Mahendra Gunjal, Sharmistha Naik*, Sachin Ekatpure, Sujoy Saha and Kaushik Banerjee

# Grapes: A Natural Pathway to Human Nutrition and Health

**Grape is a low-calorie fruit that contains about 80-85% water, and has a low amount of fat present. It provides energy to the extent of 53-94 kcal/100 g. Grape contains carbohydrates, dietary fiber, protein, vitamins such as C, K, B-complex, β-carotene, and E, and important minerals including potassium, calcium, phosphorus, and magnesium. There are a lot of antioxidants in the skin and seeds of the fruit, especially polyphenols, e.g. resveratrol, anthocyanins, quercetin, and catechins. The antioxidants make the fruit even better for health. These compounds are linked to benefits including cardiovascular protection and blood vessel health, lowering inflammation, improving metabolism, protecting the brain, and boosting the immune system. Colored grape varieties usually have more antioxidant activities. Promoting functional foods made from grapes by utilizing the processing industry by-products helps in increasing farmers' income, and supports farming systems that focus on health-oriented food strategies. It also helps ensure nutritional security, increase farmers income, and supports sustainable farming systems that focus on health-oriented food strategies.**

**Keywords:** Anthocyanins; Functional foods; Grape; Nutraceuticals; Polyphenols; Resveratrol

IN recent years, changes in eating habits and greater health awareness have lead consumers to prefer functional and nutrient-rich foods. In this context, grapes have become more popular because of their high polyphenol content and health benefits. The rising rates of lifestyle-related conditions, like heart disease, type 2 diabetes, and obesity, have increased the demand for foods that can help prevent or treat these issues. Grapes are good sources of carbohydrates including glucose and fructose, moderate amounts of dietary fiber and important micronutrients. It is well-known for having a lot of polyphenols, such as flavan-3-ols, anthocyanins, flavonols, stilbenes (resveratrol), and phenolic acids. These compounds have strong antioxidant effects and help control oxidative stress, keep blood vessels healthy, control fat metabolism, and lower inflammation.

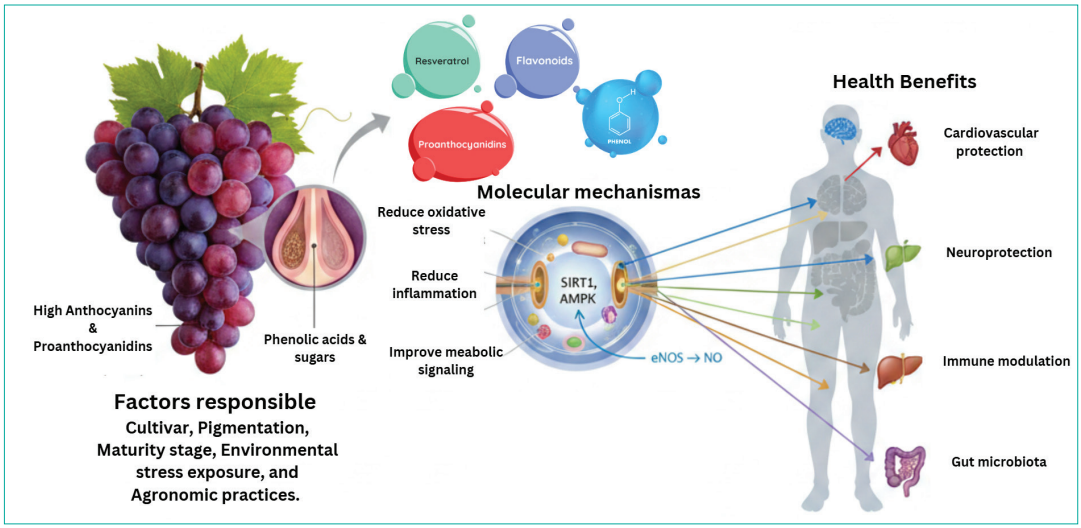
Consumption of grapes play a significant role in regulating biochemical processes, such as balancing oxidative stress, improving insulin sensitivity, supporting blood vessel function, and modulating gut bacteria. Grapes can be processed into a diverse range of products such as juice, wine, vinegar, concentrates, and grape-seed extracts, thereby contributing to nutritional security. In addition, the efficient utilization of by-products like pomace and seeds for extracting proanthocyanidins, dietary fiber, and seed oil not only minimizes waste but also enhances the availability of health-promoting compounds, supporting sustainable and nutrition-sensitive food systems.

