



Research Article

The Cardiovascular Advantages of Dark Chocolate: A Comprehensive Analysis of Bioactive Compounds and Health Implications

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Abstract | Chocolate rich in cocoa is referred to as “the drink of the Gods”. Originally called Theobroma cocoa, the cocoa tree” (meaning drink). Nutrient-dense flavanols are found in cocoa. Flavanols are unconjugated chemicals found in plants that comprise the group of polyphenols, which also include epicatechin, catechin, and procyanidin. Based on a ground-breaking study, eating foods high in flavonoids is linked to a lower risk of cancer, cardiovascular disease (CVD), and other neurological conditions, including Alzheimer’s, Parkinson’s, and others. Nevertheless, due to research constraints and confounding variables such as study design, population size, and usage of various chocolate product types, dosages, and contents, additional large-scale human experiments are required to validate and advocate the chocolate diet. An increasing amount of research shows the beneficial effects of dark chocolate high in flavonoids, particularly on cardiac arrest, hypertension, insulin resistance, oxidative stress, inflammation, and platelet functions through many mechanisms. Eating dark chocolate lowers blood pressure, both diastolic and systolic, increases the bioactivity of nitric acid, and strengthens endothelial function. However, due to the amount of sugar it contains, it adversely impacts our health, resulting in weight gain.

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Keywords | Dark chocolate, Cocoa (Theobroma cocoa), Cardiovascular disease, Flavonoid, Flavanol, Methylxanthines, Theobromine, Hypertension



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Introduction

Along with its Savory flavours, chocolate that is high in cocoa has been acknowledged for hundreds of years, as the ancient Incas called it the beverage of the gods. The name “Theobroma cocoa” for the cocoa tree was created by combining the Greek elements “theo” (meaning both “broma” and God), meaning drink. The flavanols in cocoa are rich in nutrients. Procyanidin, epicatechin, and catechin are

among the members of the polyphenol class of unconjugated compounds found in plants, including flavanols. Cocoa and other foods high in flavanols may protect the cardiovascular system, according to several studies conducted on both humans and animals. Consuming foods reduces the risk of cardiovascular disease and is linked to a high flavonoid intake, according to a groundbreaking study on the subject (Senturk, 2015).

The main reason for the effects between dark chocolate and cocoa is connected to their elevated flavan-3-ol content. Nevertheless, based on how the cocoa beans are treated after harvest, the amount of flavanol in chocolate products varies greatly. The total flavanol content is decreased by fermentation, drying, and roasting; as a result, commercial dark chocolate normally contains 1 percent flavanols by weight. Monomers, predominantly (–)-epicatechin (volatile compounds comprising 10–40 percent), and brief oligomers known as procyanidins made of epicatechin and catechin concentrations, mostly 20–80 percent total flavanols, from dimer to decamer, combine to form cocoa flavanols. Elevated levels of caffeine, theobromine (0.5–2.0 percent), and methylxanthines (0.03–0.2 percent) are also present in cocoa products; these substances have the potential to function as adenosine receptor antagonists or phosphodiesterase inhibitors. The precise roles that flavanol and methylxanthine components play in the cardioprotective benefits of frequent ingestion of dark chocolate and cocoa are still being worked out (Rull *et al.*, 2015).

Cardiovascular diseases (CVDs) are the major cause of death in both industrialized and developing nations, and their prevalence is rising quickly on a global scale. The last few decades have seen rapid economic development and a growing civilized lifestyle, which has raised the occurrence of these ailments and brought them to alarming proportions among Indians in recent years. Well-known risk factors for CVDs include metabolic risk factors like hyperglycemia, hyperlipidemia, and elevated blood pressure, as well as behaviour risk factors like an unhealthy diet high in salt, fat, and sugar, physical inactivity, hazardous alcohol and tobacco use, elevated body mass index, and waist-hip ratio (Nangia *et al.*, 2016).

