



A Review on Health Benefits of Dark Chocolate

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ABSTRACT

Chocolate is a natural or processed food derived from the seeds of the tropical tree *Theobroma cacao*. In recent years, chocolate has increasingly been recognized for its potential to support and promote good health. Given its compatibility with the food matrix of a chocolate bar and its ability to complement naturally occurring flavanols, chocolate can be developed into an ideal delivery system for nutraceuticals, essentially serving as a “polypill” that enhances health while offering the indulgence of a delicious treat.

Dark chocolate, in particular, is renowned for its substantial benefits in supporting cardiovascular health. It has been shown to improve heart health by reducing the risk of cardiovascular disease. Beyond its cardiovascular advantages, dark chocolate also offers a range of other health benefits, including powerful antioxidant properties, enhancement of endothelial function, improvement in vascular function, and increased insulin sensitivity. These effects make dark chocolate not only a satisfying snack but also a potentially valuable component of a health-conscious diet. *Theobroma cacao* trees are now widely studied in the fields of nutrition and health studies, rather than just being considered a tasty delicacy. Rich in flavonoids, especially flavanols like epicatechin, procyanidins, and catechin, dark chocolate is renowned for its potent antioxidant capabilities. These antioxidants are essential for scavenging free radicals and reducing oxidative stress, both of which are linked to a lower risk of chronic illnesses, particularly those that impact cardiovascular health.

A large amount of evidence suggests that frequent dark chocolate consumption helps reduce blood pressure, improve circulation, and strengthen endothelial function—all of which help to lessen the risk of atherosclerosis and cardiovascular disease. The benefits of dark chocolate for the cardiovascular system are further highlighted by its ability to raise high-density lipoprotein (HDL) cholesterol while inhibiting the oxidation of low-density lipoprotein (LDL) cholesterol. Better insulin sensitivity is another benefit of dark chocolate that has been connected to the management and prevention of type 2 diabetes.

Introduction

Its rich and complex flavor, along with its versatility, makes dark chocolate a popular choice in many culinary dishes, from desserts to drinks. Dark chocolate is available in various forms—liquid, paste, or solid blocks—and is often blended with flavors like vanilla to improve its taste. In contrast to milk chocolate, dark chocolate contains a higher percentage of cocoa, leading to a stronger flavor and a noticeably darker color due to the cocoa solids.^[1]

The categorization of chocolate types—milk, white, and dark—primarily hinges on the proportion of cocoa used in production. Dark chocolate, often referred to as black chocolate, typically contains 70% cocoa or more, making it a richer and more concentrated source of the beneficial compounds found in cacao. This high cocoa content is what sets dark chocolate apart, offering not only a delightful sensory experience but also a range of health benefits.^[2]

Beyond its delicious taste, dark chocolate is known for its excellent nutritional value. It provides energy, protein, and important minerals like magnesium, calcium, iron, and riboflavin, which support heart and mental health. Cocoa products are also rich in copper, sulfur, and vitamin C. One key benefit of dark chocolate is its high level of flavonoids—natural compounds thought to benefit heart health. Studies suggest these flavonoids may help reduce blood pressure, lower inflammation, and boost heart function overall.^[3]

Recent studies in the United States and Europe have highlighted the cardiovascular benefits of dark chocolate, prompting manufacturers to explore specialized processing techniques aimed at preserving these valuable flavonoids. Traditional roasting and fermentation processes can diminish up to 75% of these beneficial compounds, leading to a growing interest in methods that retain the maximum nutritional value of cacao.^[4]

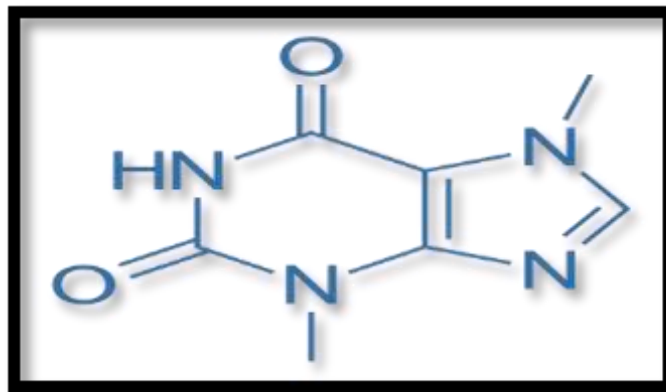
It contains theobromine, a substance related to caffeine that acts as a mild stimulant. Dark chocolate has more theobromine—usually about 10 g/kg—than milk chocolate, which boosts its stimulating effects on the central nervous system. In addition, cacao polyphenols like epicatechin and catechin are connected to antioxidant properties that support brain health.^[5]

Recent research suggests that cacao polyphenols may enhance cerebral blood flow, a factor associated with improved cognitive function. For instance, regular consumption of these compounds over several months has been shown to increase blood volume in areas of the brain linked to memory. Even a

single dose of cacao polyphenols can temporarily boost cerebral blood flow, underscoring the immediate cognitive benefits associated with dark chocolate consumption.

