

Study on the Dietary Intake of Anthocyanins in Chinese People and Effect of Anthocyanins on Cardiovascular Disease

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Abstract. Anthocyanin is one of the most important water-soluble flavonoids, which is the cause of the red and blue colors of the plants and can be always found in the berries. Anthocyanin is now known that it has many positive effects on human health, especially for cardiovascular health. One of the leading causes of mortality worldwide is cardiovascular disease. Vascular health is influenced by endothelial activity, arterial stiffness, and the formation of atherosclerotic plaques. Anthocyanins ameliorate dyslipidemia and vascular stiffness, inhibit COX-1 and COX-2 enzymes, have antiatherogenic, antihypertensive, antithrombotic, and anti-inflammatory properties. Anthocyanins can be used as medicine in prevention and treatment of cardiovascular diseases with a focus on dietary and other modifiable cardiovascular risk factors. This article aims to provide a present-day summary of the processes underlying the vascular protective action of anthocyanins obtained from food, analyze the relationship between anthocyanin intake and cardiovascular diseases, study the main anthocyanin sources of Chinese people, and provide some dietary suggestions for daily anthocyanin intake of Chinese people. Future development will pay more attention to customized health products and preventive medicine.

Keywords: Anthocyanins, Flavonoids, Cardiovascular Diseases, Dietary Intake.

1. Introduction

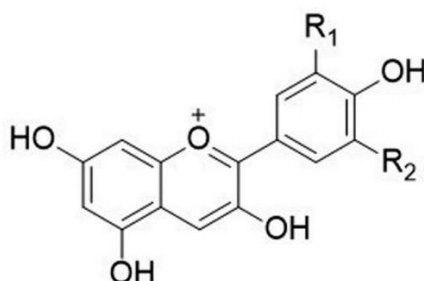
Flavonoids are a family of phenolic substances and can be widely found in plant foods [1, 2]. It refers to the general term of a series of compounds formed by the mutual connection of two benzene rings through three carbon atoms, that is, the general term of a class of compounds with C6-C3-C6 structure. At present, 9000 kinds of flavonoids have been narrated [2]. Because of their different molecular structures, they can be divided into flavonols, flavonoids, catechins, flavones, isoflavones, anthocyanins, rutin, hesperidin, quercetin, green tea polyphenols, anthocyanins, anthocyanins, etc. They can have physiological effects with more than 400 tissues of the human body. Flavonoids with different molecular structures act on different organs of the body.

Anthocyanins are pigment compounds that can be dissolved in water, which cause some fruits and vegetables to appear blue, red and purple. As the pH of the cell sap varies, anthocyanidins change color, turning crimson at pH 7, purple at pH 7-8, and blue at pH > 11 [3]. In 1947, anthocyanins were first found in the coating of peanut kernel in France and they are widely found in stem and leaf surface cells, fruit cell fluid and plant petals. Their parent nucleus' fundamental component is a 2-phenylbenzopyran cation, which is strongly conjugated. In Fig. 1, the benzene rings' carbon locations can be substituted in different ways to create anthocyanidins with a variety of structural variations [3]. They are commonly found in red to purplish blue fruits, veggies, flowers, seeds, grains and beans and a couple of roots [1, 4]. There are six common anthocyanins (aglycone): cyanidin, delphinidin, malvidin, pelargonidin, peonidin, and petunidin are often included in the human diet (Fig. 1) [1].

Cardiovascular diseases (CVDs), refer to the general term of cardiovascular and peripheral vascular diseases, also refer to the ischemia or hemorrhagic disease of the heart and peripheral blood vessels caused by hyperlipidemia, blood viscosity, atherosclerosis, hypertension, etc. There are eight major cardiovascular diseases, including cerebrovascular disease, coronary artery disease, arrhythmias, cardiac insufficiency, pulmonary vascular disease, peripheral artery disease, etc. More than 80% of global cardiovascular disease cases occur in low - and middle-income countries, such as China. There

are 290 million patients with cardiovascular diseases in China. A study shows that Chinese race has a higher probability of cardiovascular diseases than the races in other regions [5].

Dietary changes are the key component of cardiovascular diseases prevention, and consumption of plant foods and plant-based bioactive substances is strongly inversely correlated with cardiovascular diseases risks [6]. Anthocyanins have broad prospects in food and pharmaceutical industries since they are not only safe and don't have toxicity, but have many medical values as well.