In a WHO report, it was estimated that metabolic risk elements such as high blood pressure, hyperglycemia, hyperlipidemia, as well as behavioral risk factors such as an unhealthy diet high in fat, salt, and sugar, physical inactivity, risky alcohol and tobacco use, the waist-hip ratio, and body mass index, are well-known risk factors for CVDs. By 2030, the majority of the 23.6 million CVD-related deaths will be caused by heart disease and stroke. It is no longer accurate to say that cardiovascular disease (CVD) is exclusive to wealthy people in Western societies and is only becoming more common in developing nations. The majority of NCD-related deaths are caused by CVDs (17.5 mil-

lion people annually) (Balakumar *et al.*, 2016).

Materials and Methods

Dark chocolate and its composition

Across the world, chocolate is one of the most indulgent foods. Switzerland leads the league in consumption per person, coming in second with 10.77 lbs. per head in 2008 and 10.07 kg/head in the United Kingdom (CAOBISCO, 2010) (Talbot, 2012). The cacao bean is the main raw material used in the production of all cocoa-related goods. The main component used to make all chocolate and cocoa-based items is chocolate liquor, which is produced from the beans and then used to make the main chocolate and cocoa goods made in the US, such as sugar, milk powder, cocoa powder, and cocoa butter (fat phase) (Zoumas *et al.*, 2002).

The nonfat portion of cocoa, or cocoa powder, is the most significant nonfat component of chocolate in terms of flavor. Let's just state that the three types of cocoa used in chocolate are organically grown cocoa powder and butter, referred to as cocoa mass, or the combination of the two, referred to as cocoa liquor, extracted from cocoa beans Talbot (2012).

Bioactive compounds of dark chocolate

The secondary metabolites, referred to as bioactive components, give the cocoa tree additional protection against pathogens, parasites, and UV light. Cocoa and products derived from it, like dark chocolate, have significant organoleptic characteristics due to those bioactive components. Complete phenolic compounds, including epicatechin, caffeine, catechin, and flavonoids, are abundant in dark chocolate and contribute to its higher intensity of bitterness, acid taste, and cocoa flavour (Samanta *et al.*, 2022) Table 1 provides a brief elaboration.

Several positive health effects, such as reduced blood pressure, diabetes, heart disease, and antioxidants, as well as improved glucose homeostasis, immunity, the central nervous system, obesity, and lipid metabolism, have been linked to the consumption of chocolate and products containing cocoa (Khan, 2023).

Mechanism of Action

Dark chocolate and neurological disease

Although coffee was once thought to be inappropriate for people with a variety of conditions, it is today seen

as a healthy habit. One advantage of coffee drinking is a decrease in the prevalence of Alzheimer's and Parkinson's disease, which represent two of the most prominent forms of neurodegenerative disease. When it comes to caffeine, evidence appears that those who drink caffeinated coffee in their middle years have a lower chance of developing neurological disorders as they age (Franco *et al.*, 2013).

Table 1: *Dark chocolate's bioactive component.*

Components	Mechanism
Polyphenols	One of the key components in cocoa beans is polyphenol. It generates secondary metabolites and is the root cause of the strong astringency and bitterness.
Flavonoids	On a dry basis, cocoa contains 12–18% flavonoids. Flavonoids can be helpful in the management of cardiovascular disorders as well as certain forms of cancer.
Flavanols	An essential contender among the cocoa flavonoids, flavanols also contains derivatives of quercetin and kaempferol.
Anthocyanin	It successfully fights diseases of the cardiac system. Furthermore, it minimizes oxidative stress by lowering the amount of ROS and encouraging the synthesis of antioxidant enzymes including catalase and superoxide dismutase.
Procyanidins	This is an alternate form of cocoa polyphenol which acts as an anti-inflammatory by reducing interleukin mRNA expression. Therefore, it may reduce unexpected inflammation. likewise, it enhances the production of interleukin 1 β and pro-inflammatory cytokines.
Non-flavonoids resveratrol	Decreases the blood vessel wall's pressure. It may boost HDL cholesterol levels while preventing blood platelets from clumping together.
Phenolic acid	Gallic acid (GA) is one of the most abundant phenolic acid derivatives among all those mentioned, and it can be observed in cocoa beans. By passive paracellular diffusion, phenolic acid can be easily absorbed in the upper part of the gastrointestinal tract.
Non-polyphenols Methylxanthine Theobromine	Among the major bioactive substances found in cocoa beans is methylxanthines. Blood concentrations of HDL cholesterol are boosted through theobromine. It possesses the capacity to relax the smooth muscles in the lungs' bronchi and stimulate the heart.

