

# Comprehensive Analysis of Red Cabbage: Nutritional Components and Health Implications

Monoswini Banerjee

**Abstract:** Red cabbage is a nutritious vegetable also known as purple cabbage or red-kraut. You may be surprised to know that red cabbage is often used as a pH indicator, as it changes colour depending on the pH balance of the ingredient. It is consumed as salads, cooked into delicious curries, and even used in sauerkraut, a popular accompaniment to sandwiches and burgers, with the added advantage of being a vegan probiotic dish. This article offers a detailed exploration of red cabbage, a vegetable renowned for its diverse nutritional benefits. Red cabbage, known scientifically as *Brassica oleracea* var. *capitata* f. *rubra*, is a vibrant and versatile vegetable, rich in essential nutrients and phytochemicals. This review delves into the comprehensive nutritional profile of red cabbage, highlighting its high content of vitamins, minerals, dietary fibers, and potent antioxidants such as anthocyanins and sulforaphane. The health implications of these components are examined, underscoring the vegetables potential in preventing oxidative stress, aging, and chronic diseases like cancer, diabetes, and cardiovascular disorders. The article also discusses the role of red cabbage in boosting immune function and promoting overall health. Through a synthesis of current scientific research, this review aims to enhance the understanding of red cabbages nutritional value and its contribution to a balanced diet, thereby underlining its significance in the field of nutritional science and public health.

**Keywords:** Red Cabbage, Nutritional Value, Health Benefits, Antioxidant Properties, Dietary Implications

## 1. Introduction

**Red Cabbage**, also referred to as *Brassica oleracea* L. var. *capitata*, is a cruciferous Brassica vegetable hailing from the Cruciferae plant family or Mustard family. It is a fall/winter vegetable that has crunchy; mildly peppery-sweet leaves. Red cabbage, also recognized as purple cabbage, is differentiated by its texture, color, and taste. This vegetable is generally grown in most of the European countries, mainly France and Italy, as well as Africa and mainly in Minor Asia. In India, cabbage including red cabbage is cultivated in an area of 388 thousand ha producing 8755 thousand MT. In Andhra Pradesh, the crops are cultivated in 5.43 thousand ha with a production of 81.45 thousand tonnes. India is the third largest cabbage producer in the world. It is mainly grown in the states like Uttar Pradesh, Orissa, Bihar, Assam, West Bengal, Maharashtra and Karnataka. [1]

## Nutritional Composition of Red Cabbage (per 100gm)

**Table 1:** Nutritional composition of red cabbage

Constituents	Quantity
Water	90 gm
Energy	31 kcal
Protein	2.0 gm
Carbohydrates	6.9 mg
Fat	0.2 mg
Sodium	26 mg
Calcium	42 mg
Iron	0.8 mg
Vitamin A	40 I. U
Thiamine	0.09 mg
Riboflavin	0.06 mg
Ascorbic Acid	61 mg

## Polyphenolic Composition of Red Cabbage

**Table 2:** Polyphenolic composition of red cabbage

Anthocyanin (non - acylated)	Cyanidin-3-diglucoside-5-glucoside, cyanidin-3-(sinapoyl) (sinapoyl)-diglucoside-5-glucoside, cyanidin-3-(p-coumaroyl)-diglucoside-5-glucoside
Phytochemicals	Alkaloids, glycosides, flavonoids, saponin, tannin, steroids, terpenes and phytosterols.
Flavonoids	Kaempferol, quercetin, and apigenin
Polyphenolic compounds	Syringic, p-coumaric, ferulic acid, myricetin acid

Anthocyanins, betalains, carotenoids and chlorophylls are the most important natural plant derived pigments. Because anthocyanins are abundant in nature, has high health promoting advantages, such as; anti-inflammatory, anti-diabetic & anti-obesity properties, hepatoprotective & nephroprotective properties, high compatibility to biological systems & toxicity; they can be considered as the best natural colorants to be used in the food industry. Red cabbage anthocyanins help in brain function, concentration and the prevention of nerve damage than white cabbage, it could help to protect against Alzheimer's disease. Red cabbage anthocyanins presents a number of anti-cancer compounds, like lupeol, sinigrin, and changing the pH through one or more anthocyanin configurations. Sulforaphane, which is known to stimulate enzyme activity

and inhibit the growth of tumors, which can lead to cancer. [4]

Anthocyanins are considered ideal alternates for synthetic colorants due to their abundance in nature, high compatibility to biological systems, non-toxicity, and providing health-promoting advantages. The extraction process is the most crucial step for obtaining anthocyanin-rich extract with the least possible loss in physicochemical properties. The solvents commonly used to extract anthocyanins are: methanol, ethanol, water, acetone, or mixtures thereof. Acid solutions are often added to these solvents to help stabilize the flavylium cation, which is stable in highly acidic conditions (pH ~ 3). In recent years many extraction techniques have been studied by researchers

Volume 12 Issue 11, November 2023

[www.ijsr.net](http://www.ijsr.net)

Licensed Under Creative Commons Attribution CC BY

to extract antioxidant rich anthocyanins from red cabbage, followed by their application in food matrix. Some examples are: Researchers have utilized anthocyanins extract from red cabbage in development of intelligent food-packaging featuring Time-Temperature Indicators. They used a system that monitors a food's condition in real-time, indicating the overall influence of temperature on food product quality. Since change of colour of anthocyanins is dependant on temperature and pH, it indicated food quality changes through the detection of changes in the pH of packaged food products when subjected to improper storage temperatures. In various studies red cabbage anthocyanin-rich extract was microencapsulated to produce a natural food colorant. [5]

Food colour gives consumers an almost immediate impression about the freshness, flavour and quality of a product. Due to safety issues of synthetic colorants, enhanced awareness of consumers, and commercial availability of natural colorants, there is an increased demand for the utilization of plant derived extracts. Due to the high stability and chemical properties of acylated Anthocyanins, they can be considered excellent candidates for a range of natural food colors. [6]

### Aims & Objectives

The purpose of this article is to comprehensively analyze the nutritional components of red cabbage and elucidate their health implications. By reviewing various scientific studies

and nutritional data, the article aims to shed light on how red cabbage contributes to various aspects of human health, including its potential role in preventing chronic diseases, enhancing immune function, and contributing to overall dietary wellness. This exploration serves to inform both the scientific community and the general public about the nutritional significance and health benefits of incorporating red cabbage into a regular diet.

