. Fredholm, B. B., Battig, K., Holmen, J., Nehlig, A., Zvartau, E. E. Actions of caffeine in the brain with special reference to factors that contribute to its widespread use. *Pharmacol. Rev.* 1999, **51**, 83–133.
14. Smith, A. Effects of caffeine on human behavior. *Food Chem. Toxicol.* 2002, **40**, 1243–1255.
15. Nehlig, A. Pharmacological properties and neurophysiological effects of caffeine. In: *Caffeine and Activation Theory*. Smith, B. D., Gupta, U., Gupta, B. S., eds. Boca Raton, London, New York: CRC Press; 2007, pp. 43–77.
16. EFSA Panel on Dietetic Products, Nutrition and Allergies NDA. Scientific Opinion on the substantiation of health claims related to caffeine and increased fat oxidation leading to a reduction in body fat mass (ID 735, 1484), increased energy expenditure leading to a reduction in body weight (ID 1487), increased alertness (ID 736, 1101, 1187, 1485, 1491, 2063, 2103) and increased attention (ID 736, 1485, 1491, 2375) pursuant to Article 13(1) of Regulation (EC) No 1924/2006. 2011. http://www.efsa.europa.eu/en/efsajournal/pub/2054.htm (accessed May 11, 2011).
17. Paluska, S. A. Caffeine and exercise. *Curr. Sports Med. Rep*. 2003, **2**, 213–219.
18. Sinclair, C. J., Geiger, J. D. Caffeine use in sports. A pharmacological review. *J. Sports Med. Phys. Fitness*. 2000, **40**, 71–79.
19. Foskett, A., Ali, A., Gant, N. Caffeine enhances cognitive function and skill performance during simulated soccer activity. *Int. J. Sport Nutr. Exerc. Metab.* 2009, **19**, 410–423.
20. Stuart, G. R., Hopkins, W. G., Cook, C., Cairns, S. P. Multiple effects of caffeine on simulated high-intensity team-sport performance. *Med. Sci. Sports Exerc*. 2005, **37**, 1998–2005.
21. EFSA Panel on Dietetic Products, Nutrition and Allergies NDA. Scientific Opinion on the substantiation of health claims related to caffeine and increase in physical performance during short-term high-intensity exercise (ID 737, 1486, 1489), increase in endurance performance (ID 737, 1486), increase in endurance capacity (ID 1488) and reduction in the rated perceived exertion/effort during exercise (ID 1488, 1490) pursuant to Article 13(1) of Regulation (EC) No 1924/2006. 2011. http://www.efsa.europa.eu/en/efsajournal/pub/2053.htm (accessed May 11, 2011).
22. van Dam, R. M., Feskens, E. J. Coffee consumption and risk of type 2 diabetes mellitus. *Lancet* 2002, **360**, 1477–1478.
23. World Health Organization. Diabetes. Geneva, World Health Organisation. http://www.who.int/mediacentre/factsheets/fs312/en/index.html (accessed May 11, 2011).
24. World Alzheimer Report 2010. London, UK, Alzheimer's Disease International (Az). http://www.alz.co.uk/research/files/WorldAlzheimerReport2010ExecutiveSummary.pdf (accessed May 11, 2011).
25. International Agency for Research on Cancer. Coffee, Tea, Mate, Methylxanthines and Methylglyoxal. International Agency for Research on Cancer: Lyon, France, 1991.

26. World Cancer Research Fund. Food, Nutrition, Physical Activity, and the Prevention of Cancer. World Cancer Research Fund: London, UK, 2007. http://www.dietandcancerreport.org/?p=ER (accessed May 11, 2011).
27. Health Canada. Caffeine. Ministry of Health, Canada. http://hc-sc.gc.ca/hl-vs/iyh-vsv/food-aliment/caffeine-eng.php (accessed May 11, 2011).
28. Higdon, J. V., Frei, B. Coffee and health: a review of recent human research. *Crit. Rev. Food Sci. Nutr.* 2006, **46**, 101–123.
29. Smith, P., Smith, A., Miners, J., McNeill, J., Proudfood, A. Report from the expert working group on the safety aspects of dietary caffeine. Australia New Zealand Food Authority: Canberra, Australia, 2000. http://www.foodstandards.gov.au/consumerinformation/caffeine/safetyaspectsofdieta890.cfm (accessed May 11, 2011).
30. Scientific Committee on Food (EU). Opinion on Caffeine, Taurine and D-Glucurono-γ-Lactone as constituents of so-called "energy" drinks. 1-21-1999. http://ec.europa.eu/food/fs/sc/scf/out22_en.html (accessed May 11, 2011).