Dark chocolate and inflammation

The development, advancement, and rupture of plaque are all influenced by inflammation. Moderate levels of cocoa intake were significantly associated with inflammation, according to a study that compared people who regularly ate dark chocolate with people who abstained from chocolate consumption for a year. When patients consumed 20 g of cocoa every three days, their serum CRP levels were considerably lower than those of subjects who consumed no or more cocoa (Senturk, 2015).

Dark chocolate and cholesterol

Dark chocolate consumption in moderation will be beneficial to keep blood cholesterol within an appropriate range. Because cocoa reduces a certain number of receptors for cholesterol, it prevents the absorption of cholesterol and its use in biosynthesis. The cocoa-based material minimizes LDL and total blood cholesterol levels but has no significant impact on HDL levels. Cocoa polyphenols can decrease serum and liver lipid peroxidation, which in turn lowers malondialdehyde formation. However, cocoa fiber has no impact on the liver's levels of glutathione (Samantha *et al.*, 2022).

Dark chocolate and cancer

According to some research, procyanidins found in cocoa liquor considerably lowered the incidence and number of lung cancers, as well as the development of male rat thyroid adenomas, and prevented the growth of breast and pancreatic tumours in female rats. A diet comprised of dark chocolate diminished the overall quantity of abnormal crypt foci in the colon in an animal study. Cocoa procyanidins also decreased the activity of vascular endothelial growth factor. The effect was linked to the decrease in tyrosine kinase ErbB2, as indicated by COX-2 and ReIA giogenic transcription levels associated with tumors (Montagna *et al.*, 2019).

Heart-related diseases (CVD)

Around the world, coronary artery disease (also called CVD) is an alarming medical condition that leads to thirty percent of all deaths. An estimated 17.5% of the approximately fifty-eight million mortalities worldwide in 2005 were related to CVD, a figure that is nearly three times more than the total number of deaths from infectious illnesses including HIV/AIDS, TB, and malaria combined. It is anticipated that noncommunicable diseases will account for

nearly 74 percent of all deaths by 2030, particularly cardiovascular disease (CVD) deaths projected to exceed 23.4 million, up around 37% from 2004 levels. Furthermore, ischemic cardiovascular disease (IHD) and cerebral artery disease (stroke), both of which are forms of CVD, are anticipated to be the world's leading causes of mortality in 2030 (Deaton *et al.*, 2011).

Global heart and vascular risk factor prevalence

On a global scale, the prevalence of cardiovascular risk factors is expanding. As one of the primary preventable causes of premature death, hypertension affected 972 million people worldwide in 2000 and is predicted to increase by around 60% to 1.56 billion people by 2025, in accordance with a recent study conducted by the World Health Organization's In relation to total global mortality estimates, tobacco use, high cholesterol, and hypertension—all widely recognized risk factors for cardiac disease—are the top 3 causes of mortality in industrialized nations. CVD is no longer exclusive to developed countries. Similar phenomena are currently manifesting in nations that are developing, where there is a significant positive association involving rising national wealth and a higher incidence of both obesity and high cholesterol (Dahlof, 2010).

Role of flavonoids in dark chocolate

Plants, mainly fruits and vegetables, are the main source of flavonoids, a subclass of polyphenols that are widely distributed micronutrients. There are six primary groups of flavonoids that make up over 5000 in total: flavones, isoflavones, flavanones, flavanols, and nutraceuticals. The epidemiological data suggests that consuming a flavonoid-rich diet high in fruits and/or vegetables decreases the risk of coronary heart disease (Engler and Engler, 2006).

Because of their anti-inflammatory properties, flavonoids may reduce LDL oxidation, an action that is necessary for the occurrence of atherosclerotic diseases. Studies on humans and animals show that flavonoids strengthen endothelial functions, reduce blood pressure, and avoid the buildup of atherosclerotic plaques (Senturk, 2015).

Adverse effect of dark chocolate

Overindulgence in any food or nutrient could have harmful effects and could be poisonous. This also holds for overindulging in chocolate. Research showed that the health benefits of chocolate decreased at higher

doses (>45 g/week) because of its high sugar content, as shown in Swedish men. Those who consumed ≥ 1 serving of chocolate per day did not have any protective impact on the incidence of heart failure. Frequent and habitual chocolate eating may also result in dose-dependent weight gain (Khan, 2023).