### Significance of the article:

This article holds significant value in the field of nutritional science and dietetics. It comprehensively explores the myriad health benefits of red cabbage, a commonly overlooked vegetable. By delving into its rich nutritional profile, which includes vital vitamins, minerals, and antioxidants, the article sheds light on how red cabbage can contribute to various aspects of health, such as boosting immunity, aiding in diabetes management, and promoting heart and bone health. This investigation is particularly relevant in today's health-conscious society, where understanding the dietary implications of underutilized vegetables can lead to more informed and healthier food choices.

Moreover, the article's insights into the preventive and therapeutic potential of red cabbage could pave the way for further scientific research and dietary recommendations.

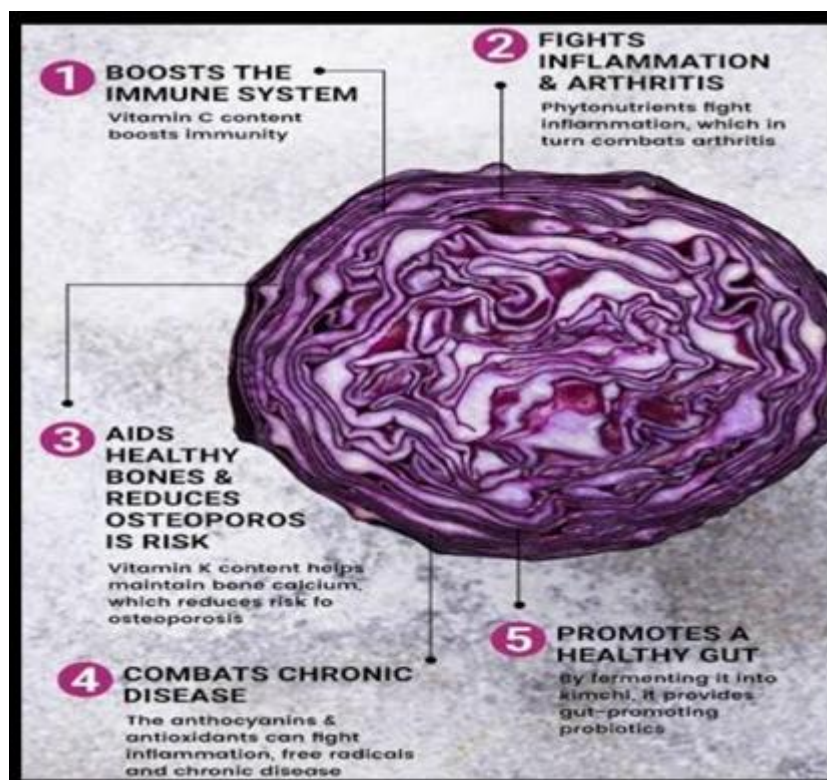


Figure 1: Red cabbage and its properties

## 2. Review of Literature

Nazila Ghareaghajlou, Somayeh Hallaj-Nezhadi, ahraGhasempour discussed stability, extraction, biological activities & applications of red cabbage anthocyanins in food systems and found that extracted anthocyanins are susceptible to degradation in exposure to high pH,

temperature, enzymes, light, oxygen, and ascorbic acid during processing and storage, among which pH value is the most influencing factor, leading to poor bioavailability and reduced stability. The application of natural deep eutectic solvents (NADES) as an alternate method to conventional solvents is recommended for future studies. [7]

Volume 12 Issue 11, November 2023

[www.ijsr.net](http://www.ijsr.net)

Licensed Under Creative Commons Attribution CC BY

**SHAMPY RANI, ARASHDEEP SINGH AND PRADEEP KUMAR** discussed about evaluation of nutritional facts and health benefits of red cabbage and found that the red cabbage is the best source of nutrients and anti-cancerous properties. Red cabbage having vitamin C content which prevent from scurvy. [8]

**Deepranjan Sarkar and Amativa Rakshithave** have shown Red Cabbage as Potential Functional Food & found that secondary plant metabolites like glucosinolates (GSs) present in red cabbage are known for the health promoting properties. These natural chemicals breakdown into compounds like indole-3-carbinol, which has anti-cancer property. Flavonoids of the crop have good therapeutic potential in inflammation and pain. [9]

**Reza Abedi-Firoozjah, ShimaYousefi, MahshidHeydari, FaezehSeyedfatehi, ShimaJafarzadeh, RezaMohammadi, MiladRouhi and FarhadGaravand** discussed about Application of Red Cabbage Anthocyanins as pH-Sensitive pigments in Smart Food Packaging and Sensors & found that smart bio polymeric films containing red cabbage anthocyanins (RCA) have a bright future in the packaging industry to prolong the shelf life of food products, monitor the food freshness and quality, and improve product and customer safety. [10]

**Draghici G. A., Lupu Maria Alexandra, BorozanAurica - Breica, Nica D., Alda S., Alda Liana, Gogoasa I., Gergen I., BordeanDespina-Maria** discussed red cabbage as functional food & found that the anthocyanins have a wide range of therapeutic advantages without adverse effects; including cardiovascular protective properties. Glucosinolates are digested into isothiocyanates that reduce inflammation and fight bacteria. At the same time the glucosinolates present in red cabbage reduce various types of cancer. [11]