The relationship between chocolate consumption and cognitive performance is well-documented, with studies indicating that regular intake of cacao polyphenols may support mental acuity, particularly under stress or fatigue. However, the effects of acute consumption—such as that from cacao polyphenol-enriched chocolate—are still being explored. While some studies report enhanced cognitive function following a single dose, others find no significant change, suggesting a need for further investigation.^[6]

Chemical formula of Dark Chocolate



Theobromine

Dark chocolate is indeed rich in cocoa solids, typically containing over 35%, and these solids contribute to its unique characteristics. The primary components within cocoa solids that contribute to its effects include:

Theobromine:

Theobromine is an alkaloid present in large amounts in dark chocolate. It acts as a mild stimulant, similar to caffeine but with gentler effects. While theobromine is safe for humans, it can be harmful to dogs and some other animals, as they process it much more slowly.^[7]

Chemical composition of Dark Chocolate

Cocoa, the raw material for chocolate, is rich in phenolic antioxidants, making up about 10% of the dry weight of the whole bean. The most common antioxidants are flavonoids like catechins, anthocyanins, and proanthocyanidins. However, during chocolate production, the flavonoid content drops significantly—up to 10 times—due to processes that remove bitterness, which is caused by these polyphenols. This reduction happens during fermentation, drying, roasting, and other steps, where some flavonoids are lost and other compounds, like Maillard products.

While most chocolate consumed today has lower polyphenol content, dark chocolate with at least 200 mg of flavonoids can benefit blood vessels, as recognized by the European Food Safety Authority. However, during fermentation, key polyphenols like procyanidins and epicatechins are drastically reduced, and anthocyanins can even disappear. The loss of these compounds varies by region, with cocoa from different countries showing different levels of flavonoid retention.^[8]

Nutritional components	Dark chocolate
Protein (g)	6.7
Lipid (g)	34.3
Cholesterol (mg)	0
Carbohydrate (g)	56.6
Sugar (g)	38.3
Total fiber (g)	1.7
Sodium (µg)	4000
Potassium (µg)	581,000
Iron (µg)	21,000

Calcium (µg)	42,000
Phosphorum (µg)	244,000
Thiamin (µg)	40
Riboflavin (µg)	10
Niacin (µg)	46
Vitamin A (µg)	0
Energy (kcal/kj)	593/233

Table No 1. Chemical composition of Dark Chocolate

Bio active component present in dark chocolate

1) Polyphenols: -

Polyphenols are one of the major components in dark chocolate. Polyphenols found in dark chocolate are of different types, such as phenolic acids, stilbenes, flavonols, flavan-3-ols, and anthocyanins. The total polyphenol content in dark chocolate is partially dependent on the cultivators of the cocoa beans from which it is made. The amount of polyphenol varies among different dark chocolate products. Dark chocolate modulates glycemic response, platelet function, and inflammation, along with systolic and diastolic arterial pressure. Dark chocolate polyphenols also possess chemoprotective, antimutagenic, anticarcinogenic, and antiproliferative effects ^[9]

2) Non – polyphenolic: -

1)Methylxanthine

Methylxanthine is one of the important bioactive compounds present in dark chocolate. Methylxanthines can be classified into theobromine (TB), caffeine (CF), and theophylline (TP). Theobromine and caffeine are the most commonly occurring compounds in dark chocolate, whereas theophylline is found in lesser amounts. Methylxanthines are rapidly absorbed in the GI tract, metabolized in the liver, and then excreted in the urine. Its concentration in blood plasma rises 30–70 minutes after ingestion. ^[10]

3) Flavonols: -

Flavonol is one of the important candidates of dark chocolate flavonoids, which comprises kaempferol and quercetin derivatives. Dark chocolate beans and their derived products generally contain a glycosylated form of the flavonol. Quercetin-3-Ogalactoside, quercetin-3-O-arabinoside, quercetin-3-O-glucoside, quercetin-3-O-rhamnoside, quercetin-3-O-rutinoside, etc., are examples of quercetin derivatives present in dark chocolate beans. Quercetin glycosides are absorbed after deglycosylation and ultimately converted into quercetin aglycones. Quercetin aglycones are further translocated with the help of intestinal mucosa by passive diffusion. ^[11]