Results and Discussion

Flavonoids have garnered attention due to their demonstrated biological activities in vitro, which include scavenging free radicals, suppressing cellular proliferation, and altering enzyme activity. Further uses for flavonoids include antibacterial, anti-allergic, anti-diarrheal, anti-inflammatory, and anti-ulcer properties (Ross and Kasum, 2002).

Drinking tea, a beverage high in flavonoids, has been shown to reduce FMD in the brachial arteries of hypertensive and normotensive patients with coronary artery disease. Similarly, it has been demonstrated that individuals with coronary artery disease who consume purple grape juice high in flavonoids have decreased oxidative stress and increased FMD (Grassi *et al.*, 2005).

Pecans, sweet cherries, plums, russet potatoes (cooked), cranberries, blueberries, prepared artichokes, berries such as black, prunes, raspberries, strawberries, red-delicious and Granny Smith apple apples (with peel), and prunes are some other ubiquitous fruits and vegetables with a high (>4000) total amount of antioxidants per serving (ranked highest to the lowest). Flavonoids are abundant in these foods, and dark chocolate in moderation may be beneficial to your heart if you consume it and lead an active and healthy lifestyle.

There have been positive or neutral effects on cholesterol levels observed in both short- and long-term clinical trials supplementing with chocolate. Indeed, a recent proposal suggested that consuming the “polymeal” daily—a conglomeration of seven food items such as almonds, dark chocolate, wine, seafood, fruits, and vegetables—could lower the incidence of cardiovascular disease by 76% and add 4–8 to 6.6 years to life expectancy. Nutrient treatment utilizing foods high in flavonoids, especially those that raise the concentrations of plasma epicatechin, is obviously advantageous in diminishing or avoiding endothelial dysfunction, whereas oxidative stress (Engler and Engler, 2006).

Conclusions and Recommendations

It has been determined that dietary changes and lifestyle modifications are crucial to the treatment of cardiovascular disease. Milk chocolate has between 20 and 30 percent cocoa, while dark chocolate has between 50 and 85 percent. When healthy, normal-weight males consume 100g of dark chocolate, it increases feelings of fullness, reduces cravings for sweets, and uses less energy than milk chocolate (100g). Because of its superior antioxidant properties, the main health benefit is the prevention of cancer. It's thought that dark chocolate scavenges free radicals. The possibilities for flavonoid-rich chocolate to interact with other foods are one aspect influencing how these study results should be interpreted. This complicates the interpretation of the data in every way. Due to genetic, sociocultural, and culinary differences, the incidence of CVD risk factors varies among ethnic groups.

Abbreviations

CVD: Cardiovascular disease.

WHO: World health organization.

CRP: C-reactive protein.

LDL: low density lipoprotein.

HDL: High density lipoprotein.

IHD: Ischemic cardiovascular disease.

FMD: Fibromuscular dysplasia.

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Novelty Statements

A novel approach in this study highlights the potential of flavonoid-rich dark chocolate as a functional food that may significantly reduce cardiovascular disease (CVD) risk factors. However, further large-scale human studies are required to validate the efficacy and optimize dietary recommendations, particularly considering variations in genetic, sociocultural, and culinary practices across different populations.

Author's Contributions

Mehak Muhammad Ashfaq: Reviewed it.

Aqsa Naeem Chawla: Wrote the original draft.

Muhammad Umaid Ali: Edited the final draft.

Adnan Ahmed Bhutto: Checked for language edit-

ing and grammatical errors.

All authors read and approved the final manuscript.

Conflict of interest

All authors of this article declare no conflict of interest in this work.