31. Committee on Toxicity of Chemicals in Foods, Consumer Products and the Environment UK. Statement on the reproductive effects of caffeine. 11-3-2008. http://cot.food.gov.uk/pdfs/cotstatementcaffeine200804.pdf (accessed May 11, 2011).
32. Katan, M. B., Schouten, E. Caffeine and arrhythmia. *Am. J. Clin. Nutr.* 2005, **81**, 539–540.
33. van Dam, R. M. Coffee consumption and risk of type 2 diabetes, cardiovascular diseases, and cancer. *Appl. Physiol. Nutr. Metab.* 2008, **33**, 1269–1283.
34. Debry, G. *Coffee and Health*. John Libbey Eurotext: Paris, France, 1994.
35. International Coffee Organisation. Total production of exporting countries. 2011. http://www.ico.org/mission.asp?section=About_Us (accessed May 23, 2011).
36. Jacobs, R. M., Yess, N. J. Survey of imported green coffee beans for pesticide residues. *Food Addit. Contam.* 1993, **10**, 575–577.
37. Pardo, E., Marin, S., Ramos, A., Sanchis, V. Occurrence of ochratoxigenic fungi and ochratoxin A in green coffee from different origins. *Food Sci. Technol.* Int. 2004, **10**, 45–49.
38. Romani, S., Sacchetti, G., Chaves, L. C., Pinnavaia, G. G., Dalla, R. M. Screening on the occurrence of ochratoxin A in green coffee beans of different origins and types. *J. Agric. Food Chem.* 2000, **48**, 3616–3619.
39. Codex Alimentarius Commission. Code of Practice for the Prevention and Reduction of Ochratoxin A Contamination in Coffee. Rome, Italy, 2009.
40. Silvarolla, M. B., Mazzafera, P., Fazuoli, L. C. Plant biochemistry—A naturally decaffeinated arabica coffee. *Nature*. 2004, **429**, 826.
41. Herz, R. S. Aromatherapy facts and fictions: a scientific analysis of olfactory effects on mood, physiology and behavior. *Int. J. Neurosci.* 2009, **119**, 263–290.
42. Seo, H. S., Hirano, M., Shibato, J., Rakwal, R., Hwang, I. K., Masuo, Y. Effects of coffee bean aroma on the rat brain stressed by sleep deprivation: a selected transcript- and 2D gel-based proteome analysis. *J. Agric. Food Chem.* 2008, **56**, 4665–4673.
43. Seo, H. S., Roidl, E., Muller, F., Negoias, S. Odors enhance visual attention to congruent objects. *Appetite* 2010, **54**, 544–549.
44. Homma, S. Chemistry II: Nonvolatile Compounds, Part II. In: *Coffee, Recent Developments*. Clarke, R. J., Vitzthum, O. G., eds. Oxford, London, Edinbourgh, Malden: Blackwell Publishing Ltd.; 2001, pp. 50–67.
45. de Paulis, T., et al. Dicinnamoylquinides in roasted coffee inhibit the human adenosine transporter. *Eur. J. Pharmacol.* 2002, **442**, 215–223.
46. Bekedam, E. K., Schols, H. A., Cammerer, B., Kroh, L. W., Van Boekel, M. A., Smit, G. Electron spin resonance (ESR) studies on the formation of roasting-induced antioxidative structures in coffee brews at different degrees of roast. *J. Agric. Food Chem.* 2008, **56**, 4597–4604.
47. Hong, B. N., Yi, T. H., Park, R., Kim, S. Y., Kang, T. H. Coffee improves auditory neuropathy in diabetic mice. *Neurosci. Lett.* 2008, **441**, 302–306.
48. Somoza, V., Lindenmeier, M., Wenzel, E., Frank, O., Erbersdobler, H. F., Hofmann, T. Activity-guided identification of a chemopreventive compound in coffee beverage using *in vitro* and *in vivo* techniques. *J. Agric. Food Chem.* 2003, **51**, 6861–6869.
49. Macrae, R. Nitrogenous components. In: *Coffee Volume 1: Chemistry*. Clarke, R. J., Macrae, R., eds. London and New York: Elsevier Applied Science; 1985, pp. 115–152.