**Eman G. E. Helal, Rasha A. A. El Sayed, Sara Ebrahiem** discussed Effect of Egyptian Red Cabbage on Some Physiological Parameters Hyperthyroidimic Rats and found that Red cabbage has a thyroid function suppressing action. Increased plasma T3 and T4 levels and decreased in TSH levels were observed in the hyperthyroid animals induced by thyroxin. Red cabbage extract effect on the lipid profile pattern in hyperthyroidism animals induced by thyroxin, was decrease in triglyceride and increase the levels of cholesterol to normal pattern as in healthy group due to anthocyanin content. [1]

**LianghuaXie, HongmingSua, ChongdeSunb, Xiaodong Zhenga, Wei Chena** discussed Recent advances in understanding the anti-obesity activity of anthocyanins and their biosynthesis in microorganisms & found thatanthocyanins extracts and purified anthocyanins from different sources to have anti-obesity effects, but whether anthocyanins play the decisive role in the extracts. Anthocyanins have a large potential to be developed as part of combined therapy for obesity, whose massive production can be achieved through biosynthesis in microorganisms. Anthocyanins have a large potential to be developed as part of combined therapy for obesity, whose massive production can be achieved through biosynthesis in microorganisms.

[13]

**Anna Podsedek, IwonaMajewska, and AlicjaKucharska** discussed Inhibitory potential of red cabbage against digestive enzymes linked to obesity and type 2 diabetes & found that obese rats treated daily with red cabbage juice (0.3 g/kg) for 4 weeks showed a reduction in their body weight, BMI and adiposity index. Daily oral ingestion (1g/kg) of ethanol red cabbage extract by diabetic rats for 60 days lowered blood glucose levels and restored body weight loss. The observed effects could be related to the influence of the red cabbage components on the absorption of dietary lipids and sugars via the inhibition of digestive enzymes. [14]

**Jayanta M Sankhari, Menaka C Thounaojam, Ravirajsinh N Jadeja, Ranjitsinh V Devkar\* and A V Ramachandran** discussed

Anthocyanin-rich Red Cabbage Extract (ARCE) attenuates cardiac and hepatic oxidative stress in rats fed an atherogenic (ATH) diet & found hypolipidaemic/hypocholesterolaemicpotentiality of red cabbage extract in rats fed an ATH diet. Also, the hepatoprotective and cardio protective potential of ARCE extract against ATH-induced oxidative stress and tissue injury & indicates a protective role of red cabbage against tissue injury associated with hypercholesterolemia. [15]

**Shaum Shiyam, Herlina, Lita Rizkika**

**SARI** discussed Nephroprotective effects of anthocyanin pigments extract formed cabbage against Gentamicin-Captopril-Induced nephrotoxicity in rats & found that Extract anthocyanin pigments of red cabbage were shown to repair the kidney function of rats induced with gentamycin-captopril. The extract of anthocyanin could accelerate the repairment of renal functions, in a dose of 100 mg/kg BW. [16]

**Ying Li, Shu-Hao Ku, Shen-Ming Chen, M. Ajmal Ali, Fahad M. A. AlHemaid** discussed about Photo electrochemistry for Red Cabbage Extract asNatural Dye to Develop a Dye-Sensitized Solar Cells and found that The red cabbage extract provided the photosensitive for dye. Absorption spectrum also shows that dye from red cabbage extract is found to be highly absorbingat high concentrations. [17]

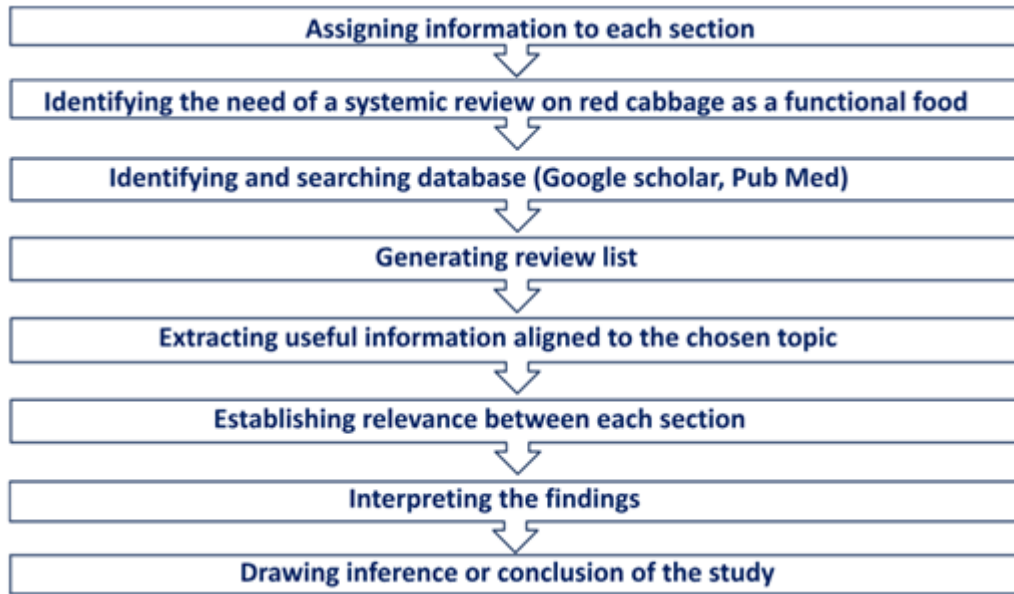
**Karunrat Sakulnarmrat, DenchaiWongsrikaew b, Izabela Konczak c** discussed Microencapsulation of red cabbage anthocyanin-rich extract by drum drying technique and found encapsulation of red cabbage anthocyanin-rich extract with combinations of maltodextrin and arabic gum using drum drying produced a high encapsulation efficiency and satisfactory physical and chemical properties of the encapsulated extract. After encapsulation increased antioxidant capacity and extended shelf life of the product. [18]