## Nutritional composition and health significance of grapes

Grape contains nutrients as well as other bioactive substances, and composition of these in berries depends on genetic differences, environmental factors, ripeness of the fruit, and farming practices. However, the basic nutritional profile remains the same across different grape products. The composition of the nutrients in the fruit indicates that it is not only a source of energy but also a functional food that can influence many physiological systems in the body (Figure 1). Fresh grape contains 80 to 85% water, and it is essential for hydrating the body and controlling temperature in the body. Fresh grapes provide approximately 224–395 kJ (53–94 kcal) per 100 grams. Carbohydrates constitute the major component of fresh grapes, ranging from 12 to 20 g/100 g. These carbohydrates are primarily present as simple sugars, which are rapidly absorbed in the intestine through glucose transporters. However, their impact on blood sugar levels is moderated by the dietary fiber content, which ranges from 1.15 to 1.64 g/100 g.

Although grapes contain relatively low protein levels (0.6–1.4 g/100 g), their amino acids contribute to various physiological functions in the body. The lipid content in the fruit pulp is also minimal (0.26–0.46 g/100 g); however, grape seeds are rich in essential fatty acids, including saturated, monounsaturated, and polyunsaturated forms. Among these, linoleic acid is a prominent polyunsaturated

fatty acid in grape seed oil. It plays important roles in eicosanoid synthesis, maintenance of membrane fluidity, and lipid signaling. Owing to these functional properties, grape seed lipids have attracted considerable interest for the development of health-promoting products.



