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A Review on Chemical Composition and Properties of Anthocyanin and its Effect on Human Health

Zia Parveen and Sunita Mishra*

Department of Food and Nutrition, Babasaheb Bhimrao Ambedkar University (A Central University), Vidya Vihar, Raebareli Road, Uttar Pradesh, India

Correspondence should be addressed to Sunita Mishra, Department of Food and Nutrition, Babasaheb Bhimrao Ambedkar University (A Central University), Vidya Vihar, Raebareli Road, Lucknow - 226025 (U.P.), India, Email: sunitabbau@gmail.com

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ABSTRACT

Anthocyanins are phenolic pigments that are coloured and water soluble. These natural sources pigments can be found in berries, currants, grapes, and some tropical fruits. Leafy vegetables can come in various colours from red to purple blue. The edible vegetables with the highest levels of anthocyanin are grains, roots, and tubers. There are merely six distinct Anthocyanins that can be encountered in nature: cyaniding, delphinine, petunidin, peonidin, pelargonidin, and malvidin. Anthocyanins have oxygenated heterocycle structures composed of two aromatic rings connected by three carbons. Due to their various hues and beneficial qualities like antioxidant activity, anti-carcinogenic characteristics, and anti-inflammatory effects, anthocyanins attracted a lot of interest. Beneficial in preventing cardiovascular disease and cancer. Anthocyanin has recently drawn considerable interest from the food sector as a substitute for artificial colouring compounds, which have been found to have an extremely negative influence on human health when consumed. Due to their unique antioxidant capabilities, anthocyanins are said to have health benefits in this research. Therefore. The properties of anthocyanin and their effects on human health are the main topics of this review.

KEYWORDS

Anthocyanins; Sources; Chemical composition; Properties; Human health

INTRODUCTION

In 1835, Marquart coined the term anthocyanin to describe the blue pigments found in flowers. The name is a combination of the Greek words for flower and blue [1]. Vegetables and flowers carry the vascular pigment anthocyanin. In essence, anthocyanins are found in red onions, red radish, and blackberries.

The group of phytochemicals known as flavonoids, which includes anthocyanin, is made up mostly of foods including cereals, chocolate, olive oil, nuts, vegetables, fruits, vegetables, wine, and honey. There are various uses for this pigment that is also present in rose and aparajita flower petals. So far, 25 distinct anthocyanin pigments have been identified, some of which contain aglycone derivatives of cyanidin (CY) and pelargonidin (Pg). The typical

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replacement sugars were rhamnose and arabinose, but rutinose and glucose were also used the food colouring industry is particularly interested in anthocyanins due to their capacity to produce vivid hues. Due to their numerous physiological properties, anthocyanins have been consumed by humans for ages and have been used as traditional herbal medicines for hypertension, pyrexia, liver disorders, CVD, dysentery and diarrhoea, urinary issues, and the common cold. Materials containing anthocyanins have recently been incorporated to food goods, but more study is needed to show how these products affect our bodies physiological [2]. one of major factors in the popularity of blackberries, raspberries, black currant and other small fruits in the human diet is that they are a good source of natural antioxidants. The majority of these fruits are found in the 250 species-strong Rubus genus. Many fruits from the Rubus genus are eaten either raw or processed into jams, jellies, candy, syrups, and wines. Numerous medicinal uses have been made of the leaves and roots. The antioxidant, anti-inflammatory, and chemo preventive properties of blackberries and raspberries, as well as black raspberries' biological activity against esophageal, colon, and oral cancers, are critical for the positive health effects associated with these foods. The major and minor anthocyanins in blackberries have long been identified as cyanidin-3-glucoside and cyanidin-3-rutinoside. Fruits and other natural sources from related species frequently exhibit different levels of biological activity, with some species being completely dormant and others displaying exceptionally high activity [3]. Many fruits and vegetables have an appealing colour due to the presence of anthocyanin. Because anthocyanin flavylium nuclei are electron deficient, they are highly reactive, and as a result, these compounds undergo undesirable colour changes during fruit processing and storage. Anthocyanin pigments are degraded by oxygen, ascorbic acid, temperature, metals, enzymes, sugars, and other chemicals.

