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THE ROLE OF ANTHOCYANINS FROM RED CABBAGE: A REVIEW

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Abstract
Red cabbage is a nutrient-dense food rich in anthocyanins, powerful pigments with diverse health benefits and applications. This revssssiew aims to summarize the current knowledge on the nutritional, cosmeceutical, and environmental significance of anthocyanins from red cabbage. We discuss their chemical properties, biosynthesis, and bioavailability, as well as their role in preventing chronic diseases, such as cancer, diabetes, and cardiovascular disorders. Additionally, we explore their potential applications in cosmetics as natural colorants, UV protectants, and skin brightening agents. The extraction and safety aspects of anthocyanins from red cabbage are also examined. Our review highlights the importance of red cabbage as a valuable crop for both human health and sustainable agriculture, and underscores the need for further research to fully understand the benefits and applications of its anthocyanins.

Keywords: Red cabbage, Anthocyanins, Antioxidant, Anti-inflammatory, anti-cancer, Cosmetices, food industry, Natural colorants

1. Introduction

1.1 Background of Red cabbage

The Red cabbage, also known as purple cabbage, belongs to the purple-leaved varieties of ***Brassica oleracea Capitata*** Group [1]. It is highly nutritious, containing an abundance of minerals, vitamins, oligosaccharides, and various bioactive substances such as anthocyanins, flavonols, and glucosinolates [2]. Red cabbage offers numerous health benefits, including cancer and diabetes prevention, immune system enhancement, body detoxification, weight loss promotion, skin improvement, inflammation reduction, gut healing, and constipation relief. Its antioxidant properties aid in preventing chronic diseases and managing conditions like Alzheimer's and depression [3].

1.2 Taxonomical classification of Red cabbage [4].

Kingdom: Plantae
Class: Angiospermae
Order: Papaverales
Family: Cruciferae or Brassicaceae
Genus: Brassica

Species: Brassica oleracea

1.3 Geographical source

Originally native to the Mediterranean region, red cabbage has adapted well to various parts of India, especially in cooler climates. It is grown in areas like Himachal Pradesh, Uttarakhand, Jammu and Kashmir, the Nilgiri Hills in Tamil Nadu, and the Pune region of Maharashtra. These regions offer the temperate climate that red cabbage requires, and its cultivation has increased due to the growing demand in urban markets.[5]

1.4 Chemical constituents

1.4.1 Anthocyanins

Anthocyanins, a group of flavonoids, represent the largest collection of water-soluble pigments found in the plant kingdom [6-7]. These secondary plant metabolites are categorized as di- or tri-hydroxy B-ring-substituted flavonoids containing a flavylium cation. Recently, anthocyanins have attracted considerable attention due to their vivid colors and their health-enhancing and immunity-boosting properties [8]. A key aspect of anthocyanins is their antioxidant activity, which is crucial in preventing neuronal and cardiovascular diseases, cancer, diabetes, and other health conditions. Numerous studies have focused on the role of anthocyanins in cancer treatments, human nutrition, and their biological activities [9-10].

1.4.2. Glucosinolates:

Glucosinolates are sulfur-rich compounds that, when decomposed by the enzyme myrosinase, produce several bioactive substances such as isothiocyanates. These compounds have been researched for their potential anti-cancer effects [11].

1.4.3Vitamins and Minerals:

Red cabbage is abundant in vitamins, including vitamin C, vitamin K, and various B vitamins. Additionally, it is a good source of minerals such as potassium, manganese, and calcium [12].

1.4.4 Dietary Fiber:

Red cabbage is a valuable source of dietary fiber, which helps with digestion and promotes gut health [13].

1.4.5 Phenolic Compounds:

These compounds, such as flavonoids and phenolic acids, enhance the antioxidant properties of red cabbage and help reduce oxidative stress in the body [14].