4) Non- flavonol: -

1) phenolic acid

Phenolic acids are present in lower amounts in dark chocolate. Hydroxybenzoic acids (protocatechuic acid, gallic acid (GA), vanillic acid (VA), syringic acid (SA)) and hydroxycinnamic acids (coumaric acid (CuA), caffeic acid (CA), chlorogenic acid (CHA), and ferulic acid (FA)) are commonly occurring derivatives of phenolic acids. In the stomach, FA, GA, CuA, CA, and CHA are absorbed. Of these, GA has the highest absorption rate. It is metabolized rapidly and excreted shortly after ingestion. The bioavailability of esterified phenolic acids is 0.3– 0.4%. Hydrolysis of esterified phenolic acids occurs in the enterocytes before reaching the bloodstream. Since intestinal enzymes cannot break the esterified bonds, these acids enter the colon where they are metabolized by colon microflora. ^[12]

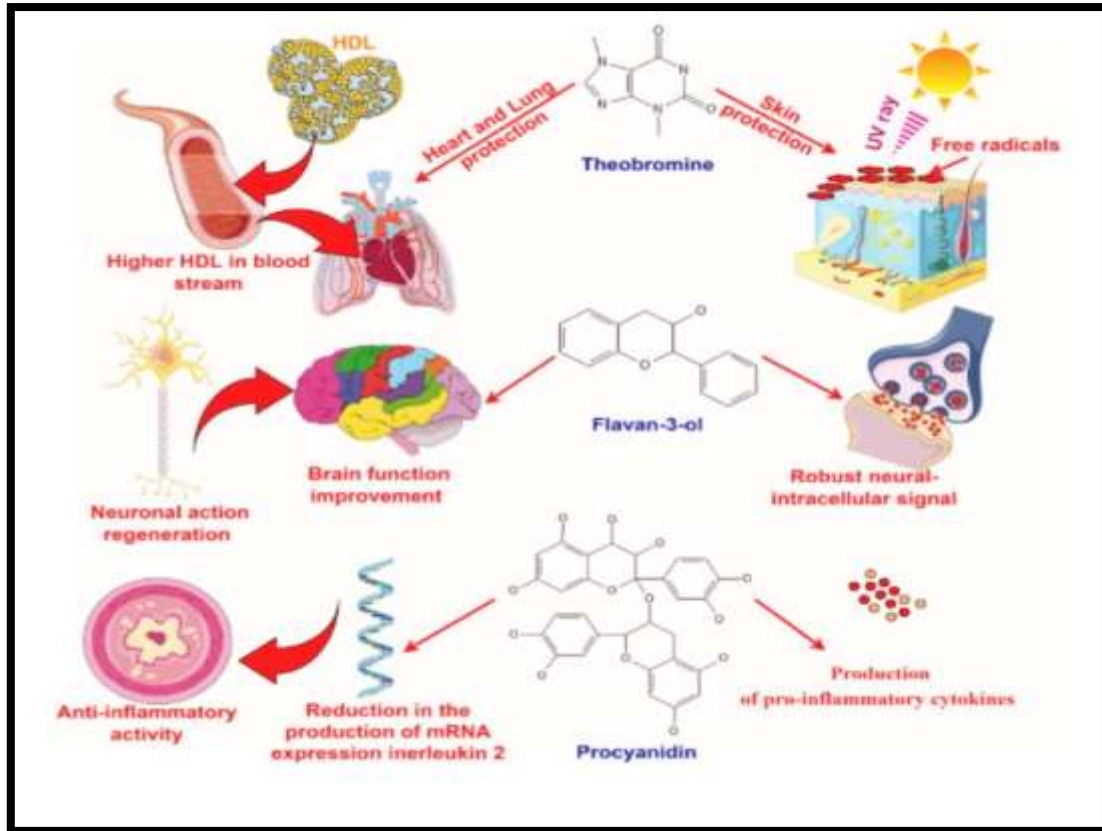


Fig. 1. Bioactive components present in dark chocolate and their health benefits.

Manufacturing processes of Dark Chocolate



Fig No. 2 Dark Chocolate

- **Harvesting:** Cocoa pods are hand-harvested from the *Theobroma cacao* tree. Each pod contains 20-50 cocoa beans, which are extracted from the sweet pulp.
- **Fermentation:** Beans are fermented for 5-7 days in wooden boxes or covered with leaves. This process develops flavor and reduces bitterness and acidity.
- **Roasting:** Dried beans are roasted at 250°F to 350°F (121°C to 177°C) for 30 minutes to 2 hours to enhance flavor and remove moisture. Darker roasts yield deeper flavors.
- **Cracking and Winnowing:** Roasted beans are cracked to separate the hard shell from the cocoa nibs, which are the main ingredient for chocolate.