Pure anthocyanin model systems have been used to gain insight into the types of degradative reactions that anthocyanins may undergo during food processing. The precise chemical transformations of anthocyanins, however, are unknown. The presence of cellular constituents that cause anthocyanin deterioration complicates matters even further in fruit products [4]. Anthocyanins are almost universally found in higher plants (found in about 30 families), but they appear to be absent in liverworts, algae, and other lower plants in general, with the exception of mosses and ferns, where some have been identified. One of the first branches of general propanoid metabolism was anthocyanin biosynthesis to be identified, owing to the ease with which mutations and genetic imbalances can be detected and controlled, as well as the biosynthetic enzymes and associated transcription factors. Anthocyanins can successfully donate hydrogen. Due to the positive charge of anthocyanin, the number and configuration of aromatic hydroxyl groups, the degree of structural conjugation, and the presence of both electron-donating and electron-withdrawing substituents in the ring structure, these compounds can readily donate protons to highly reactive free radicals, preventing the formation of new radicals [5].

Sources of Anthocyanins from Fruits and Vegetables

Anthocyanins are derived from a relatively small number of foods in the human diet. The primary sources are orange-red, purple, and blue fruits and vegetables and other natural sources. The total AC content of vegetables and fruits ranges from 28 mg/100 g to 148 mg/100 g. Berries such as blueberries, blackcurrants, chokeberries, and elderberries, in particular, reported AC contest ranges of 160 mg/100 g - 1300 mg/100 g weight [6-8]. Anthocyanins are found in every part of the plant. Although they are mostly found in flowers and fruits, they are also found in leaves, stems, and storage organs [9]. The total anthocyanin content varies greatly between plants or even cultivars within the same plant (10 April 2008). Richest sources of anthocyanin discussed in given table no 1.

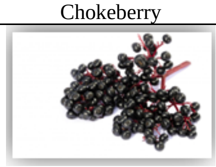
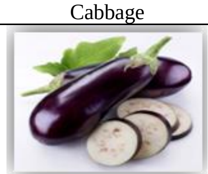
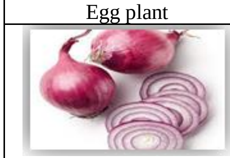
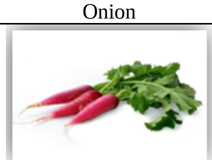
Fruits	Concentration (mg)	Description
 Blueberry	25-495	Purple peel and flesh
 Chokeberry	410-1480	Black peel
 Elderberry	200- 1816	Black peel
 Grape	80 - 3880	lowbush
 Raspberry	763 - 4277	Red peel
 Currant	130 - 476	Black peel
Vegetables		
 Cabbage	250	Purple peel
 Egg plant	7500	Purple peel
 Onion	Up to 250	Red peel
 Radish	110 - 600	Yellow and red peel

Table 1: Richest source of anthocyanin and its concentration in selected fruits and vegetable.

