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INTERNATIONAL JOURNAL OF MULTIDISCIPLINARY EDUCATIONAL RESEARCH
ISSN:2277-7881; IMPACT FACTOR :9.014(2024); IC VALUE:5.16; ISI VALUE:2.286
UGC Approved (2017), Peer Reviewed and Refereed International Journal
Volume:13, Issue:10(3), October: 2024
Scopus Review ID: A2B96D3ACF3FEA2A
Article Received: Reviewed : Accepted
Publisher: Sucharitha Publication, India
Online Copy of Article Publication Available : www.ijmer.in

THE ROLE OF COFFEE IN FAT LOSS: A REVIEW OF LITERATURE ON MECHANISMS, EFFICACY, AND IMPLICATIONS

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ABSTRACT

This literature review explores the potential role of black coffee in promoting fat loss, with a focus on its bioactive compounds, particularly caffeine, and their metabolic effects. Black coffee, known for its low-calorie content and rich antioxidant profile, has gained popularity as a weight management aid. The review synthesizes findings from various studies examining how caffeine influences thermogenesis, lipolysis, and appetite suppression, as well as its effects on exercise performance and energy expenditure. The paper also discusses the impact of individual factors, such as caffeine tolerance and metabolic rate, on fat loss outcomes. While numerous studies highlight the fat-burning properties of black coffee, the evidence is varied, with some findings indicating potential health risks associated with overconsumption. This review aims to provide a comprehensive understanding of the current evidence on black coffee's efficacy in fat loss, addressing both the physiological mechanisms and the practical implications for weight management. Further research is needed to clarify the long-term effects and optimal consumption strategies for achieving fat loss through black coffee consumption.

Keywords: Coffee, Caffeine, Antioxidant, Fat Loss, Lipolysis, Weight Management

INTRODUCTION-

Obesity is a growing global public health challenge, significantly increasing the risk for a variety of comorbid conditions, including cardiovascular disease (CVD), gastrointestinal disorders, type 2 diabetes (T2D), joint and muscular disorders, respiratory complications, and psychological disturbances. These conditions substantially impact individuals' daily functioning and contribute to elevated mortality risks. While obesity-associated comorbidities are diverse, even modest weight loss has been shown to mitigate the risk of several health issues, such as CVD, diabetes, obstructive sleep apnea (OSA), and hypertension. Evidence suggests that a relatively small weight reduction, approximately 5%, can lead to meaningful improvements in clinical outcomes and serve as a catalyst for further weight loss, which can be sustained through a series of incremental steps.

Regulation of Energy Homeostasis and Its Implications for Obesity-

Obesity is a cause for metabolic conditions as there is excess accumulation of fat in adipose tissue.A clear example of the regulation of food intake is the increase in consumption (hyperphagia) observed following a period of fasting. The balance between energy intake (food consumption) and energy expenditure—comprising basal metabolic rate (the biochemical processes essential for cellular function), physical activity, and adaptive thermogenesis—is tightly regulated by a homeostatic network. This network sustains energy reserves through complex interactions between central nervous system (CNS) feeding regulatory centers, particularly within the hypothalamus, and the processes governing fat storage and mobilization. These mechanisms collectively ensure the maintenance of energy stores in the body. Consequently, genes encoding the molecular components of this regulatory system may play a crucial role in the development of obesity and related metabolic disorders. Recent research has uncovered key molecular and genetic factors that contribute to the pathophysiology of obesity and its associated conditions. (1)

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Metabolic Roles of Distinct Adipose Tissue Depots-

Numerous studies have demonstrated that excess fat accumulation in the upper body, specifically in the central or abdominal region (referred to as android or male-type obesity), is more strongly associated with increased mortality and heightened risk for metabolic disorders such as diabetes, hyperlipidemia, hypertension, and atherosclerosis affecting coronary, cerebral, and peripheral vessels, compared to fat distribution in the lower body, including the gluteofemoral or peripheral depot (gynoid or female-type obesity). Abdominal fat consists of both subcutaneous and intra-abdominal fat, the latter of which includes visceral (intraperitoneal) fat. Visceral fat is particularly linked to disruptions in insulin-glucose homeostasis and adverse alterations in plasma lipoprotein-lipid profiles, such as elevated plasma triglyceride levels and reduced concentrations of high-density lipoprotein (HDL) cholesterol. These dyslipidemic effects may arise from the relationship between insulin resistance and disturbances in lipid transport and lipoprotein metabolism. Furthermore, free fatty acid (FFA) mobilization occurs more rapidly from visceral fat than from subcutaneous fat due to the heightened lipolytic activity of visceral adipocytes. This difference is thought to be related to the increased expression and activity of β-adrenoreceptors, coupled with reduced insulin receptor affinity and impaired signal transduction in visceral adipocytes. These variations influence the actions of lipolysis-regulating hormones, such as catecholamines and insulin. (1)