Cyanidin: $R_1=OH$, $R_2=H$

Pelargonidin: $R_1=H$, $R_2=H$

Delphinidin: $R_1=OH$, $R_2=OH$

Peonidin: $R_1=OMe$, $R_2=H$

Petunidin: $R_1=OMe$, $R_2=OH$

Malvidin: $R_1=OMe$, $R_2=OMe$

Fig. 1 Common chemical structures of anthocyanins [3]

2. Effect of Anthocyanins on Cardiovascular Disease

2.1. Relationship Between Anthocyanin Intake and Cardiovascular Morbidity

By 2030, it is anticipated that every year, close to 28 million individuals would pass away from cardiovascular disease [3]. The high supply of anthocyanin is linked to a 17% less morbidity of coronary heart disease (CHD) [6]. Higher intake of anthocyanins reduces the risk of hypertension by 8-10% [7]. The incidence and death rates of CHDs are typically lower for women who routinely consume foods high in anthocyanins. Additionally, the risk of myocardial infarction is decreased by up to 32%, greatly lowering the incidence rate of this condition [3]. A study shows that anthocyanin intake is associated with a 27% less danger of total CVDs, and anthocyanins have a more obvious protective effect on females [6].

Cardiovascular and cerebrovascular disease is a kind of disease with high mortality, high recurrence rate and difficult to cure. Nearly 3 million people die of cardiovascular and cerebrovascular diseases in China every year, and 75% of those who survive lose their ability to work. Anthocyanins not only greatly improve the cure chances of cardiovascular and cerebrovascular diseases, but also reduce the recurrence rate by more than 80% and the mortality rate by more than 90%. Moreover, more than 80% of the long-term users (more than one month) have no risk of recurrence, and very few have mild recurrence.

2.2. Mechanism of action

The total length of blood vessels in the human body is about 100000 kilometers. Blood vessels are responsible for supplying oxygen and nutrition to human cells. If there is a problem with blood vessels, it will directly threaten life. Anthocyanins are very important for blood vessels. If the body lacks anthocyanins, it will cause capillary embrittlement, bleeding, purple blood spots, and even hemophilia, lung, stomach, nose bleeding, etc. Vascular health is affected by endothelial function, arterial stiffness and the presence of atherosclerotic plaques [8]. Consumption of anthocyanin-rich foods (mainly

blueberries) led to a 5-6% reduction in systolic pressure and diastolic pressure and favorable changes in arterial rigidity [4]. Anthocyanins can also enhance the toughness of the vascular wall, prevent rupture and penetration, and thus prevent the occurrence of vascular bleeding. Moreover, anthocyanins can remove cholesterol from the blood vessel wall and gradually return the hardened blood vessels to normal. In addition, a high intake of anthocyanins has beneficial effects on total cholesterol and low density lipoprotein (LDL) cholesterol levels by enhancing the efflux ability of cholesterol [4]. Anthocyanins inhibit the development of atherosclerosis, alter the signaling pathways of cells involved in vascular inflammation and degrade the size of coronary artery infarction and perfusion [4]. It can also enhance carbohydrate metabolism, interfering with the intestinal absorption of glucose through encumber α -glucosidases and α -amylases [8].

2.2.1 Antioxidant effect

Flavone is a strong antioxidant, which can effectively eliminate oxygen free radicals in the body. The antioxidant principle of anthocyanins is essentially that the phenolic hydroxyl group in its structure reacts with the free radical molecules in the human body to generate a semi quinone free radical, thereby reducing the free radicals in the body to achieve the purpose of antioxidant. Additionally, anthocyanins can exist in the human body for a long time, so its elimination of free radicals in the human body is greatly enhanced. Anthocyanins can inhibit the whole stage overflow of lipid peroxides. Thus, it can prevent cell degradation and aging, and also prevent cancer.

2.2.2 Anti-inflammatory effect

After excessive intake of certain substances, the human body will produce a kind of BGE2 and LTB4 substance that can cause fever, pain and swelling. This substance will cause excessive reaction of the immune system and then cause inflammation. Flavonoids can inhibit the exudation of inflammatory biological enzymes, thereby effectively preventing inflammation and promoting wound healing.