Types of Anthocyanins Founds in Plants

Anthocyanins are most commonly found as glycosides. Other than as artefacts, aglycones are rarely found in plants; the 3-deoxy forms the main exceptions, appearing in red-skinned bananas, sorghum, and black Glycosides are the most common type of anthocyanins. Antioxidant characteristics and analysis 2012) the 3-deoxy forms are the primary exceptions, showing in, for example, red-skinned bananas, sorghum, and black tea. The aglycones are usually found in plants as remnants. The most recurring sugars are glucose (the most frequent), galactose, rhamnose, arabinose, xylose, and glucuronic acid; these sugars are commonly found as 3-glycosides or 3, 5-diglycosides; 3-diglycosides and 3-diglycoside-5-monoglycosides are less frequent [10,11]. Rutinose, sambubiose, lathyrose, and sophorose are the four main biosides which are encountered. In the case of glycoside distribution concerns the most abundant anthocyanin is cyaniding-3-glucoside, which occurs approximately 2.5 times more frequently than 3, 5-diglycosides [12]. Anthocyanidins are the de-glycosilated or aglycone forms of anthocyanins; both parent names were introduced by Willstatter and Everest (1913) in their important study of the topic [13]. a several types of anthocyanin The number and arrangement of hydroxyl and methoxyl groups, a kind and proportion of sugars associated to the molecule, the position of this attachment, and the degree and type of esterification with aliphatic or aromatic acids coupled to sugars in the molecule are all differences among anthocyanins The three inputs of the B ring are where these six common anthocyanidins differ chemically from each other The six common anthocyanidins found in larger plants have served as the basis for the most of additional anthocyanins discovered in the past fifteen years All Anthocyanins and anthocyanidins appearing in nature show an unclosed hydroxyl group in the 4position. However, anthocyanins often found in plants as salts (which seems represented by the positive charges on the heterocyclic ring), and the way they combine affects how colored the cells are in plants. Fruits and vegetables are brightly coloured in red, blue, and purple, and deciduous trees' autumn foliage is also brightly coloured due to the conjugation bonds in their structures (light conjugated double bonds having a positive charge), which absorb light with a wavelength of about 500 nm. Anthocyanins help in creating salts with either acids or bases and are all amphoteric with the exception of green, all bright colors have been observed (natural or synthetic), depending on variables such as the type of substituents in the B-ring, the local pH, the anthocyanins' state of aggregation, complexation with organic molecules, or, in the case of the blue color, complexation to metal cations Keep in recall that the majority of green pigments in plant food are chlorophylls. Green-brown or brown shades can also be referred to chlorophyll degradation products. Types and chemical structure of anthocyanin are discussed in the given Table 2.

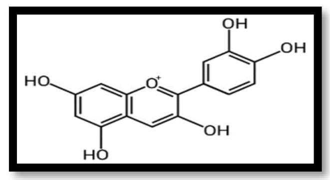
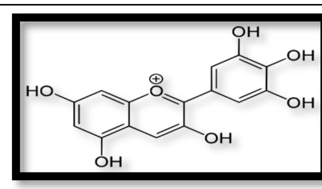
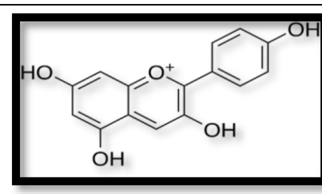
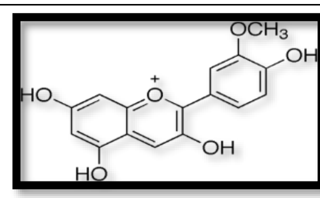
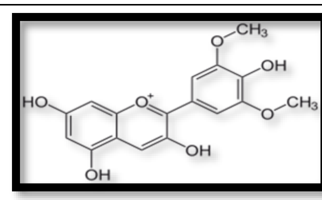
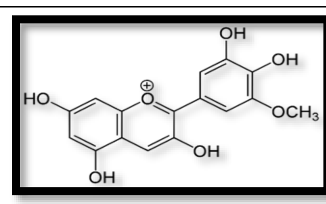
S. No	Compound name	Sources	Structure	References
1.	Cyanidin	Red berries Bilberry cranberry raspberry		**[14]**
2.	Delphindin	Cran berries Pomegranates bilberries		**[15]**
3.	Pelargonidin	Blue berries Chokeberries Blackberries, Plums and Pomegranates.		**[16]**
4.	Peonidin	Red grapes orange. Black current		**[17]**
5.	Malvidin	Blueberries cranberries elderberries raspberry and strawberries		**[18]**
6.	Petunidin	Chokeberries redberries redberries saskatoon berries.		**[19]**

Table 2: Types of Anthocyanin.