**Dayang Norulfairuz AbangZaidela, Nur Shakira Sahata, Yanti MaslinaMohdJusoha, Ida Idayu Muhamad** and discussed Encapsulation of Anthocyanin from Red Cabbage for Stabilization of Water-in-Oil Emulsion and found encapsulated red cabbage. The encapsulated anthocyanins

that have higher moisture content and solubility will produce margarine with higher sedimentation stability which means low stability. [19]

### 3. Materials & Method

For the review work the following review protocol was followed-



### 4. Discussion

Discussion on Red Cabbage as a functional Food & it's mechanism of action;

#### Antioxidant Activity

- Antioxidant activity of red cabbage anthocyanins and all acylatedcyanidin glycosides has higher antioxidant capacity than non-acylated ones.

- Researchers have found anthocyanin-rich extract of red cabbage reduces intracellular oxidative stress on human hepatocellular carcinoma (HepG2) cells and thereby improved cell apoptosis and viability.
- Anthocyanins, as dietary antioxidant has protective activity against oxidative damage of blood plasma protein and lipid; also it helps in reducing the damage induced by lipopolysaccharide. [20]



**Figure 2:** Health benefits of red cabbage of anthocyanin

#### Hepatoprotective Activity

- Anthocyanins from red cabbage & its aqueous extract has a hepatoprotective effect.
- Red cabbage and its aqueous extract has hepatoprotective effects on mild degrees of fibrotic, and necrotic changes

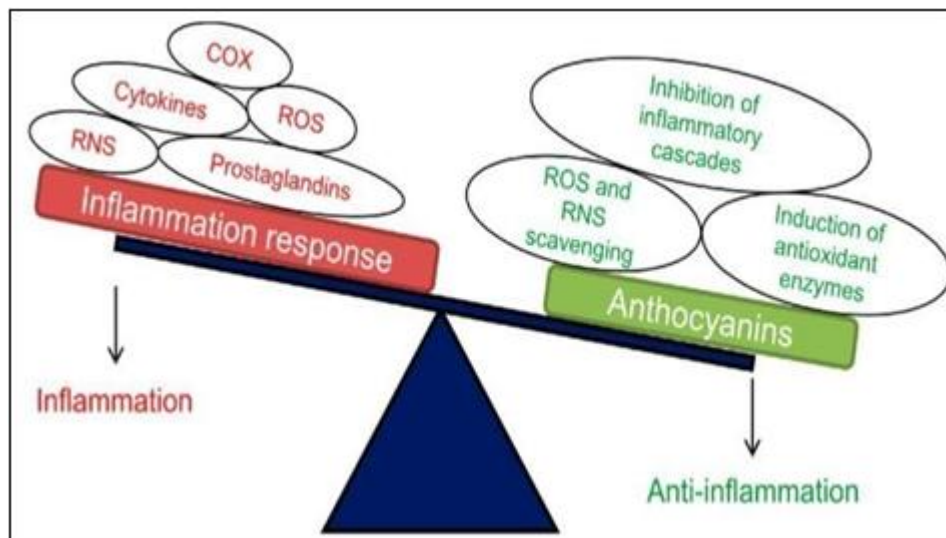
which observed in hepatic parenchyma of hyper-cholesterolaemic diet-induced oxidative stressed rabbits.

- With high doses it can ameliorate the necrosis, inflammation and fibrosis of liver tissue in rats fed with a cholesterol-rich diet. [21]

Volume 12 Issue 11, November 2023

[www.ijsr.net](http://www.ijsr.net)

Licensed Under Creative Commons Attribution CC BY



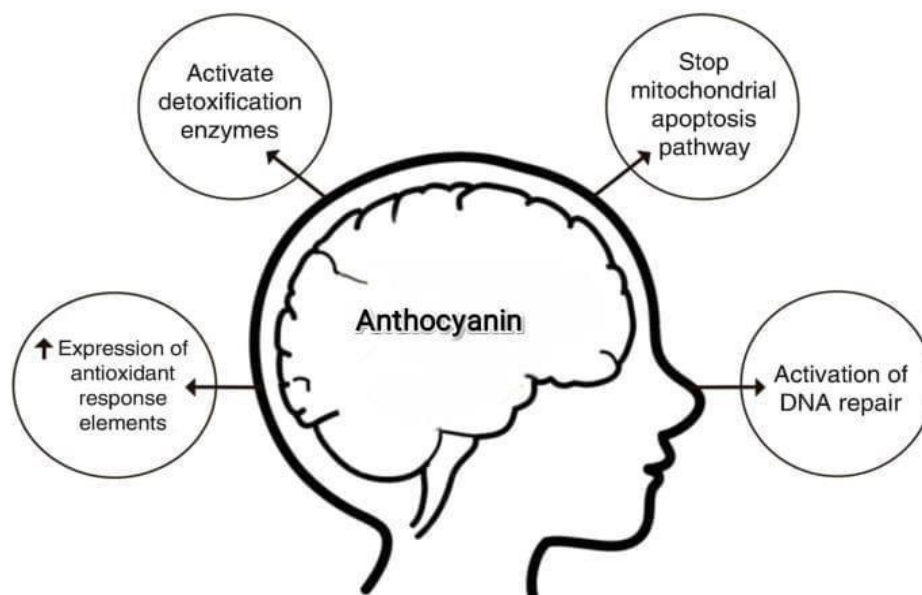
**Figure 3:** Schematic representation of the main positive effects exerted by anthocyanins as anti-inflammatory compounds