A major mechanism driving several cardiovascular and metabolic-related disorders is inflammation [9]. In several investigations, dietary anthocyanins were found to lessen vascular and systemic inflammation. Being a chronic inflammatory illness, atherosclerosis can be slowed down by the anti-inflammatory properties of anthocyanins. Anthocyanins restrict nuclear factor (NF)- κ beta activation and prevent vascular smooth muscle cells from expressing cyclooxygenase (COX)-2 and the adhesion molecule for smooth muscle cells. By triggering the nuclear factor 2 pathway, anthocyanins reduce inflammation [8]. In hypercholesterolemic individuals, anthocyanins dramatically reduced the levels of inflammatory indicators [8]. A vessel-protecting mechanism, anthocyanins, particularly non-acylated anthocyanins, control vascular inflammation by avoiding excessive immune cell infiltration [8]. Tumor necrosis factor (TNF)- α and circulating C-reactive protein (CRP) are two typical indicators of persistent low-grade inflammation. TNF- α and circulating CRP concentrations can be considerably reduced by supplementing with pure anthocyanins [6].

2.2.3 Metabolic effect

The ability of anthocyanins to prevent cardiovascular disease by improving lipid homeostasis is connected to their potential to give metabolic advantages [9]. Strong lipid-lowering benefits of anthocyanins have been shown in both clinical and preclinical studies, and it is predicted that proper control of blood lipids will result in roughly 30% fewer cardiovascular disease events in Chinese hypertensive adults [6].

Anthocyanidins boost anti-atherogenic high density lipoprotein (HDL) cholesterol while lowering atherogenic LDL cholesterol levels in the blood [9]. Anthocyanidins are linked to the suppression of LDL oxidation in vitro [9]. Purified anthocyanins as a supplement may result in substantial increases in blood HDL-C and marked decreases in blood LDL-C concentrations [6]. The liver's expression of peroxisome proliferator-activated receptors (PPAR) was raised by anthocyanins from cornelian cherries, which helped to provide an anti-atherosclerotic effect [8]. The growth of vascular smooth

muscle cells is prevented when Nrf2 is activated by anthocyanins, and the amount of oxidized LDL is decreased by activating the CD 36 scavenger receptor [8].

Supplementing with anthocyanins may inhibit the cholesteryl ester transfer protein (CETP), resulting in elevated antiatherogenic HDL-C and decreased levels of proatherogenic LDL-C in dyslipidemia [6]. Raising anthocyanin consumption can raise acidic and neutral sterol expression in the feces, lowering plasma cholesterol [9]. By blocking the enzymes -amylase and -glucosidase, which convert dietary carbohydrates to glucose, and by affecting glucose transport, anthocyanins also affect lipid and sugar metabolism [9]. Moreover, they enhance insulin resistance and reduce inducible nitric oxide synthase, COX2, and NF-B expression. Weight reduction is also made possible by the anti-inflammatory properties of anthocyanins and their impact on insulin sensitivity [8].

2.2.4 Anti-ischemic and cardioprotective effect

Flavonoids supplementation reduces the size of myocardial infarcts, enhances aortic flow and contractile function, lowers the incidence of cardiac arrhythmia, and lessens the severity of ischemia-reperfusion damage. Increasing anthocyanin intake can also decrease hypertension [9]. It has been demonstrated that anthocyanins inhibit heart hypertrophy in addition to hypertension [8].

Even though all anthocyanin supplements utilized in the included RCTs were made from berries, the conclusion is that cardiovascular advantages of pure anthocyanins were superior to those of berry products high in anthocyanins [6].

2.2.5 Effect on other aspects

Administration of cranberries that rich in anthocyanins may drastically lower BMI, which shows that taking cranberries can help control weight and make body healthier [6]. Anthocyanin rich plants or their extracts have excellent effects on depressive symptoms.

In addition, administration of berries high in anthocyanins may dramatically but only marginally lower blood triglycerides [6]. It has been proved in animal experiments that anthocyanin acid can reduce blood sugar by 26% and triglyceride by 39%. The effect of reducing blood sugar is amazing, but more importantly, it has a good effect on stabilizing collagen. Therefore, it has a good effect on retinopathy and capillary embrittlement caused by diabetes.

Flavonoids also have the functions of anti-toxicity, anti-asthma, anti-sensitivity, anti-radiation, regulating body function, promoting metabolism. Anthocyanins can also inhibit a variety of bacteria. Anthocyanins decimate the integrity of cell walls and cell membranes, inhibit the biosynthesis of DNA, RNA and protein, destroy the structural components of bacteria, and change the morphology of bacteria. Peroxide can reduce the activity of liver function, and anthocyanin can obviously weaken this effect, thereby improving liver function. Anthocyanins can scavenge free radicals produced in the brain, thereby protecting neurons and improving memory. Anthocyanins also have a certain delaying effect on aging.