References

- Balakumar, P., Maung-U, K., and Jagadeesh, G. 2016. Prevalence and prevention of cardiovascular disease and diabetes mellitus. *Pharmacol. Res.*, 113: 600–609. <https://doi.org/10.1016/j.phrs.2016.09.040>
- Dahlöf, B. 2010. Cardiovascular Disease Risk Factors: Epidemiology and Risk Assessment. *Am. J. Cardiol.*, 105(1): 3A-9A. <https://doi.org/10.1016/j.amjcard.2009.10.007>
- Deaton, C., Froelicher, E. Sivaraja., Wu, L. Ha., Ho, C., Shishani, K., and Jaarsma, T. 2011. The Global Burden of Cardiovascular Disease. *Eur. J. Cardiovasc. Nurs.*, 10(2_suppl): S5–S13. [https://doi.org/10.1016/S1474-5151\(11\)00111-3](https://doi.org/10.1016/S1474-5151(11)00111-3)
- Engler, M.B. and Engler, M.M. 2006. The emerging role of flavonoid-rich cocoa and chocolate in cardiovascular health and disease. *Nutr. Rev.*, 64(3): 109–118. <https://doi.org/10.1111/j.1753-4887.2006.tb00194.x>
- Franco, R., Oñatibia-Astibia, A., and Martínez-Pinilla, E. 2013. Health Benefits of Methylxanthines in Cacao and Chocolate. *Nutrients*, 5(10): 4159–4173. <https://doi.org/10.3390/nu5104159>
- Grassi, D., Necozione, S., Lippi, C., Croce, G., Valeri, L., Pasqualetti, P., Desideri, G., Blumberg, J.B., and Ferri, C. 2005. Cocoa reduces blood pressure and insulin resistance and improves endothelium-dependent vasodilation in hypertensives. *Hypertension*, 46(2): 398–405. <https://doi.org/10.1161/01.HYP.0000174990.46027.70>
- Khan, N. 2023. Health Effects of Dark Chocolate. *Emerg. Challenges Agric. Food Sci.* 8: 76–87. BP International (a part of SCIENCE DO-MAIN International). <https://doi.org/10.9734/bpi/mono/978-81-19217-36-6/CH5>
- Montagna, M.T., Diella, G., Triggiano, F., Caponio, G.R., Giglio, O. de, Caggiano, G., Ciaula, A. di and Portincasa, P. 2019. Chocolate, “Food of the Gods”: History, Science, and Human Health.

- Int. J. Environ. Res. Public Health, 16(24): 4960. <https://doi.org/10.3390/ijerph16244960>
- Nangia, R., Singh, H., and Kaur, K. 2016. Prevalence of cardiovascular disease (CVD) risk factors. Med. J. Armed Forces India, 72(4): 315–319. <https://doi.org/10.1016/j.mjafi.2014.07.007>
- Rull, G., Mohd-Zain, Z.N., Shiel, J., Lundberg, M.H., Collier, D.J., Johnston, A., Warner, T.D., and Corder, R. 2015. Effects of high flavanol dark chocolate on cardiovascular function and platelet aggregation. Vasc. Pharmacol., 71: 70–78 <https://doi.org/10.1016/j.vph.2015.02.010>
- Ross, J.A., and Kasum, C.M. 2002. Dietary flavonoids: Bioavailability, metabolic effects, and safety. Annu. Rev. Nutr., 22(1): 19–34. <https://doi.org/10.1146/annurev.nutr.22.111401.144957>
- Samanta, S., Sarkar, T., Chakraborty, R., Rebezov, M., Shariati, M. A., Thiruvengadam, M., and Rengasamy, K.R.R. 2022. Dark chocolate: An overview of its biological activity, processing, and fortification approaches. Curr. Res. Food Sci., 5: 1916–1943. <https://doi.org/10.1016/j.crfs.2022.10.017>
- Senturk, T. 2015. The Mysterious Light of Dark Chocolate. *Türk Kardiyoloji Dernegi Arsivi-Archives of the Turkish Society of Cardiology*. <https://doi.org/10.5543/tkda.2015.70360>
- Talbot, G. 2012. Chocolate and Cocoa Butter-Structure and Composition. In *Cocoa Butter and Related Compounds*, Elsevier, pp. 1–33. <https://doi.org/10.1016/B978-0-9830791-2-5.50004>
- Zoumas, B.L., Azzara, C.D. and Bouzas, J. 2002. Chocolate and Cocoa. In *Kirk-Othmer Encyclopedia of Chemical Technology*. Wiley. <https://doi.org/10.1002/0471238961.0308150326152113.a01.pub2>