### Nephroprotective Activity

- Alcoholic extract of red cabbage contains high content of antioxidants, protects renal tissues against the nephrotoxicity induced by gentamicin at a dose of 80 mg/kg BW.
- Oral administration of red cabbage extract decreased serum levels of urea nitrogen, uric acid, and creatinine, resulting in ameliorated functions of kidneys.
- Prolonged administration of red cabbage extract ameliorated nephropathy by reducing renal function markers including urea and uric acid, which increased in rats fed a cholesterol-rich diet.
- The effect of repairment on renal function was due to the active compound content of anthocyanins in red cabbage. Anthocyanin has antioxidant activity, potentially in pressing the occurrence of free radicals from gentamicin that damage kidney cells. Anthocyanin, as an antioxidant, can prevent supercoiled DNA strand cuts caused by reactive oxidative species. [22]

### Neuroprotective Activity

- The neuroinflammation plays a crucial role in the development of many brain disorders, anthocyanins can significantly reduce the chronic inflammatory state in such pathological conditions. Red cabbage anthocyanins shows neuroprotective role in the central nervous system (CNS).
- The main neuroprotective mechanisms is the inhibition of neuroinflammation and oxidative stress. Red cabbage anthocyanins are the major contributors of neuronal cell protection against amyloid  $\beta$  protein induced neurotoxicity.
- Anthocyanins have emerged as potential dietary neuroprotective agents for brain diseases.
- Phenolic compounds can be suitable therapeutic agents for CNS disorders, targeting the neuroinflammatory pathways underlying brain's innate immune system. [23]



**Figure 4:** Neuroprotective function of red cabbage

### Anti Diabetic Activity

- Red cabbage anthocyanin-rich extract has an inhibitory

effect on  $\alpha$ -glucosidase and  $\alpha$ -amylase, more effective against  $\alpha$ -glucosidase than  $\alpha$ -amylase.

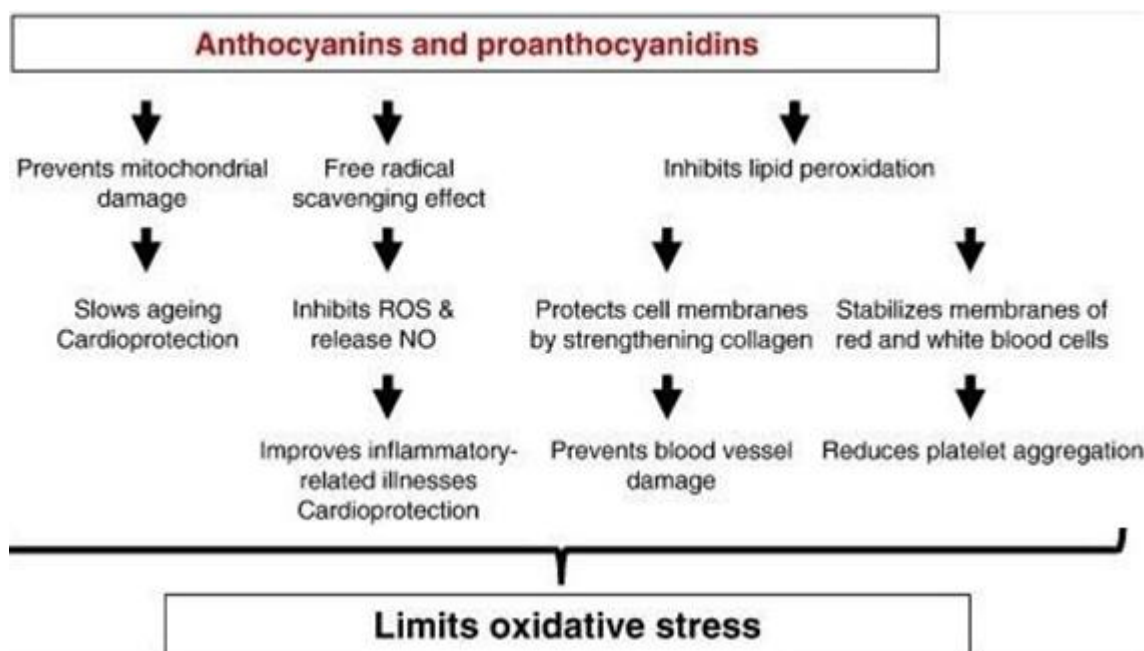
- Deacylated anthocyanins possess much lower inhibitory activity than acylated ones.
- Anthocyanin supplementation exerts beneficial metabolic effects in subjects with type 2 diabetes by improving dyslipidaemia, enhancing antioxidant capacity, and preventing insulin resistance compared to the placebo group. [24]

**Cardioprotective Activity and Hypocholesterolemic**

**Activity:**

- Red cabbage extract elevates cardiopathy by restoring cardiac marker enzymes.
- Anthocyanin-rich red cabbage extract mediates cardio and reduces the chance of myocardial infarction.
- Anthocyanin-rich red cabbage extract provides a cardioprotective effect through the prevention of changes in cardiac enzymatic and non-enzymatic antioxidants.