1.5 Morphological Character [15].

Characteristic	Description
Plant Type	Biennial (typically grown as an annual for its edible head)
Head Shape	Compact, round to oval-shaped
Leaf Color	Reddish-purple, varying in intensity depending on soil pH (deep purple in acidic soils, reddish in neutral to alkaline soils)
Head Size	Typically 10 to 20 cm in diameter

2. Structure of Anthocyanin

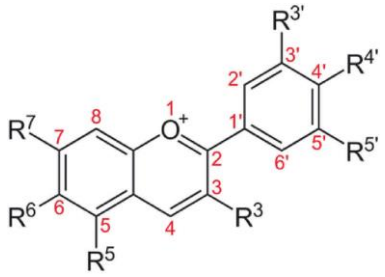

Figure 1: General chemical and with basic structure of Anthocyanin [16]

3. Types of Anthocyanins in Red Cabbage

3.1 Cyanidin-3-diglucoside-5-glucoside
3.2 Cyanidin-3-sophoroside-5-glucoside
3.3 Cyanidin-3-glucoside-5-(sinapoyl) glucoside
3.4 Cyanidin-3-glucoside
3.5 Cyanidin-3-sophoroside-5-(feruloyl) glucoside

4. Chemical Properties of Anthocyanins

4.1 Stability:

Red cabbage's anthocyanin stability is affected by a number of variables, including pH, temperature, and light. While they can break down in alkaline environments, anthocyanins are usually stable in acidic environments. Their color varies with pH as a result of several anthocyanin forms forming [22].

4.2 pH Indicator Properties

The color of red cabbage anthocyanins can vary from red in acidic (pH < 4) to purple and blue in alkaline (pH > 7) and neutral (pH < 4). They are helpful for detecting a wide variety of pH levels due to their large color spectrum [23].

4.3 Biosynthesis:

Red cabbage uses the flavonoid pathway to generate anthocyanins. Phenylalanine is converted during the biosynthesis process to cinnamic acid, anthocyanidins, and finally anthocyanins by glycosylation [24].

4.4 Glycosylation:

Glycosylation enhances the solubility and stability of anthocyanins. In red cabbage, anthocyanins are commonly found as glucosides or malonyl-glucosides, which affect their color and stability [23].

5. Bioavailability and Metabolism of Anthocyanins

5.1 Bioavailability:

5.1.1 Absorption:

Anthocyanins are absorbed in the gastrointestinal system. The main forms of anthocyanins found in red cabbage are glycosides, which are less accessible until they are broken down in the gastrointestinal tract. When compared to other sources, such as berries, red cabbage's anthocyanin bioavailability has been determined to be comparatively low. Studies show that the glycosylation pattern of the anthocyanin and the presence of other food components affect absorption [25].

5.2 Metabolism:

5.2.1 Transformation:

Anthocyanins are mostly processed in the liver after absorption. They change into a number of conjugated forms, such as sulfates and glucuronides. These changes improve their solubility and

make excretion easier. Research indicates that the anthocyanin-rich red cabbage's metabolic pathways produce a number of distinct metabolites from other anthocyanin-rich meals [26].

5.2.2 Excretion

Urine serves as the main excretion pathway for metabolites of anthocyanins. Depending on the particular anthocyanin type and how it is conjugated, the excretion rate and pattern can change. Red cabbage's anthocyanins are excreted in their conjugated forms after consumption, frequently as glucuronides and sulfates, according to research [27].

6. Role of Anthocyanins

6.1 Color Variation Based on pH [28]

The pH level of red cabbage has a significant impact on the color of its anthocyanins. **Acidic Conditions (pH < 7):** The anthocyanins in red cabbage turn red in an acidic environment. The flavylium cation form, which predominates at low pH values, is the cause of this. **Neutral (pH ~7):** Anthocyanins usually exhibit a purple color at this pH because they can exist in several Forms including, quinonoidal base. **Alkaline Conditions (pH > 7):** The anthocyanins change from blue to green in alkaline settings. The anionic quinonoidal base and the production of chalcone are the causes of this color shift.

6.2 Antioxidant Properties

Red cabbage's anthocyanins are known for having strong antioxidant properties. They combat free radicals and shield cells from oxidative damage, which is linked to aging and a number of chronic illnesses, including cancer and heart disease [29].