50. European Food Safety Authority Panel on Dietetic Products, Nutrition and Allergies NDA. Scientific Opinion on the substantiation of health claims related to niacin and energy-yielding metabolism (ID 43, 49, 54), function of the nervous system (ID 44, 53), maintenance of the skin and mucous membranes (ID 45, 48, 50, 52), maintenance of normal LDL-cholesterol, HDL cholesterol and triglyceride concentrations (ID 46), maintenance of bone (ID 50), maintenance of teeth (ID 50), maintenance of hair (ID 50, 2875) and maintenance of nails (ID 50, 2875) pursuant to Article 13(1) of Regulation (EC) No 1924/2006. 2009. http://www.efsa.europa.eu/en/efsajournal/pub/1224.htm (accessed May 11, 2011).
51. European Food Safety Authority Panel on Dietetic Products, Nutrition and Allergies NDA. Scientific Opinion on the substantiation of health claims related to niacin and reduction of tiredness and fatigue (ID 47), contribution to normal energy-yielding metabolism (ID 51), contribution to normal psychological functions (ID 55), maintenance of normal blood flow (ID 211), and maintenance of normal skin and mucous membranes (ID 4700) pursuant to Article 13(1) of Regulation (EC) No 1924/20061. 2010. http://www.efsa.europa.eu/en/efsajournal/doc/1757.pdf (accessed May 11, 2011).
52. McCarthy, J. P., Adinolfi, J., McMullin, S. L., Rehman, W. C., Zalon P. S., Zuckerman, L. M. NCA survey of pesticide residues in brewed coffees. Associacion Scientifique Internationale du Cafe. ASIC, 14th Colloque, 175–182. 1991. Montpellier, France.
53. Blanc, M., Pittet, A., Munoz-Box, R., Viani, R. Behavior of Ochratoxin A during Green Coffee Roasting and Soluble Coffee Manufacture. *J. Agric. Food Chem.* 1998, **46**, 673–675.
54. Commission of the European Communities. Commission Regulation (EC) No 1881/2006 of 19 December 2006 setting maximum levels for certain contaminants in foodstuffs. 1881/2006. 2006.
55. Lantz, I., Ternite, R., Wilkens, J., Hoenicke, K., Guenther, H., van der Stegen, G. H. D. Studies on acrylamide levels in roasting, storage and brewing of coffee. *Mol. Nutr. Food Res.* 2006, **50**, 1039–1046.
56. Misik, M., et al. Impact of paper filtered coffee on oxidative DNA-damage: results of a clinical trial. *Mutat. Res.* 2010, **692**, 42–48.
57. Guenther, H., Hoenicke, K., Biesterveld, S., Gerhard-Rieben, E., Lantz, I. Furan in coffee: pilot studies on formation during roasting and losses during production steps and consumer handling. *Food Addit. Contamin. Part A.* 2010, **27**, 283–920.
58. Heilmann, W. Technology II: Decaffeination of coffee. In: *Coffee, Recent Developments*. Clarke, R. J., Vitzthum, O. G., eds. Oxford, London, Edinbourgh, Malden: Blackwell Publishing Ltd.; 2001, pp. 108–124.
59. Clarke, R. J. Technology III: Instant coffee. In: *Coffee, Recent Developments*. Clarke, R. J., Vitzthum, O. G., eds. Oxford, London, Edinbourgh, Malden: Blackwell Publishing Ltd.; 2001, pp. 125–139.
60. Asano, I., Ikeda, Y., Fujii, S., Iino, H. Effects of mannooligosaccharides from coffee on microbiota and short chain fatty acids in rat cecum. *Food Sci. Technol. Res.* 2004, **10**, 273–277.
61. Asano, I., Umemura, M., Fujii, S., Hoshino, H., Iino, H. Effects of mannooligosaccharides from coffee mannan on fecal microflora and defecation in healthy volunteers. *Food Sci. Technol. Res.* 2004, **10**, 93–97.
62. Umemura, M., Fujii, S., Asano, I., Hoshino, H., Iino, H. Effect of "coffee mix drink" containing mannooligosaccharides from coffee mannan on defecation and fecal microbiota in healthy volunteers. *Food Sci. Technol. Res.* 2004, **10**, 195–198.
63. Umemura, M., Fujii, S., Asano, I., Hoshino, H., Iino, H. Effect of small dose of mannooligosaccharides from coffee mannan on defecating conditions and fecal microflora. *Food Sci. Technol. Res.* 2004, **10**, 174–179.
64. Kumao, T., Fuji, S., Ozaki, K. T. I. Effect of diets with mannooligosaccharides from coffee on fat in blood serum in healthy volunteers. *Jpn. J. Food Eng.* 2005, **6**, 301–304.
65. Asano, I., Fujii, S., Kaneko, M., Takehara, S., Fukuhara, I. Investigation of mannooligosaccharides blended coffee beverage on abdominal fat reduction in humans. *Jpn J. Med. Pharm. Sci.* 2006, **55**, 93–103.