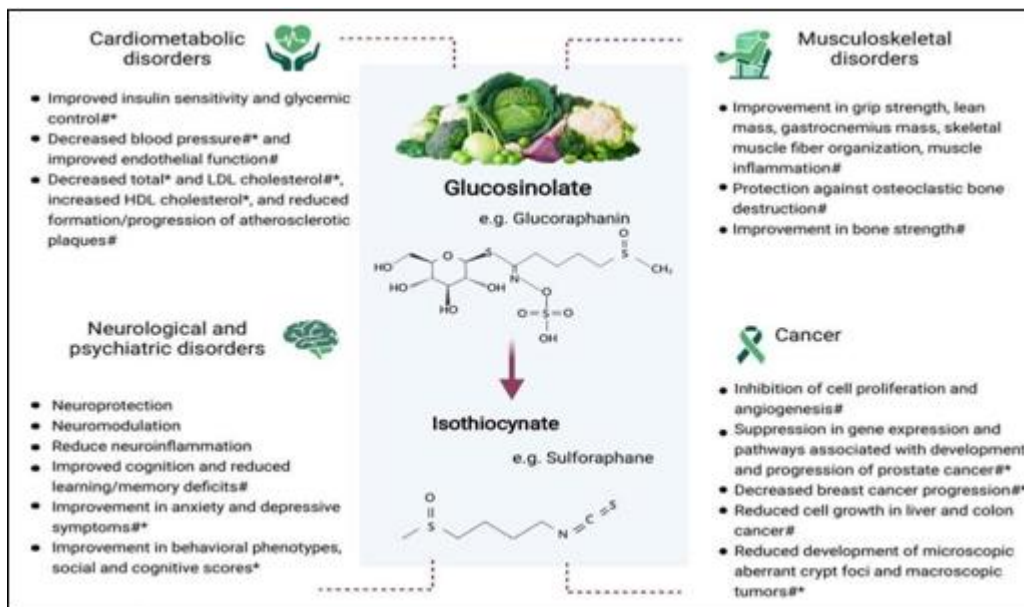
- [25]
- Anthocyanins from red cabbage display potent hypocholesterolaemic activity through taking part in the metabolism of cholesterol.
- Researchers have found that red cabbage extract (anthocyanin) exhibited hypocholesterolaemic activity through the inhibition of cholesterol biosynthesis and its subsequent catabolism into bile acids.
- Red cabbage extract (anthocyanin) decreased serum levels of lipid, total cholesterol, low-density lipoprotein (LDL), and triglyceride and increased high-density lipoprotein (HDL) levels.
- Red cabbage extract effect on the lipid profile pattern in hyperthyroidism animals induced by thyroxin, was decrease in triglyceride and increase the levels of cholesterol to normal pattern as in healthy group due to anthocyanin content. [26]



**Figure 5:** Functions of anthocyanin and proanthocyanin

**Anti Obesity Activity:**

- Anthocyanin has an inhibitory action on pancreatic lipase. Pancreatic lipase splits triacylglycerols into monoacylglycerols and free fatty acids, the inhibition of this enzyme leads to weight loss by reducing fat absorption.
- It is found that treatment of obese rats with red cabbage juice (300 mg/kg BW) for 4 weeks decreased their body weight, BMI, and adiposity index.
- Red cabbage powder or extract alone or in combination with chromium is beneficial for obesity caused by a high fat diet. [27]



**Figure 6:** Potential benefits of glucosinolate consumption on cardiometabolic, neurological and psychiatric, and musculoskeletal conditions, and cancer.

### Cancer Protective Activity:

- Red cabbage may help protect against certain types cancers. Experts believe this may be because it contains sulforaphane and anthocyanins — two compounds researched for their cancer-fighting properties.
- High intakes of cruciferous vegetables, including cabbage, to an 18% lower risk of colon cancer. Diets rich in cruciferous vegetables have also been linked to a lower risk of breast cancer.
- Sulforaphane found in purple cabbage and other cruciferous vegetables may help kill cancer cells or prevent them from growing and spreading.
- The mechanisms of the anticancer action of glucosinolates degradation products are based on the ability to modulate the expression of enzymes of phase I and II detoxification, the prevention of DNA damage in the cell as well as cell cycle regulation and apoptosis. [28]

### Recent Advances in Research with Antioxidants from Red Cabbage

The extraction process is the most crucial step for obtaining anthocyanin-rich extract with the least possible loss in

physicochemical properties. The solvents commonly used to extract anthocyanins are: methanol, ethanol, water, acetone, or mixtures thereof. Acid solutions are often added to these solvents to help stabilize the flavylium cation, which is stable in highly acidic conditions (pH ~ 3). Anthocyanins are best alternates for synthetic colorants due to their abundance in nature, high compatibility to biological systems, non-toxicity, and providing health-promoting advantages. In recent years many extraction techniques have been studied by researchers to extract antioxidant rich anthocyanins from red cabbage, followed by their application in food matrix. Some examples are:

Researchers have utilized anthocyanins extract from red cabbage in development of intelligent food-packaging featuring Time-Temperature Indicators. They used a system that monitors a food's condition in real-time, indicating the overall influence of temperature on food product quality. Since change of colour of anthocyanins is dependant on temperature and pH, it indicated food quality changes through the detection of changes in the pH of packaged food products when subjected to improper storage temperatures. [29]



**Figure 7:** The colours of the red cabbage anthocyanin in different pH values

Red cabbage extracts are also experimentally used with other polymers such as chitosan in active packaging, the presence of anthocyanins contributes to the conservation as well as antioxidant property of food.

In various studies red cabbage anthocyanin-rich extract was microencapsulated to produce a natural food colorant. Four different forms of anthocyanins are in equilibrium with each other in aqueous solutions: Flavylium cation (red), Quinonoidal (violet to blue), Colorless forms (carbinolpseudobase and chalcone). Thus, variation in solution color is obtained cabbage. In recent years, a lot of epidemiological studies have confirmed that anthocyanin displays a wide range of therapeutic activities, including having significant effects on blood vessels, platelets and lipoproteins which are able to reduce the risk of cardiovascular diseases (CVDs) [30]



Figure 8: uses of red cabbage extract

## 5. Summary & Conclusion

In conclusion, this comprehensive analysis of red cabbage reveals its significant role in promoting health and wellness. Rich in vital nutrients, antioxidants, and phytochemicals, red cabbage stands out as a superfood with a myriad of health benefits. From its potent anti-aging properties and immune system support to its efficacy in managing diabetes and enhancing heart and bone health, red cabbage is more than just a colorful addition to our diets. Its diverse applications in culinary contexts, coupled with its low caloric value, make it an ideal dietary choice for individuals seeking a balanced and healthy lifestyle. This review highlights the importance of incorporating red cabbage into daily nutrition and paves the way for further research to explore its full potential in preventive healthcare and dietary planning. The insights gained from this study underscore the need to recognize and utilize the nutritional treasures found in our natural food sources, like red cabbage, in our quest for better health and well-being.