6.3. Health Benefits

6.3.1 Cardiovascular Health:

Red cabbage's anthocyanins have been demonstrated to improve cholesterol profiles and lower blood pressure, which supports cardiovascular health. They support the fight against inflammation and oxidative stress, two major contributors to cardiovascular illnesses [30].

6.3.2 Anti-Inflammatory Properties:

Red cabbage anthocyanins have strong anti-inflammatory effects, reducing pro-inflammatory cytokines like TNF-α and IL-6 and modulating the NF-κB signaling pathway. They also lower oxidative stress, which is linked to inflammation. Studies in humans and animals show that red cabbage anthocyanins reduce inflammatory markers, suggesting their potential as a dietary supplement for managing inflammation. [31-32].

6.3.3 Anti cancer property

Red cabbage anthocyanins have anti-cancer properties by preventing tumor growth, inducing cancer cell apoptosis, and reducing oxidative stress. These pigments can block cancer initiation, progression, and spread. Research shows they inhibit cancer cell growth by influencing apoptotic pathways and cell cycle regulators. Studies in both in vitro and in vivo models support these effects, suggesting that consuming anthocyanin-rich foods like red cabbage may aid in cancer prevention and treatment. [33-34].

6.3.4 Anti-diabetic

Red cabbage anthocyanins show potential anti-diabetic effects by improving insulin sensitivity, lowering blood glucose, and reducing diabetes-related oxidative stress. They help regulate glucose metabolism and enhance insulin activity, which can aid in diabetes management and prevention. Studies indicate that these anthocyanins lower fasting blood glucose, HbA1c levels, improve lipid profiles, and reduce inflammation in diabetic conditions. These findings suggest that including anthocyanin-rich foods like red cabbage may offer therapeutic benefits for managing diabetes. [35-36].

6.4 Environmental and Agricultural Significance

Red cabbage anthocyanins play an important role in environmental and agricultural contexts. Environmentally, they act as natural antioxidants, protecting plants from oxidative damage and UV radiation, improving resilience to stressors like drought and extreme temperatures. Agriculturally, these pigments enhance crop quality, boost nutritional value, and attract consumers with their vibrant color, while also supporting plant-pollinator interactions and potentially increasing yields. [37-38]

6.5 Uses of Anthocyanin in Cosmetics

6.5.1 UV Protection

Red cabbage anthocyanins can absorb ultraviolet (UV) light, making them promising natural UV protectants for cosmetic products. Acting as organic sunscreens, they help prevent skin damage like sunburn and aging. Their antioxidant and UV-absorbing properties protect skin from harmful UV rays and counteract free radicals. Studies suggest that anthocyanins are effective in preventing UV damage and recommend their use in sunscreens and skincare products. [39]

6.5.2 Natural Colorant

Red cabbage anthocyanins, which produce colors ranging from pink to deep purple depending on pH, are widely used as natural colorants in cosmetics. They serve as a preferable alternative to artificial dyes in products like lipsticks, blushes, and eyeshadows. Their pH-neutral stability makes them versatile for enhancing the aesthetic appeal and clean-label appearance of cosmetics. Additionally, their antioxidant properties improve both the skin benefits and the stability of these products. [40-41]

6.5.3 Skin brightning

Red cabbage anthocyanins show potential in skin lightening by inhibiting tyrosinase, a key enzyme in melanin production. By reducing melanin formation, they help achieve a more even skin tone and minimize hyperpigmentation and dark spots. This natural approach is particularly appealing in cosmetics aimed at creating a radiant complexion while reducing discoloration. Additionally, their antioxidant properties protect against oxidative stress, further supporting skin health and even tone. [42]

6.5.4 Antioxidant

Red cabbage anthocyanins, powerful antioxidants, are valued in cosmetics for protecting skin from oxidative stress caused by pollutants and UV rays. By neutralizing free radicals, which can lead to premature aging, inflammation, and skin cell damage, anthocyanins help maintain youthful skin. When used in creams, serums, and masks, they offer anti-aging benefits, improve skin elasticity, and enhance overall skin health, making them a natural and safe ingredient for a radiant complexion. [43]