- **Grinding:** Cocoa nibs are ground into cocoa mass (or liquor), releasing cocoa butter. The texture is refined over several hours to achieve a particle size around 20 microns.
- **Conching:** The cocoa mass is mechanically mixed for 6 to 72 hours to improve texture and flavor by reducing particle size and removing volatile acids.
- **Tempering:** Chocolate is melted and then cooled to stabilize the cocoa butter crystals, ensuring a smooth shine and a crisp texture.
- **Cutting and Reheating:** Tempered chocolate is poured into molds and vibrated to release air bubbles, then chilled to solidify.
- **Packaging:** Once cooled, chocolate is inspected, wrapped in protective materials, and stored in cool, dry conditions to maintain freshness^[13-14]

Health benefits of Dark Chocolate

1) For cardiovascular diseases

Research indicates that flavan-3-ols, cocoa, and chocolate may help avoid heart disease. Foods high in flavonols have been linked to heart health improvements, suggesting that this class of flavonoids may have important cardioprotective benefits. By decreasing arterial hardness and thickening, increasing arterial flexibility, and lowering white blood cell adherence to blood vessel walls, dark chocolate may help lower the risk of atherosclerosis. These flavonoids may have the following effects: they may lessen oxidative stress, increase prostacyclin production from the endothelium, improve blood vessel function, increase sensitivity to insulin receptors, stop lipid oxidation, and inhibit the angiotensin-converting enzyme. Theobromine at a daily dose of 6 mg/kg in dark chocolate was consumed during the study period, hence the findings may not directly apply to people with particular illnesses or ailments.^[15]

2) As cardiorespiratory stimulant

Theobromine's Cardiorespiratory Effects The main alkaloid in cocoa, theobromine, has modest stimulatory effects on the central nervous system (CNS). Its cardiovascular effects are only approximately a tenth of those of other methylxanthines, like theophylline and caffeine. Similar to coffee, theobromine can increase energy, motivation, and alertness, but its effects are not as strong. In young people in good health, theobromine does not cause any appreciable acute alterations in electrophysiological parameters or heart function when taken in the form of a large chocolate bar. The pharmacokinetics of theobromine were similar, according to studies that measured theobromine levels following a 14-day period without any methylxanthines and one week of dark chocolate eating giving 6 mg/kg/day of theobromine.^[16]

3) For endothelial and vascular function

Dark chocolate led to a quick and notable enhancement of endothelial and platelet function in healthy smokers within 2-8 hours of consumption. Cigarette smokers show increased atherogenic potential due to their persistent endothelial and platelet dysfunction, which is linked to a heightened cardiovascular risk. These effects are attributed to the antioxidant properties of polyphenol-rich dark chocolate. Hypertension and excess body weight are key contributors to endothelial dysfunction. Emerging research indicates that high-polyphenol dark chocolate enhances endothelial function and reduces blood pressure in individuals with stage 1 hypertension. As a result, consuming chocolate bars led to decreases in both systolic and diastolic blood pressure.^[17]

4) Blood sugar

Dark chocolate supports vascular health and maintains proper circulation, which is beneficial for protecting against type 2 diabetes. The flavonoids found in dark chocolate play a role in decreasing insulin resistance by enhancing the normal functioning of cells, allowing them to utilize the body's insulin more effectively. Additionally, dark chocolate has a low glycemic index, which means it does not lead to significant spikes in blood sugar levels.^[18]

5) For oral hygiene

Theobromine, a substance present in dark chocolate, has been demonstrated to fortify dental enamel. In conjunction with proper dental hygiene habits, this increase in enamel hardness may help reduce the incidence of cavities. Furthermore, theobromine contains qualities that can lessen coughing, while being a less potent stimulant than coffee. It alleviates the symptoms of a cough by blocking the activation of the vagus nerve, which is what causes coughing.^[19]

6) Antioxidants

Antioxidants found in dark chocolate are important for fighting free radicals. Free radicals can harm cells and are linked to aging and a higher risk of cancer. Eating foods high in antioxidants, like dark chocolate, may help reduce the risk of cancer and slow down the aging process.

I. Better Circulation:

Antioxidants such as flavonoids improve vascular function and blood flow. This can enhance cardiovascular health generally, which lowers the chance of heart disease.