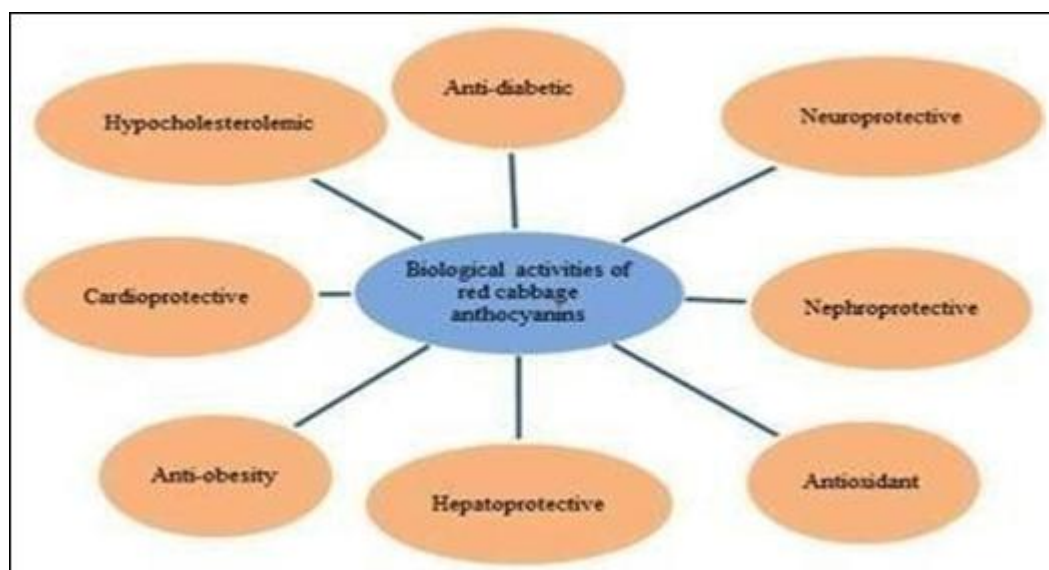


Figure 9: Biological activities of red cabbage anthocyanins



## References

- [1] Sarkar, D., Sankar, A., Devika, O. S., Singh, S., Parihar, M., Rakshit, A., . . . & Datta, R. (2021). Optimizing nutrient use efficiency, productivity, energetics, and economics of red cabbage following mineral fertilization and biopriming with compatible rhizosphere microbes. *Scientific reports*, 11 (1), 1-14.
- [2] RANI, S., SINGH, A., & KUMAR, P. (2021). Evaluation of nutritional facts and health benefits of red cabbage (*Brassica oleracea* var. *capitata* f. *rubra*). *The Journal of Rural and Agricultural Research*, 21, 37-39.
- [3] Heimler, D., Vignolini, P., Dini, M. G., Vincieri, F. F., & Romani, A. (2006). Antiradical activity and polyphenol composition of local Brassicaceae edible varieties. *Food chemistry*, 99 (3), 464-469.
- [4] Sarkar, D., & Rakshit, A. (2017). Red cabbage as potential functional food in the present perspective. *International Journal of Bioresource Science*, 4 (1), 7-8.
- [5] Zaidel, D. N. A., Sahat, N. S., Jusoh, Y. M. M., & Muhamad, I. I. (2014). Encapsulation of anthocyanin from roselle and red cabbage for stabilization of water-in-oil emulsion. *Agriculture and Agricultural Science Procedia*, 2, 82-89.
- [6] Dyrby, M., Westergaard, N., & Stapelfeldt, H. (2001). Light and heat sensitivity of red cabbage extract in soft drink model systems. *Food chemistry*, 72 (4), 431-437.
- [7] Ghareaghajlou, N., Hallaj-Nezhadi, S., & Ghasempour, Z. (2021). Red cabbage anthocyanins: Stability, extraction, biological activities and applications in food systems. *Food Chemistry*, 365, 130482.
- [8] RANI, S., SINGH, A., & KUMAR, P. (2021). Evaluation of nutritional facts and health benefits of red cabbage (*Brassica oleracea* var. *capitata* f. *rubra*). *The Journal of Rural and Agricultural Research*, 21, 37-39.
- [9] Sarkar, D., & Rakshit, A. (2017). Red cabbage as potential functional food in the present perspective. *International Journal of Bio resource Science*, 4 (1), 7-8.
- [10] Abedi-Firoozjah, R., Yousefi, S., Heydari, M., Seyed fatehi, F., Jafarzadeh, S., Mohammadi, R., ... & Garavand, F. (2022). Application of red cabbage anthocyanins as pH-sensitive pigments in smart food packaging and sensors. *Polymers*, 14 (8), 1629.
- [11] Draghici, G. A., Alexandra, L. M., Aurica-Breica, B., Nica, D., Alda, S., Liana, A., ... & Despina-Maria, B. (2013). Red cabbage, millennium's functional food. *Journal of Horticulture, Forestry, and Biotechnology*, 17 (4), 52-55.
- [12] Helal, E., El Sayed, R. A., & Ebrahiem, S. (2017). Effect of Egyptian Red Cabbage on Some Physiological Parameters in Hyperthyroidimic Rats. *The Egyptian Journal of Hospital Medicine*, 69 (3), 2137-2142.
- [13] Xie, L., Su, H., Sun, C., Zheng, X., & Chen, W. (2018). Recent advances in understanding the anti-obesity activity of anthocyanins and their biosynthesis in microorganisms. *Trends in Food Science & Technology*, 72, 13-24.
- [14] Podśędek, A., Majewska, I., & Kucharska, A. Z. (2017). Inhibitory potential of red cabbage against digestive enzymes linked to obesity and type 2 diabetes. *Journal of agricultural and food chemistry*, 65 (33), 7192-7199.
- [15] Sankhari, J. M., Thounaojam, M. C., Jadeja, R. N., Devkar, R. V., & Ramachandran, A. V. (2012). Anthocyanin rich red cabbage (*Brassica oleracea* L. ) extract attenuates cardiac and hepatic oxidative stress in rats fed an atherogenic diet. *Journal of the Science of Food and Agriculture*, 92 (8), 1688-1693.