3. Common Dietary Sources of Anthocyanins

Berries have the highest anthocyanin concentration in the diet, while the amount and structure of anthocyanins in plant foods vary widely and are greatly affected by cultivation, preservation and processing [1, 6]. With the exception of berries, where they can be found in both the skin and flesh, they are mostly located in the fruit's skin [4]. They typically have concentrations of up to 1.0 percent of dry weight, ranging from 0.1 percent to that much [4]. Fruits such as berries, radishes, plums and red grapes can provide rich anthocyanins for the human body, and products obtained from fruit reprocessing such as red wine and fruit juice are also rich sources of anthocyanins (Fig. 2) [4]. Two servings of fresh blueberries have an average amount of 240 mg, whereas two glasses of red wine have an average amount of 56 mg, despite the fact that levels can vary greatly depending on growth and storage circumstances [4].

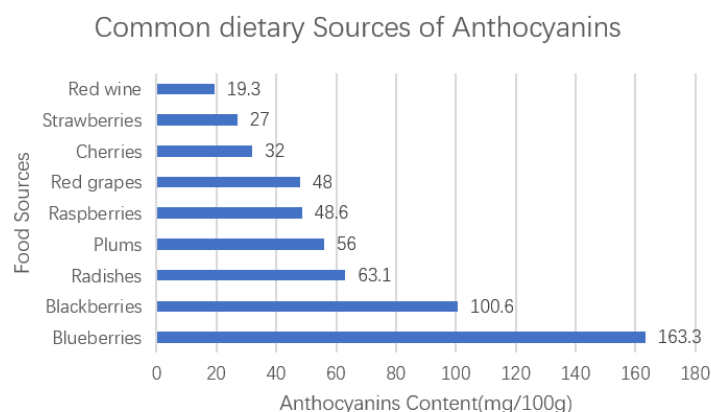


Fig. 2 Common Dietary Sources of Anthocyanins [4]

3.1. Anthocyanin Sources of Chinese People

Among the foods in Fig. 3, Chinese dietary patterns usually only include radishes, plums, red grapes, cherries and strawberries. They usually don't have the habit of drinking red wine containing large amounts of anthocyanins, because these habits came from the Western country instead of originating in China. The dietary pattern of Chinese people is very different from that of other western countries. Chinese people prefer cooked food to raw food and seldom have the habit of drinking red wine, so anthocyanin sources of Chinese people is very limited. Therefore, the anthocyanin intake of Chinese people is relatively low compared with that of people in other regions.



Fig. 3 Common foods with high anthocyanin [3]

3.2. Dietary Recommendations for Daily Intake of Anthocyanins

At present, China has determined the specific recommended level of anthocyanins as 50 mg/d [9]. In Dietary guidelines for Chinese Residents (2022), Chinese residents are recommended to have vegetables for each meal with eating no less than 300 grams of fresh vegetables every day. Dark vegetables should account for about a half of the total. Another recommendation is eating fruit every day with 200-350 grams of fresh fruit.

Anthocyanin content can generally be determined by color, which is useful for nutritional advice [1]. Thus, it is recommended that Chinese people can select blue, red and purple fresh vegetables and fruits to consume if they lack the knowledge of the dietary source of anthocyanins for plants that present these colors usually contain high levels of anthocyanins. It's also a good idea to try to make sure that the colors of the food are diversified at every meal. The Mediterranean diet and lifestyle include a lot of anthocyanin-rich foods, which has positive health impacts [8]. Therefore, some Chinese people can also refer to the Mediterranean diet menu to arrange the meals in order to ensure a sufficient intake of anthocyanins.

Mulberry has high content of polyphenol, including flavonoids and anthocyanins. More importantly, mulberry is originated in China, which has a long history of cultivation and a wide range of planting. China has the most varieties of mulberry trees, and its mulberry output ranks first in the world [3]. In China and other countries, solvent extraction is being utilized extensively to extract mulberry anthocyanins [3]. Therefore, Chinese people can appropriately increase the intake of mulberry in order to improve the intake of anthocyanins.

Southern China produces a significant amount of bayberry fruit, which has anti-oxidant, anti-cancer, and hypoglycemic properties due to its high anthocyanin content. Bayberry has a high anthocyanin concentration of up to 76.2 mg/100 g [3]. For Chinese people, taking more bayberry is also a good way to increase anthocyanin intake.