II. Blood Pressure Reduction:

Eating dark chocolate on a regular basis, which is high in antioxidants, can help reduce blood pressure on both the systolic and diastolic levels.^[20]

7) Vitamins and minerals

Dark chocolate is full of various natural vitamins, minerals, and nutrients that benefit health. It contains proteins, saturated fats, and calories, as well as essential vitamins like B1, B2, B3, B9, and K. Additionally, dark chocolate offers important minerals such as calcium, dietary fiber, magnesium, phosphorus, manganese, selenium, iron, potassium, copper, and zinc. [21]

8) For brain

Drug high in flavonoids may help prevent cancer, according to data. Breast cancer cells are specifically vulnerable to the cytotoxic effects of cocoa-derived pentameric procyanidin, according to an in vitro study. This suggests that the compound's ability to inhibit cellular proliferation is linked to the site-specific dephosphorylation or down-regulation of a number of cell cycle regulatory proteins. By interfering with cell cycle regulatory proteins, studies have shown that procyanidins produced from cocoa can specifically target and stop the growth of cancer cells, including breast cancer cells.[22]

9) For diabetes

Dark chocolate improves insulin sensitivity by decreasing insulin resistance. It promotes healthy blood vessels and ensures smooth blood flow. A reduction in nitric oxide (NO) production by the nitric oxide synthase (NOS) enzyme can contribute to impaired insulin production, leading to insulin resistance. Epicatechin, found in cocoa, boosts the production of endogenous NO, which activates the PI3K signaling pathway. This pathway plays a key role in insulin activation and glucose transport in metabolic tissues, culminating in Akt activation. Insulin's hemodynamic effect is marked by increased capillary recruitment, enhancing glucose uptake. Cocoa polyphenols employ a dual mechanism (via the Akt/PI3K and ERK1/2 pathways) to stimulate insulin secretion from pancreatic β -cells. Procyanidin, another beneficial compound in dark chocolate, helps reduce postprandial blood glucose levels. Although its bioavailability is low, procyanidin can still interact with glucose transporters. The translocation of GLUT4 to muscle cells further facilitates glucose clearance and improves insulin signalling

10) For skin

The bioactive compounds in dark chocolate may provide notable benefits for your skin. Flavanols, specifically, can aid in protecting against sun damage, boosting blood flow to the skin, and enhancing skin density and hydration. The minimal erythema dose (MED) is the lowest amount of UVB radiation needed to cause skin redness 24 hours after exposure.

Studies have demonstrated that consuming high-flavanol dark chocolate or cocoa for 12 weeks can considerably increase MED levels, even doubling them in some cases. This suggests improved natural protection against UV rays. If you're preparing for a beach trip, adding more dark chocolate to your diet in the weeks or months leading up to it may help.

Conclusion:

Dark chocolate, particularly varieties rich in cacao polyphenols, offers notable cardiovascular benefits. These polyphenols, including epicatechin, catechin, and procyanidins, are powerful antioxidants that improve blood flow and support vascular health. Regular consumption of dark chocolate can enhance endothelial function, leading to better circulation and lower blood pressure. This makes dark chocolate a valuable addition to a heart-healthy diet, potentially reducing the risk of heart disease.

Along with its antioxidants, dark chocolate provides essential nutrients like magnesium, iron, calcium, and riboflavin. These nutrients are vital for supporting heart health and general well-being. Magnesium helps manage blood pressure and maintains a consistent heart rhythm, while iron is essential for oxygen transport throughout the body. Calcium is important for proper muscle function, including that of the heart, and riboflavin plays a significant role in energy metabolism. Theobromine, a gentle stimulant present in cacao, provides advantages for cognitive function. It can improve mental alertness and concentration, making dark chocolate a useful snack for enhancing brain activity. Although its stimulating effects are milder than those of caffeine, it can still help boost focus, especially during periods of mental tiredness or stress.

Studies indicate that consistently consuming cacao polyphenols can enhance brain health, especially in areas associated with memory and cognition. Research has shown that these polyphenols boost blood circulation to the brain, leading to improvements in memory and cognitive abilities. This effect is particularly advantageous for older adults, as it may aid in slowing down cognitive decline and preserving mental clarity over time.

In summary, dark chocolate with high cacao content is beneficial for both your brain and heart. Its minerals support overall health, and its antioxidants help keep your heart healthy. Theobromine in dark chocolate can boost your alertness, and regularly consuming cacao polyphenols may help maintain brain function. When enjoyed in moderation, dark chocolate can be a delicious and healthy addition to your diet.

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