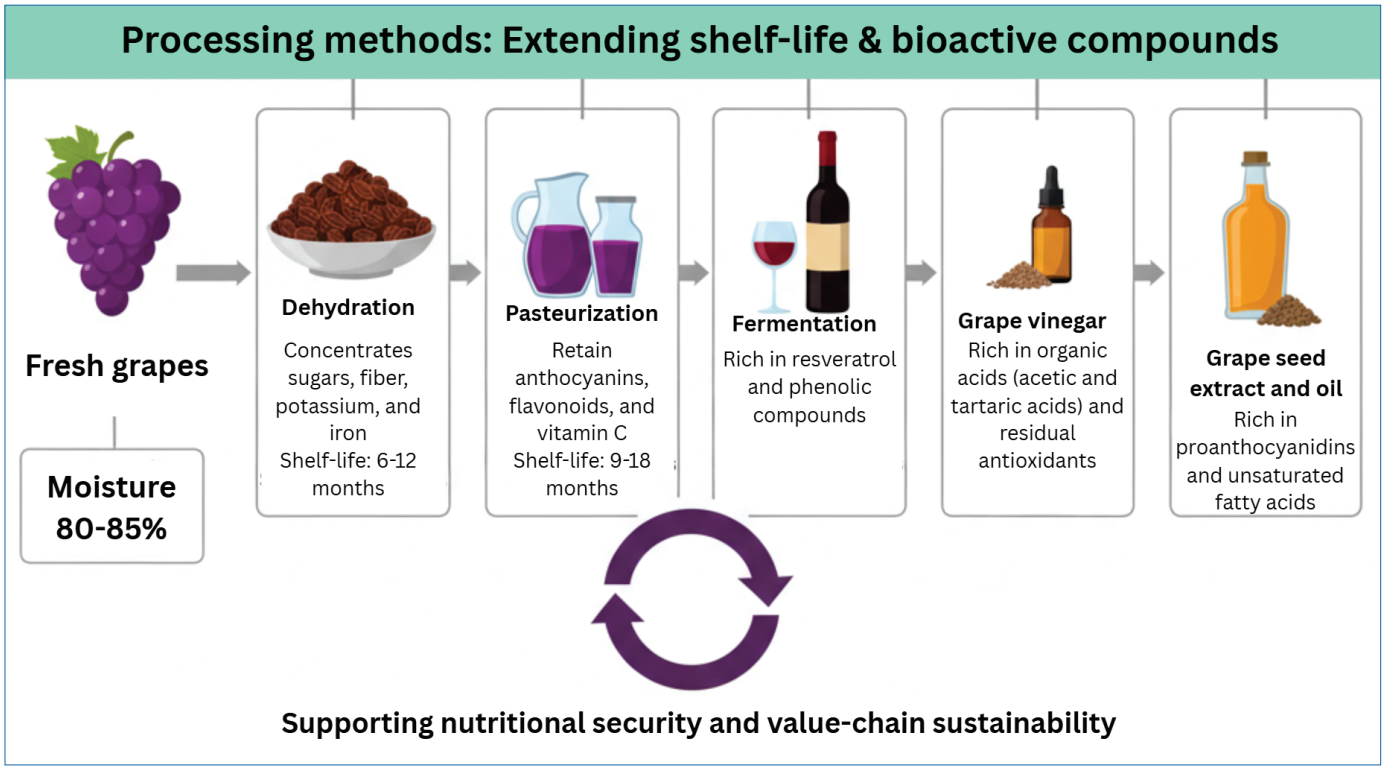

*The bioactive compounds in grapes and their health benefits*

The characteristic feature of grapes, nevertheless, is the varied polyphenolic structure. Polyphenols are secondary metabolites that have an aromatic ring structure with hydroxyl groups that can donate electrons in redox reactions. These molecules are found to be localized in the skin and seeds, along with minor amounts in the pulp. Their biosynthesis is known to be induced by environmental stress factors such as exposure to UV light and pathogens, as part of the protective response in the defense mechanisms of the plant. Of the polyphenols in grapes, resveratrol, a stilbene derivative, has been the focus of much scientific investigations. Resveratrol has been found to have significant antioxidant properties by quenching reactive oxygen species (ROS) and inducing the activity of endogenous antioxidant enzymes such as catalase and glutathione peroxidase. More importantly, it modulates cellular signaling cascades through sirtuin-1 (SIRT1) and AMP-activated protein kinase (AMPK) activation, which are important in the regulation of mitochondrial biogenesis, lipid metabolism, and insulin sensitivity. These polyphenols are important in cardioprotective, antidiabetic, neuroprotective, and anti-proliferative activities. It also enhances endothelial nitric oxide synthase (eNOS) activity, thereby increasing nitric oxide production and vasodilation. Moreover, it shows inhibitory properties against low-density lipoprotein (LDL) oxidation and platelet aggregation.

Flavonoids make up the major class of grape polyphenols and consist of flavonols, flavan-3-ols, and anthocyanins. Quercetin has anti-inflammatory properties and acts on the cyclooxygenase and lipoxygenase pathways and on NF-kB, which controls cytokine (small proteins that act as vital chemical messengers regulating immunity, inflammation, and hematopoiesis) production from immune cells. Catechins and epicatechins increase endothelial reactivity and decrease lipid peroxidation by increasing the bioavailability of nitric oxide. Anthocyanins, responsible for the red and purple color of grapes, have strong free radical scavenging activities and modulate signaling for apoptosis, angiogenesis, and inflammatory modulation. Epidemiological studies have shown anthocyanins to have cardiovascular and cognitive benefits by increasing cerebral perfusion.

*Manjri Naveen*

Among the bioactive compounds, grape seed has been reported to have high levels of proanthocyanidins, which are basically condensed tannins with high antioxidant activities. This oligomeric flavan-3-ol has been reported to have antioxidant properties,




Different processing methods for improving shelf-life and bioactive compounds

and potential to strengthen connective tissue and capillary integrity by inhibiting matrix metalloproteinases. The importance of grapes to the body's physiological functions can be attributed to the synergistic effect of these nutrients and bioactive compounds, rather than the bioactive compounds acting in isolation. These bioactive compounds have been reported to modulate transcription factors, nuclear receptors, and epigenetic mechanisms, which regulate genes responsible for oxidative stress response, inflammation, and metabolism.