7. Extraction of Anthocyanin

A contact time of 1 minute were maintained consistently across all extractions. Various solvents were employed, including water, acidified water, mixtures of ethanol with water and acidified water in different volume ratios, methanol, acidified methanol, acetone, and 70% aqueous acetone. The anthocyanin extract from each extraction was filtered through muslin cloth to remove coarse particles. Red cabbage leaves were cut into small pieces, and 25 g of these leaves were extracted using 50 mL of extraction media, ensuring thorough contact in a mixing unit. A solid–liquid ratio (leaves to extraction media) of 1:2[44].

8. Safety Aspects of Anthocyanins

8.1 General Safety and Toxicity

Low Toxicity: Anthocyanins are frequently ingested as part of a diet high in fruits and vegetables because of their well-known low toxicity. Regulatory bodies like the U.S. Food and Drug Administration (FDA) consider them to be generally regarded as safe (GRAS) [45].

Levels of Consumption: Anthocyanins found in foods like red cabbage can be consumed in moderation without posing a serious health risk. Studies in clinical settings have also demonstrated the safety of high dosages in supplement form [46].

8.2 Potential Allergic Reactions:

Rare Reactions: Allergic reactions to anthocyanins are rare but possible. Most people can consume anthocyanin-rich foods without adverse effects. Individuals with allergies to specific fruits or vegetables should be cautious and consult a healthcare provider if needed [47-48]

8.3 Interactions with Medications:

No Significant Interactions: At this time, anthocyanins and common drugs do not have any known negative interactions. To be sure there are no special contraindications; anyone taking particular medications should speak with their healthcare professional [49].

9. MARKETED FORMULATION.

SR NO.	PRODUCT NAME	COMPANY NAME	USE
1.	Red Cabbage Juice	Terravita Red Cabbage Juice - 450 Mg	Red cabbage juice alters the composition of increasing the abundance of good bacteria.
2.	Red cabbage pickle	Hand on tummy Sauekraut	Reduce inflammation in our bodies as well as protect our hearts.
3.	Red Cabbage Powder	Terraavitta Red cabbage powder	Cabbage powder is a dehydrated and ground form of cabbage often used as a food ingredients and supplement.
4.	Purple cabbage mask sheet Purple cabbage mask sheet	Shinny Purple Cabbage Mask Sheet	Is infused with antioxidants that help delay the occurrence of wrinkles, offer suppleness to the skin and strengthen skin cells. Achieve youthful glowing, plump and radiant skin
5.	Face Serum	SERUMKIND	• Reduces Redness & Soothes Irritation: Alleviates irritated skin and reinforces skin barrier
6.	Toning and Invigorating Lotion with Vitamin C - Red Cabbag	AWELEBIZ	*allow better circulation and therefore a better skin glow.*
7.	Nutraceutical bilberry extrct anthocyanins	BIOTREX	Supplement Provides Proper Vision And Nutrition For The Eyes.
8.	Natural Food Coloring Red Cabbage Red Pigment Powder	Nutrihub	usad as natural food colorants

10. Conclusion

The anthocyanins present in red cabbage have been shown to possess a wide range of health benefits, including antioxidant, anti-inflammatory, anti-cancer, and anti-diabetic properties. These pigments have also been found to have potential applications in the cosmetics industry as natural colorants, UV protectants, and skin brightening agents. The extraction and safety aspects of anthocyanins from red cabbage have also been discussed, highlighting their low toxicity and potential for use in various marketed formulations. Furthermore, the environmental and agricultural significance of anthocyanins in red cabbage cannot be overstated, as they play a vital role in protecting the plant from oxidative damage and enhancing its nutritional value. Overall, the anthocyanins present in red cabbage make it a valuable crop for both human health and sustainable agriculture. Future research should continue to explore the potential applications and benefits of these remarkable pigments."

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