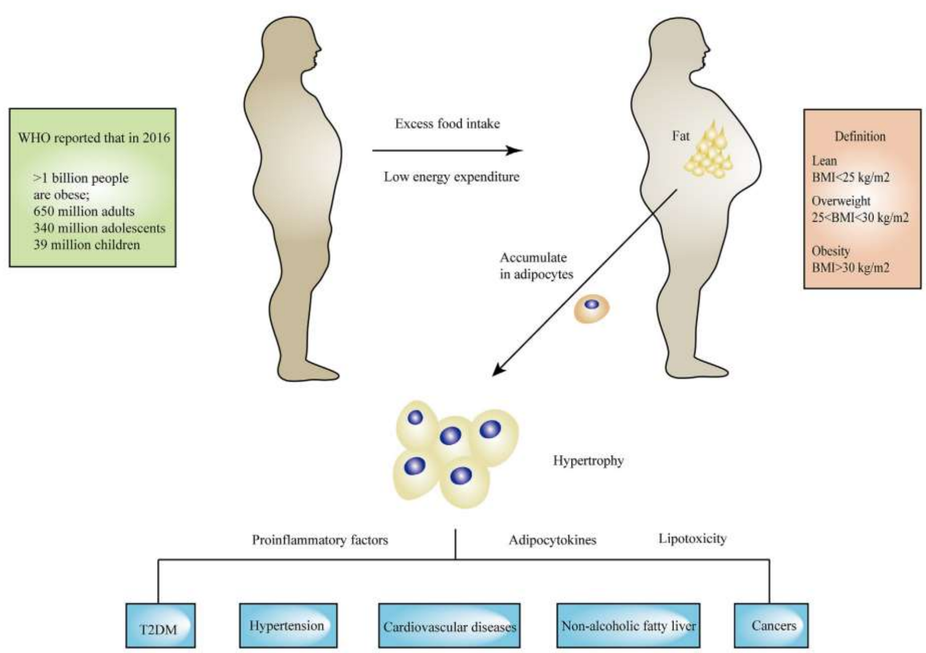

Figure 1. Overview of the obesity epidemic, obesity definition and obesity-associated diseases (2)

Obesity is predominantly linked to a sustained positive energy balance over an extended period. However, its development is influenced by various factors, including genetic predispositions, chronobiological elements, and gut microbiota. Consequently, effective management of obesity requires a multifactorial approach aimed at facilitating fat mass reduction. Although pharmacological and surgical treatments exist, lifestyle intervention remains the primary therapeutic strategy, emphasizing healthy dietary practices and adequate physical activity to create an energy deficit. Despite the efficacy of lifestyle interventions, adherence is often suboptimal, resulting in a high failure rate among individuals with overweight or obesity. This underscores the need for novel strategies that can enhance fat mass reduction with improved long-term adherence, while synergistically complementing lifestyle changes and minimizing side effects compared to pharmacological or surgical interventions. Increasing the intake of foods rich in bioactive compounds,

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particularly polyphenols, has been identified as a promising strategy, as research indicates that these compounds confer beneficial cardiometabolic effects and may provide protective benefits against obesity. [3]

Coffee as a Source of Polyphenols-

Coffee is recognized as the primary dietary source of polyphenols, specifically phenolic acids, within the European diet. Its complex chemical composition includes over 1,000 distinct phytochemicals alongside macro- and micronutrients. The specific composition of coffee is influenced by various factors, including coffee variety, quality, and roasting conditions. For example, the caffeine content in Coffea arabica is approximately 1.5% of the bean's weight, while in Coffea canephora (Robusta), it approaches 2.7%. Importantly, the levels of phenolic compounds and the antioxidant capacity of coffee can be significantly affected by the roasting process. Among the key polyphenols present in coffee, hydroxycinnamic acids are particularly noteworthy, including monocaffeoylquinic and dicaffeoylquinic acids, such as chlorogenic acid (5-caffeoylquinic acid), which have been associated with various health benefits. Notably, coffee consumption accounts for approximately 78.2% of total intake of 5-caffeoylquinic acid, 97.5% of 4-caffeoylquinic acid, and 92.4% of 3-caffeoylquinic acid in the European diet. Other minor sources of these hydroxycinnamic acids include potatoes, apples, pears, stone fruits, and tea. [4]

Coffee History-

The coffee plant is classified as a short tree or shrub endemic to Africa, yielding red fruits commonly referred to as coffee "cherries." The two principal species employed in beverage production are Coffea arabica (Arabica coffee) and Coffea canephora (Robusta coffee).