In the gastrointestinal tract, grape polyphenols undergo bioconversion by microorganisms, which leads to the production of smaller bioavailable phenolic compounds. This interaction favors the growth of *Lactobacillus* and *Bifidobacterium*, while inhibiting pathogenic microorganisms. This increase in microbial diversity enhances nutrient uptake, intestinal integrity, and reduces systemic inflammation. Short-chain fatty acids, which are produced during metabolism of dietary fiber components of grape, also play a crucial role in managing the regulatory process of metabolic and immune homeostasis. The systemic contribution of grapes, as per the system biology approach, can be viewed as an integrated effect on different physiological domains. Cardiovascular protection is provided by potassium-mediated blood pressure control and polyphenol-mediated improvement of endothelial function. Regulation of metabolism is provided by a moderated glycaemic response, improvement of insulin sensitivity, and reduction of oxidative stress. The neuroprotective effect of grapes is provided by reduced inflammation of neurons and improvement of blood flow to the brain. The immune system is protected by vitamin C-mediated improvement of leukocyte function, while the stabilizing effect on connective tissue and skin is provided by proanthocyanidin-mediated preservation of collagen integrity.

Grapes provide a multidimensional health benefits that includes hydration, electrolyte balance, micronutrient supplementation, organic acid functionality, and phytochemical bioactivity, making it a nutritionally dense fruit with significant scientific validity for maintaining health, preventing diseases, and providing a basis for the use of grapes as a functional food for health-promoting diets.

**Value-added products and nutritional enhancement**

Grape is a seasonal fruit, and processing is essential to ensure its availability throughout the year while retaining all nutritional and functional properties. Value addition makes them more important for nutrition by making sure they are always available in different forms. Such processing not only extends shelf-life of the products but also helps concentrate nutrients and bioactive compounds, thereby enhancing their functional and commercial value. Furthermore, the development of grape-derived products allows for better utilization of the fruit, increased economic returns, and preservation of key phytochemicals with potential health benefits (Fig. 2).

Raisins are processed by dehydrating grapes, which reduces their moisture content to 15-18%. The process increases the energy value by concentrating natural sugars, fiber, potassium, and iron contents. Although drying might lose some potency of bioactive substances, the polyphenols usually retain their bioactivity. Grape juice, a ready-to-serve beverage, retains its bioactive components such as anthocyanins, flavonoids, and vitamin C during processing, provided the temperature is appropriately regulated during the process. Pasteurization of grape

*Sharad Seedless*

juice makes it safe for consumption while minimizing the loss of polyphenols. Apart from these, micronutrients such as iron and vitamin C can be added to enhance these benefits. Wine, especially red wine, is prepared by a process of fermentation, and through extended skin contact, the extraction of resveratrol and diverse phenolic compounds increases. Moderate wine consumption has been found to have beneficial effects on blood vessel function and oxidative stress levels. Vinegar made from grapes has organic acids such as acetic acid and tartaric acid, as well as the antioxidants that remain intact after processing. These have beneficial effects on digestion and blood sugar levels. Grape seed extract and oil are rich in proanthocyanidins and unsaturated fatty acids. Processing increases the products' shelf life and provides a market for these products, which has beneficial effects on nutrition and value chains

## SUMMARY

Grapes have been recognized for their nutritional value, containing carbohydrates, essential vitamins and minerals, and various antioxidants including polyphenolic compounds, which play a crucial role in maintaining heart, and regulating metabolic, immune, and cell health. The bioactive components of grapes, including flavonoids and proanthocyanidins, have been reported to prevent diseases and reduce oxidative stress. The processed products derived from grapes, including raisins, juice, wine, vinegar, and grape seed extract, increase the shelf-life and enhance the nutritional value. Grapes, therefore, have been recognized for their nutritional and health benefits, along with their contribution to economic sustainability.

*For further correspondence, contact:*
Dr. Sharmistha Naik, Scientist, ICAR-National Research Centre for Grapes, Pune 412 307, Maharashtra, India. Email: naiksharmistha@gmail.com