S.No	Chemical compound in anthocyanin	Derivative of the compound	Sources
1.	Phenolic compounds	Cinnamic acid Benzoic acid derivatives P- hydroxybenzoic acid Salicyclic acid Gallic acid Ellagic acid P- coumaric acid Caffeic acid Ferulic acid	Pomegranates
2.	Tannins	Epicatechin Catechin	Grape, raspberries, blackberry, peach
3.	Stilbenes	3-β-mono-D-glucoside Trans- resveratrol	Grape
4.	Carotenoids	Lycopene, β-carotene Z-Carotene B- cryptoxanthin Lutein 5,6- epoxylutein Trans- violaxanthin Neoxanthin	Pomegranates, corn
5.	Sugars	Glucose	Strawberries, red plum

Table 3: Chemical composition of anthocyanin**.**

Chemical Composition of Anthocyanin

Anthocyanin could be found in a variety of plant communities, although it is primarily found in the skin's outer layers, where it is almost completely absent from cell walls and flesh tissue. Major chemical compounds which is found in anthocyanin are i.e., phenolic compound, tannins, stilbenes, carotenoids and sugar. Chemical composition of anthocyanin discussed in given Table 3.

Properties of Anthocyanin

Anthocyanin is a flavonoid (phenolic phytochemical) secondary metabolite found in plants. [20]. Anthocyanins are members of the flavonoid's family, but what distinguishes them from other flavonoids is that they appear in the form of flavylium cations Anthocyanins primarily taste astringent and have almost no stench. Anthocyanin pigments are responsible for the glossy orange, blue, purple, pink, and red tones of many plants' vegetables and fruits as well as flowers. [21]. The structure, pH, temperature, enzymes, UV radiation, co-pigmentation, and the presence of oxygen all have a significant impact on anthocyanin colour Anthocyanins can have different colors depending on their pH, such as salmon-pink, red, violet, or blue

Anthocyanins, natural food colorings with molecular weights between 400 and 1200, are water-soluble. Although anthocyanins are polar, they can be dispersed by polar solvents such as methanol, ethanol, and water. The glycosides of flavylium salts (2-phenyl benzo pyrylium) serve as the chemical foundation for anthocyanins. However, there are structural differences in the number of hydroxyl groups, methylation levels, and the types and number of sugar moieties attached to the molecule. The anthocyanin structure is influenced by the type, proportion, and arrangement of aliphatic or aromatic acids attached to sugars. Anthocyanins are primarily composed of one glucoside unit, though some varieties include one or more sugars connected at various points or attached as oligosaccharide side chains. [22]. The presence of hydroxyl and methoxyl groups influences the hue type and intensity of anthocyanins.

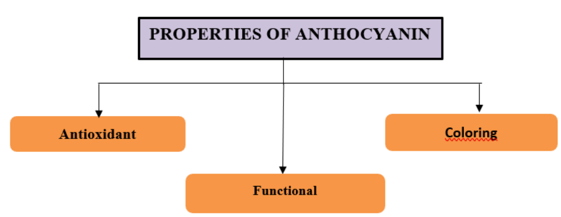


Figure 1: Different properties of Anthocyanin.

Antioxidant Properties of Anthocyanin

The anthocyanin structure contains a conjugated double bond that can make it incredibly reactive and act as a protective measure to antioxidants or radical compounds. [23-24]. the intensity of anthocyanin's antioxidant activity increases as the number of phenolic hydroxyl groups that are connected to it. [25]. A range of free radicals released from reactive oxygen, include peroxyl (ROO), hydroxyl (OH), and singlet oxygen (O2), can combine with anthocyanin. Free radicals are compounds that can be generated by prooxidative enzymes inside the structure itself as well as by environmental exposures like cigarette smoke, pollution, fat oxidation, exhaust fumes, and association with other chemicals [26].

Antioxidants can prevent the beginning stages of colon cancer by decreasing DNA damage inflicted on by carcinogens, in addition to reducing DNA mutation by eliminating radicals [27]. In addition to stabilizing free radicals and preventing the occurrence of chain reactions from the formation of free radicals that can cause oxidative stress, antioxidants can prevent DNA mutation by blocking the initiation stage of cancer by inhibiting DNA damage caused by carcinogens. Moreover, antioxidants can dissolve peroxide, reduce singlet oxygen, and scavenge free radicals [28].