The amounts of anthocyanins extracted from purple potatoes using 70% ethanol as the extractant is 170.5 mg/100 g [3]. The anthocyanins found in purple sweet potatoes, which have physiological effects including decreasing blood lipids, antioxidation, and anti-aging, are abundant in China and are widely grown there [3]. Although China has only introduced purple potatoes in recent years, breeding and farming techniques are well developed. In comparison to white potatoes, purple potatoes have a 3–4 times higher anthocyanin content and a 2.5–3 times higher capacity to scavenge free radicals [3]. Since purple potatoes are inexpensive, highly adaptable, and produce enormous amounts, they may be used as a rich supply of anthocyanins.

The above four recommended foods: mulberry, bayberry, purple sweet potato and purple potato (Fig. 2) are all common and inexpensive foods with high anthocyanins.

Simply eating 1-2 pieces of blueberries, raspberries, or strawberries will considerably raise anthocyanin intakes to levels that have been linked to a lower risk of cardiovascular diseases, so consciously taking a little more berries every day can play a significant role in preventing and treating cardiovascular diseases [4].

4. Anthocyanin Based Health Products and Medicine

Firstly, since the anthocyanidin concentration of different fruits might vary, the daily consumption will change greatly between people and day to day [9]. Secondly, as mentioned above, the effect of pure anthocyanin on cardiovascular diseases is more obvious than that of berry products with high anthocyanin content [6]. Therefore, it is necessary for professionals to develop customized purified anthocyanin health products for people with different health conditions, different health care and treatment purposes and different age groups.

Edible pigments must typically be added during food processing and manufacture in order to enhance sensory qualities, which in turn encourage people to buy items, boosting sales [3]. Nowadays, most of the pigments used in the food business are chemically manufactured, affordable, accessible, and include some toxicity [3]. Natural pigments are safer than manufactured ones and may possibly

have some significant medical benefits [3]. At present, consumers are more and more repellent to synthetic pigments, but they are more concerned and looking forward to the application of natural pigments [10]. As a result, there is an increasing demand for natural pigment research and development. According to FAO /WHO, anthocyanins can be used as new food additives [10]. Anthocyanins are predicted to be extensively employed in the food business in the future since they may be used as safe, non-toxic food additives and nutrition boosters [3]. The use of anthocyanins as an alternative to chemically created colors is being researched by the pharmaceutical manufactures [3]. A large number of experiments have confirmed that adding appropriate amount of anthocyanins to food can not only make the color of food uniform and beautiful, but also keep it for a long time without any change in color and uniformity, and its stability is even better than that of synthetic pigments [10]. Anthocyanins are effective substitutes for drugs; however, future studies should focus on determining the accurate dosages in order to reach the prospective effects [3].

5. Conclusion

Recent scientific data from epidemiological, observational, intervention, randomized controlled trials, and mechanistic studies suggests that anthocyanins are a cheap, accessible, and effective method for lowering atherosclerosis, cardiovascular risk, and cardiovascular aging. Future studies should focus on comprehending the role of the microbiota and inter-individual variation in metabolism following consumption. Anthocyanins have the potential to improve cardiovascular health through a variety of processes, which have positive effects on endothelial function, COX-1 and COX-2 enzyme inhibition, anti-atherogenic, anti-hypertensive, antithrombotic, and anti-inflammatory actions, and they reduce dyslipidemia and arterial stiffness. Additionally, anthocyanins can affect the vasodilation and relaxation that occur during exercise. Anthocyanins intake can greatly reduce the risk of cardiovascular disease. At present, preventive medicine deserves special attention, focusing on preventable cardiovascular risk factors, especially diet. Anthocyanins can used as preventive and therapeutic drugs. Eating fruits and vegetables rich in anthocyanins can reduce the risk of cardiovascular disease. Chinese dietary patterns lack anthocyanins, so they should eat more food containing anthocyanins.

Anthocyanins should play a bigger part in the world's food system, and everyone should be aware of the effects their dietary choices have on their health for extending healthy lifespan, decreasing cardiovascular aging, and preventing cardiovascular illnesses. Some findings showed that frequent ingestion of pure anthocyanins could reduce lipid levels and reduce inflammation, hence preventing CVDs, which even has a better effect than anthocyanin-rich berries. Thus, it is necessary to get more studies to focus on research and development of purified anthocyanin health products and anthocyanin-based natural pigments.

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