- [16] Shiyan, S. H. A. U. M., Herlina, H., & Sari, L. R. (2018). Nephroprotective of anthocyanin pigments extract from red cabbage (*Brassica oleracea* L. Var. *Capitata* f. *rubra*) against gentamicin-captopril-induced nephrotoxicity in rats. *Asian J Pharm Clin Res*, 11 (4), 432-436.
- [17] Li, Y., Ku, S. H., Chen, S. M., Ali, M. A., & AlHemaid, F. M. (2013). Photo electrochemistry for red cabbage extract as natural dye to develop adye-sensitized solar cells. *Int. J. Electrochem. Sci*, 8 (1), 1237-1245.
- [18] Sakulnarmrat, K., Wongsrikaew, D., & Konczak, I. (2021). Microencapsulation of red cabbage anthocyanin-rich extract by drum drying technique. *LWT*, 137, 110473.
- [19] Zaidel, D. N. A., Sahat, N. S., Jusoh, Y. M. M., & Muhamad, I. I. (2014). Encapsulation of anthocyanin from roselle and red cabbage for stabilization of water-in-oil emulsion. *Agriculture and Agricultural Science Procedia*, 2, 82-89.
- [20] Wiczowski, W., Szawara-Nowak, D., & Topolska, J. (2013). Red cabbage anthocyanins: Profile, isolation, identification, and antioxidant activity. *Food research international*, 51 (1), 303-309.
- [21] Sankhari, J. M., Thounaojam, M. C., Jadeja, R. N., Devkar, R. V., & Ramachandran, A. V. (2012). Anthocyanin rich red cabbage (*Brassica oleracea* L. ) extract attenuates cardiac and hepatic oxidative stress in rats fed an atherogenic diet. *Journal of the Science of Food and Agriculture*, 92 (8), 1688-1693.
- [22] Shiyan, S. H. A. U. M., Herlina, H., & Sari, L. R. (2018). Nephroprotective of anthocyanin pigments extract from red cabbage (*Brassica oleracea* L. Var. *Capitata* f. *rubra*) against gentamicin-captopril-induced nephrotoxicity in rats. *Asian J Pharm Clin Res*, 11 (4), 432-436.
- [23] Beretta, H. V., Torres-Palazzolo, C., Ramírez, D. A., & Camargo, A. B. (2021). Brassica Vegetables: Rich Sources of Neuroprotective Compounds. In *Psychiatry and Neuroscience Update* (pp.327-341). Springer, Cham.
- [24] Buko, V., Zavodnik, I., Kanuka, O., Belonovskaya, E., Naruta, E., Lukivskaya, O., ... & Sybirna, N. (2018). Antidiabetic effects and erythrocyte stabilization by red cabbage extract in streptozotocin-treated rats. *Food & function*, 9 (3), 1850-1863.
- [25] Mohamed, D., Mabrok, H., Abdelgayed, S., & Elbakry, H. (2021). Cardioprotective potency of anthocyanin-rich extract of red cabbage against isoproterenol-induced myocardial infarction in experimental animals. *Journal of Applied Pharmaceutical Science*, 11 (08), 022-030.
- [26] Helal, E., El Sayed, R. A., & Ebrahiem, S. (2017).

Effect of Egyptian Red Cabbage on Some Physiological Parameters in Hyperthyroidimic Rats. The Egyptian Journal of Hospital Medicine, 69 (3), 2137-2142.

- [27] Podsedek, A., Majewska, I., & Kucharska, A. Z. (2017). Inhibitory potential of red cabbage against digestive enzymes linked to obesity and type 2 diabetes. *Journal of agricultural and food chemistry*, 65 (33), 7192-7199.
- [28] Tajalli, F., Saeedi, M., & Malekabadi, A. V. (2020). Anticancer and antioxidant effects of red cabbage on three cancerous cell lines and comparison with a normal cell line (HFF-3). *Journal of Genes and Cells*, 6 (1), 12-20.
- [29] Bernstein, A., & Noreña, C. P. Z. (2015). Encapsulation of red cabbage (*Brassica oleracea* L. var. *capitata* L. f. *rubra*) anthocyanins by spray drying using different encapsulating agents. *Brazilian Archives of Biology and Technology*, 58, 944-952.
- [30] Machado, M. H., da Rosa Almeida, A., Maciel, M. V. D. O. B., Vitorino, V. B., Bazzo, G. C., da Rosa, C. G., ... & Barreto, P. L. M. (2022). Microencapsulation by spray drying of red cabbage anthocyanin-rich extract for the production of a natural food colorant. *Biocatalysis and Agricultural Biotechnology*, 39, 1022