Functional Properties of Anthocyanin

Food extracts with such a high phenolic content are a valuable source of nutrition for the production of functional foods and have already been used in a variety of dietary foods. Anthocyanin extracts from purple maize, for example, can be obtained as an antioxidant in daily dietary supplements (with the goal of promoting healthier, younger-looking, and more radiant, beautiful skin). Similarly, concentrated extracts of cyanidin-3-O-glucoside and delphinidin-3-O-glucoside derived from black currants and Norwegian bilberries (Vaccinium myrtillus) (Ribes nigrum) (Amazon Botanicals, 2005-2009; Bio link Group, 2009) are present (Amazon Botanicals, 2005-2009; Biolink Group, 2009). Red rice is used in food coloring agents such as bread, ice cream and liquor. It has long been used as a functional food in China to relieve abdominal pain and help control cardiovascular issues. In order to decrease cholesterol levels, fermented red rice is sold Furthermore, due to its high levels of anthocyanins (primarily 3-deoxyanthocyanidin derivatives like luteolin and apigeninidin), black sorghum bran has a higher potential for incorporation in functional anthocyanin food products than the majority of fruits and vegetables (which range from 0.2 mg/g to 10 mg/g fresh weight). Anthocyanins are abundant in flowers and fruits, but they can also be found in grains, leaves, stems, storage organs, and spores Anthocyanins were found in the highest concentrations in various berries and black currants, as well as eggplant and cereals containing purple and blue pigments. Anthocyanins are widely consumed by humans due to their abundance in fruits, vegetables, and red wines. Anthocyanin consumption has been estimated to range from several milligrams to hundreds of milligrams per person, depending on nationality and dietary habits. [29]. Consumption of anthocyanins is increasing as a result of the potential health benefits of anthocyanins becoming widely known, as well as the viability of extracts and juices from fruits and vegetables with high anthocyanin contents.

Colorant Properties of Anthocyanin

The consumer's assessment of the flavor and taste of a food product is changed by its colour, which is also considered as a clear indication of the product's quality. [30]. As a side effect, manufactures will use the most effective strategies to give a clear picture of food, retaining in mind the relevance of preserving the natural appearance of foods and the fact that colour is one of the major concerns confronting the food industry Because of this, the food industry has used synthetic pigments for many times. However, as consumers' reservations about their health increase, they are now refusing the use of synthetic dyes and pigments in food. Because natural alternatives produce improved health outcomes, they are now the new trends in the food industry.

[31]. For processed foods and beverages to be greater than the combined by consumers, natural coloring agents and additives must be utilized. Anthocyanins are some of the pigments which are natively coloured and acquired from plants. Red, blue, and purple pigments are known anthocyanins and are derived from plants. These pigments are low- to non-toxic colorants. In certain ways, natural colorants are safer to consume than synthetic colorants, because synthetic colors are very harmful for health. Even in excessive densities. Natural colorants anthocyanins offer positive health benefits. [32]. these qualities include anti-oxidants, and have several health advantages such as an antibacterial and antifungal activities and the prevention of chronic diseases, in addition to nutraceutical features.

HEALTH EFFECTS OF ANTHOCYANIN

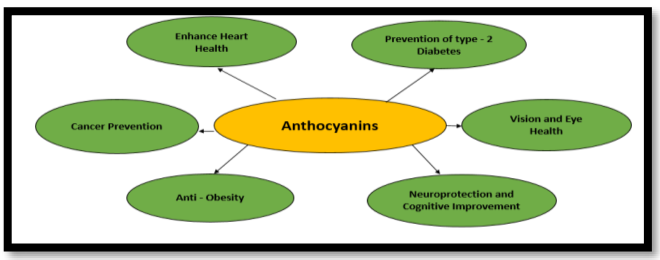


Figure 2: Different health effects of anthocyanin.