The predominant bioactive compound in these cherries is caffeine (1,3,7-trimethylxanthine), an alkaloid that serves as a phytochemical defense mechanism against herbivory. In addition to caffeine, coffee cherries are rich in a variety of phytochemicals, including:

- **Trigonelline:** An alkaloid with demonstrated pharmacological properties.
- **Chlorogenic acid:** A polyphenolic compound noted for its antioxidant and anti-inflammatory effects.
- **Ferulic acid:** A phenolic compound associated with numerous health-promoting effects.
- **Diterpenes:** Such as cafestrol and kahweol, which may modulate lipid metabolism and influence cholesterol levels.
- **Melanoidins:** Complex compounds generated during the roasting process, contributing to organoleptic properties and potential health benefits.
- Coffee lipids and trace elements: Essential for various biochemical pathways.

These constituents collectively contribute to the organoleptic characteristics and health-related attributes of coffee, highlighting its complexity and significance as a globally consumed beverage. [5]

Chemical compounds found in coffee-

Recent studies have identified a variety of compounds in coffee that are associated with beneficial health effects. Coffee is a complex mixture of chemicals, notably containing significant amounts of chlorogenic acid and caffeine. Key chemical constituents include caffeine, chlorogenic acid, cafestol, kahweol, and various micronutrients. This composite beverage comprises thousands of chemicals, featuring potential bioactive molecules such as chlorogenic acid, caffeine, and the diterpenes cafestol and kahweol. [6]

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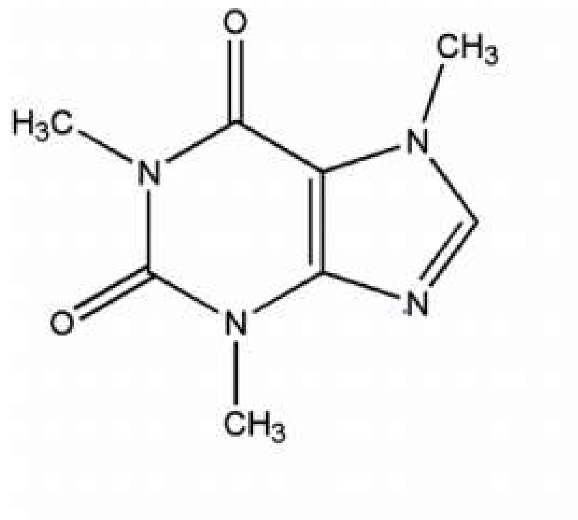

Fig 2 – Chemical structure of Caffeine [6]

Caffeine, the primary active compound in coffee, tea, cocoa, and various beverages, functions as an antagonist of adenosine receptors. As one of the most widely consumed psychoactive substances, it holds significant prominence in both recreational and research contexts. [7]

Caffeine (1,3,7-trimethylxanthine) is the most widely consumed psychoactive substance globally, with coffee serving as its primary source. In 1978, estimates indicated that adults over the age of 18 in the United States consumed an average of approximately 200 mg of caffeine daily, with coffee contributing to roughly 75% of this total. An average cup of coffee was reported to contain about 85 mg of caffeine, leading to an average consumption of just over two cups per day. However, individual consumption exhibited considerable variability, with those in the 99th percentile ingesting up to 563 mg of caffeine, equivalent to approximately seven cups of coffee daily. [8]

Health benefits of coffee-

Liver diseases-

A total of 72 studies (5.6%) have examined the impact of coffee consumption on liver disorders, specifically focusing on liver function and enzymes as well as gallstones and gallstone disease. Evidence suggests that coffee may provide protective effects against alcohol-induced liver damage and hepatic inflammation induced by alcohol. Notably, these protective effects do not appear to be associated with caffeine content or antioxidant activity. Some studies indicate that these beneficial effects are more pronounced in males and smokers compared to females and nonsmokers, respectively. Conversely, strong cafetiere (unfiltered) coffee may yield detrimental effects; a 24-week randomized controlled trial found that consuming 5 to 6 cups daily adversely affected liver cell integrity. There is ongoing debate in the literature regarding whether the diterpenes, such as kahweol found in coffee oil, are responsible for these effects. [9]

Coffee & Cancer-

Higher coffee consumption has been associated with overall anti-inflammatory effects and protective benefits against certain cancers, wherein coffee may function as both a chemopreventive and chemotherapeutic agent. The mechanisms by which coffee exerts these effects are influenced by its constituent compounds, including chlorogenic acids, polyphenols, terpenoids, alkaloids, and various other phytochemicals. [10]

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Coffee & Hypertension-

Studies have reported contrasting findings. A large cohort study conducted in 2021 among middle-aged adults in Brazil indicated that individuals who consumed moderate amounts of coffee (1 to 3 cups per day) exhibited a lower risk of developing hypertension compared to those who rarely or never consumed coffee. [11]