66. Salinardi, T. C., Rubin, K. H., Black, R. M., St-Onge, M. P. Coffee mannooligosaccharides, consumed as part of a free-living, weight-maintaining diet, increase the proportional reduction in body volume in overweight men. *J. Nutr.* 2010, **140**, 1943–1948.
67. Hoelzl, C., et al. Instant coffee with high chlorogenic acid levels protects humans against oxidative damage of macromolecules. *Mol. Nutr. Food Res.* 2010, **54**, 1722–1733.
68. Greenberg, J. A., Boozer, C. N., Geliebter, A. Coffee, diabetes, and weight control. *Am. J. Clin. Nutr.* 2006, **84**, 682–693.

69. Johnston, K. L., Clifford, M. N., Morgan, L. M. Coffee acutely modifies gastrointestinal hormone secretion and glucose tolerance in humans: glycemic effects of chlorogenic acid and caffeine. *Am. J. Clin. Nutr.* 2003, **78**, 728–733.
70. Onakpoya, I., Terry, R., Ernst, E. The use of green coffee extract as a weight loss supplement: a systematic review and meta-analysis of randomised clinical trials. *Gastroenterol. Res. Pract.* 2011, pii, 382852.
71. Bakuradze, T., et al. Antioxidant effectiveness of coffee extracts and selected constituents in cell-free systems and human colon cell lines. *Mol. Nutr. Food Res.* 2010, **54**, 1734–1743.
72. Bakuradze, T., et al. Antioxidant-rich coffee reduces DNA damage, elevates glutathione status and contributes to weight control: results from an intervention study. *Mol. Nutr. Food Res.* 2011, **55**, 793–797.
73. Petracco M. Technology IV: Beverage Preparation: Brewing Trends for the New Millenium. In: *Coffee, Recent Developments*. Clarke, R. J., Vitzthum, O. G., eds. Oxford, London, Edinbourgh, Malden: Blackwell Publishing Ltd; 2001, pp. 140–164.
74. Urgert, R., Katan, M. B. The cholesterol-raising factor from coffee beans. *Annu. Rev. Nutr.* 1997, **17**, 305–324.
75. Cavin, C., Mace, K., Offord, E. A., Schilter, B. Protective effects of coffee diterpenes against aflatoxin B1-induced genotoxicity: mechanisms in rat and human cells. *Food Chem. Toxicol.* 2001, **39**, 549–556.
76. Huber, W. W., et al. Potential chemoprotective effects of the coffee components kahweol and cafestol palmitates via modification of hepatic *N*-acetyltransferase and glutathione S-transferase activities. *Environ. Mol. Mutagen.* 2004, **44**, 265–276.
77. Lee, K. J., Choi, J. H., Jeong, H. G. Hepatoprotective and antioxidant effects of the coffee diterpenes kahweol and cafestol on carbon tetrachloride-induced liver damage in mice. *Food Chem. Toxicol.* 2007, **45**, 2118–2125.
78. Urgert, R., van derWeg, G., Krosmeijer-Schuil, T. G., van de Bovenkamp, P. HRKMB. Levels of the cholesterol-elevating diterpenes cafestol and kahweol in various coffee brews. *J. Agric. Food Chem.* 1995, **43**, 2167–2172.
79. Gross, G., Jaccaud, E., Huggett, A. C. Analysis of the content of the diterpenes cafestol and kahweol in coffee brews. *Food Chem. Toxicol.* 1997, **35**, 547–554.
80. Boekschoten, M. V., van Cruchten, S. T., Kosmeijer-Schuil, T. G., Katan, M. B. [Negligible amounts of cholesterol-raising diterpenes in coffee made with coffee pads in comparison with unfiltered coffee]. *Ned. Tijdschr. Geneeskd.* 2006, **150**, 2873–2875.
81. D'Amicis, A., Viani, R. The Consumption of Coffee. In: *Caffeine, Coffee, and Health*. Garattini, S., ed. New York: Raven Press; 1993, pp. 1–16.
82. International Trade Centre. Trends in the trade of certified coffees. 2010. Geneva. Technical Paper.
83. NHANES. What We Eat in America, NHANES 2007–2008. 2010. U.S. Department of Agriculture, Agricultural Research Service 2010. http://www.ars.usda.gov/SP2UserFiles/Place/12355000/pdf/0708/Table_1_NIN_GEN_07.pdf (accessed May 15, 2011).
84. Deutscher Kaffeeverband. Kaffee-Kompass 2009/10. 2010. Hamburg, Germany, Deutscher Kaffeeverband.