Enhance Heart Health

In 2010, a study published in Nutrition Reviews investigated anthocyanin-focused nutrients and conjectured those berries (regardless of whether fresh, squeezed, or freeze-dried) and cleaned anthocyanin extracts make an important contribution to improvements in cardiovascular risk factors. Like LDL oxidation, lipid peroxidation, absolute plasma cell reinforcement limit, dyslipidemia, and glucose metabolism. Based on the findings, anthocyanins were beneficial for both healthy subjects and those who already had cardiovascular risk factors. Anthocyanins increase endothelial nitric oxide arrangement, reduce oxidative pressure, and decrease inflammation, among other potential benefits. A higher intake of anthocyanins and flavones, contrary to common belief, is associated with reduced blood vessel brittleness, focal circulatory strain, and atherosclerosis [33,34].

Prevention in Type -2 Diabetes

Food compounds classified as anthocyanins, which are polyphenols, may play a particular role in the prevention of type 2 diabetes. Numerous studies have been conducted to explain the mechanism by which performance was better control the body's carbohydrate metabolism and reduced insulin resistance. These findings have entangled both human participants and experimental animals. These substances interact only with body in a number of ways. Moreover, anthocyanins inhibit intestinal-glucosidase and pancreatic-amylase in in addition to controlling GLUT4 gene expression and translocation, PPAR activation in adipose tissue and skeletal muscles, AMP-activated protein kinase activation, adiponectin and leptin secretion, retinol binding protein 4 expression, and AMP-activated protein kinase Furthermore, anthocyanins improve rodent pancreatic cell insulin secretion. Furthermore, it was revealed that these compounds shelter pancreatic cells in animals treated against streptozotocin-induced necrosis. The particular anthocyanins and their glycosides, however, were discovered to have different levels of action It is, therefore, necessary to include a variety of plant products in the daily diet, because they contain various anthocyanins. For contrast, cyanidin is found primarily in blackberries and red cabbage, delphinidin in eggplant, malvidin in blueberries and red grapes, and pelargonidin in radish. The results from the research reported by previous researchers, taking into account the influence of anthocyanins on the management of glycemia and decrease of insulin resistance, is notable despite the fact that a variety of factors contribute to the development of type 2 diabetes. Therefore, it seems that one of the aspects supporting the prevention and treatment of type 2 diabetes would be the consumption of foods that are high in these compounds. [35].

Cancer Prevention of Anthocyanin

A subclass of flavonoids that is a component of the polyphenol class is anthocyanins. The antioxidant activity of the anthocyanin polyphenol is affected by its structure. The majority of methodologies used for anthocyanin antioxidant analysis were based on their mechanisms, as were those for lipid peroxidation inhibition, metal ion chelation, and antiradical and reducing activities by 2, 2-diphenyl-1-picrylhydrazyl (DPPH) and ferric reducing antioxidant power (FRAP) assays. Antioxidant capacity has long been thought to be the primary line of defence against the first stage of the mutagenesis process. [36]. Revealed that delphinidin derivatives with C3 glycosylation had antioxidant effects on colorectal cancer cells by reducing ROS and promoting glutathione reductase (GSR) protein expression. This was accomplished by scavenging free radicals, which reduced DNA damage and attempted to prevent the formation of tumour tissues. It was also discovered that the antioxidant properties of anthocyanins may help to prevent stomach and colorectal cancer by providing electrons. Furthermore, anthocyanins must have been discovered to activate the antioxidant pathway regulated by nuclear factor erythroid 2 (Nrf2) in colon cancer cells, thereby contributing to antioxidant prevention. [37,38]. it was also strongly motivated that anthocyanins have a higher antioxidant capacity, which could be due to increased hydroxylation on the B ring of polyphenols, which is effective in the prevention of colorectal cancer and breast cancer. Anthocyanins have antioxidant properties that appear to be beneficial in the prevention of many cancers, not just the ones listed above. It is intriguing that the majority of antioxidant protection studies used in vitro cell line research. In this context, future in vivo testing may focus on the systematic investigation of anthocyanins with anti-oxidant properties.