Coffee & Cardiovascular disease-

Boiled coffee, due to its high diterpene content—particularly cafestol and kahweol—exhibits atherogenic properties by inhibiting bile acid synthesis, which affects lipid metabolism. In contrast, filtered coffee, largely free from these compounds, demonstrates antiatherogenic effects by enhancing high-density lipoprotein (HDL)-mediated cholesterol efflux from macrophages through the action of plasma phenolic acids. As a result, cholesterol levels are influenced by the method of coffee preparation (boiled vs. filtered). However, studies on the relationship between coffee consumption and cardiovascular disease risk, particularly coronary heart disease, remain inconsistent, with variations attributed to factors such as sex, genetics, and smoking status. [11]

Coffee & Gastrointestinal diseases-

The impact of coffee on digestive processes has been recognized for a considerable time, with post-meal coffee consumption becoming a common practice. Coffee is believed to enhance digestion by stimulating gastric acid secretion, promoting bile and pancreatic secretions, and increasing colonic motility. [12]

Mechanism of action of coffee in fat loss-

Lipid metabolism-

Numerous studies have reported the regulatory effects of coffee and its bioactive compounds on fatty acid β-oxidation. Compounds such as chlorogenic acid (CGA), caffeine, and cafestol have been shown to enhance the activity of carnitine palmitoyl transferase (CPT), a key rate-limiting enzyme in mitochondrial fatty acid β-oxidation, facilitating the transport of acyl-CoA from the cytosol into mitochondria. Additionally, CGA and caffeine have been found to increase peroxisomal fatty acid β-oxidation by regulating acyl-CoA oxidases (ACOX), the enzymes involved in the initial step of this pathway.

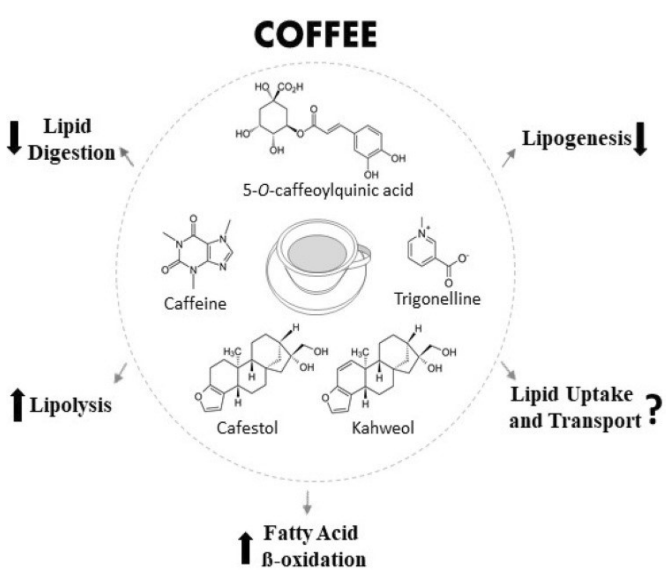

Fig- 3 Lipid oxidation [13]

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Coffee is thought to modulate fatty acid β-oxidation enzymes by activating peroxisome proliferator-activated receptor alpha (PPARα) in liver and adipose tissues. Moreover, PPARβ/δ, which regulates fatty acid β-oxidation in muscle tissue, may also contribute to coffee's metabolic effects, as caffeine has been shown to upregulate PPARβ/δ in muscle cells. Furthermore, caffeine is suggested to enhance lipolysis in adipose tissue by inhibiting adenosine receptors and increasing catecholamine levels via activation of the sympathetic nervous system. [(13)]

CONCLUSION

This review highlights the significant role of black coffee and its bioactive compounds in fat metabolism and overall weight management, with a particular focus on their effects on fatty acid β-oxidation, lipolysis, and energy expenditure. The stimulatory effects of caffeine, chlorogenic acid (CGA), and cafestol on key metabolic enzymes and pathways, including mitochondrial and peroxisomal β-oxidation, are well-supported by research. Additionally, coffee's ability to modulate enzyme activity through the activation of PPAR receptors in various tissues suggests its potential as an aid for fat loss. However, individual variability, such as genetic factors, tolerance to caffeine, and lifestyle habits, can influence these outcomes, highlighting the need for personalized approaches to coffee consumption for fat loss. While moderate coffee intake appears to confer metabolic benefits, the long-term effects and optimal consumption strategies require further investigation. This paper underscores the need for more controlled studies to fully elucidate coffee's role in weight management and its implications for health.

ACKNOWLEDGEMENTS

The author would like to express sincere gratitude to all those who have contributed to the successful completion of this research paper. First and foremost, we extend our heartfelt appreciation to the Head of the dept. Dietitian Tulika Bakshi and Faculty Sayali Gambhir for their guidance and support, and valuable insights throughout the entire research process.

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