Vision and Eye Health

BCA has been demonstrated to increase eye and eyesight health for glaucoma patients, healthy human subjects, and chickens. The oral administration of BCA and the intravenous infusion of major blackcurrant Anthocyanins significantly reduced the elongation of the vitreous chamber depth and axial length carried out by negative lenses in chicks [39,40]. Acute BCA intake in healthy people enhanced the effect of work-induced short-term blindness and dark adaptation. [41]. In healthy individuals, administration of BCA for two weeks reduced dramatically intraocular pressure [42,43]. Patients having glaucoma were also evaluated to see how BCA influenced their eye health. It was discovered that conducting BCA for 24 months decreased intraocular pressure in glaucoma patients, postponed the loss of visual field, and improved ocular blood flow the mechanisms underlying BCA's advantage for vision have not been investigated properly. One theory involved plasma endothelin-1 (ET-1) as a mediator [44]. It has been proposed that the powerful vasoconstrictor ET-1 contributes to the local autoregulation of blood flow. However, when you consider the incorrect conclusions in regard.

Anti-Obesity

Our group released the analysis in 2003 that have shown anthocyanins had the capability to prevent the accumulation of body fat. [45]. In summary, cyanidin 3-glucoside (C3G; 2 g/kg) supplements significantly reduced body fat accumulation in C57BL/6J mice fed a high-fat diet (60 percent fat), which was associated with a decrease in lipid production in the liver and white adipose tissue When anthocyanins interact with adipose tissue, they alter adipocytokine expression levels, among other things. We discovered that C3G or its aglycones increase adiponectin, which increases insulin sensitivity, in isolated rat and human adipocytes even though these processes were not observed in. In C57BL/6 mice, lyophilized wild blueberry powder (WBP) had no effect but did cause body fat accumulation, whereas feeding a high-fat diet (45% fat) supplemented with anthocyanins extracted from blueberries significantly suppressed increases in body weight and body fat accumulation. In another study, the same group discovered that feeding mice a high-fat diet (45% energy fat) had no effect on body weight gain or the weight of white adipose tissue (epididymal and retroperitoneal fat) [46]. Similar findings were also reported by another study [47]. on the other hand, discovered that feeding Zucker fatty rats a high-fat diet (45% fat) instead of 2% WBP reduced intraperitoneal fat weight and increased PPAR activity in white adipose tissue and skeletal muscle [48]. Specifically, 8 weeks of feeding a diet supplemented with 8% WBP increased blood adiponectin levels, decreased inflammation markers in white adipose tissue, and improved dyslipidemia [49]. but did not affect fasting blood glucose and insulin levels.

Neuroprotection and Cognitive Improvement

Anthocyanins might be used to prevent a diverse range of neurodegenerative diseases, such as Parkinson's disease (PD) and Alzheimer's disease (AD), according to substantial evidence from epidemiological studies that they contain neuroprotective effects that improve cognitive, memory, and motor performance [50]. Dopaminergic neurons in the midbrain are gone as a result of the neurodegenerative condition PD. It has recently been claimed that dopaminergic cell loss contributes to the emergence of PD [51]. started to show that anthocyanin-rich extract from blueberries, grape seed pods, hibiscus, blackcurrants, and Chinese mulberries greatly decreased rotenone-induced dopaminergic cell death by ability to inhibit microglial activation and improving mitochondrial dysfunction After an ischemic stroke, mitochondrial dysfunction carried on by oxidative stress also result in neuronal damage. By preventing AIF release from mitochondrial, cyanidin 3-O-glucoside has been shown to have neuroprotection against ischemic stroke in mice [52].

CONCLUSION AND FUTURE PERSPECTIVES

Pigments are essential in the human diet because they not only increase the overall intake of health-promoting compounds, but also diversify the daily diet in terms of colour, flavour, and chemical composition, which imparts distinct functional effects on the human body.

More research into the relationship between the health effects of antioxidant-rich anthocyanin and the mechanism of action responsible for the same is needed in the future. Furthermore, Post-harvest research and processing will make anthocyanin's various compounds less susceptible to degradation and easier to use in the design of functional foods and as a natural colorant in the food industry

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