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An Overview of Berries' Bioactive Components

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Abstract: Berries are among the most nutrient-rich and bioactive-dense fruits, widely consumed for their palatability and extensive health benefits. This review explores the diverse classes of bioactive compounds found in berries—primarily phenolic acids, flavonoids, tannins, stilbenes, lignans, and carotenoids—as well as essential micronutrients like vitamin C. These constituents contribute to a range of biological activities, including antioxidant, anti-inflammatory, antimicrobial, neuroprotective, anti-diabetic, cardioprotective, and anticancer effects. Phenolic compounds, especially anthocyanins and flavonols, are emphasized for their role in reducing oxidative stress and modulating various metabolic pathways associated with chronic diseases. The health-promoting properties of berry consumption are supported by both in vitro and in vivo studies, with growing evidence pointing to their role in preventing conditions such as cardiovascular diseases, neurodegenerative disorders, obesity, and certain cancers. Additionally, the interaction of berry polyphenols with the gut microbiota has emerged as a key factor in enhancing their bioavailability and systemic effects. While berries show immense promise as natural therapeutic agents, further clinical research is necessary to determine optimal dosages, mechanisms of action, and long-term impacts on human health. This review underscores the importance of integrating berries into daily dietary practices and highlights their potential as functional foods and natural nutraceuticals.

Keywords: Berries, Bioactive compounds, Polyphenols, Antioxidant, Anthocyanins, Chronic disease prevention, Functional foods, Vitamin C

I. INTRODUCTION

Fruits are high in nutritive elements such as vitamins, minerals, carbohydrates, and essential oils; therefore their consumption has risen in recent years. Fruit juices include bioactive chemicals that have anticancer, antimutagenic, antibacterial, anti-inflammatory, and anti-neurodegenerative activities. Berries are the most commonly consumed fruit since they are delicious and give several health advantages. Berries from the Rosaceae (strawberry, raspberry, and blackberry), Ericaceae (blueberry), and Vitaceae (black and green grapes) families are high in BAC (bioactive compounds)(Skrovankova et al., 2015).

In Europe, America, and Australia, berries are widely farmed and consumed. (Yang et al., 2020).They can be eaten raw, frozen, or made into wines, juices, and jams(Siracusa et al., 2019). The most often consumed berries are blackberry (Rubus spp.), blueberry (Vacciniumcorymbosum), red raspberry (Rubusidaeus), and strawberry (Fragaria spp.)(Luíset al.,2018) .Berryfruits have recently piqued the interest of academics all over the world due to its high content and diverse spectrum of health-promoting phenolic chemicals(Stoner et al., 2015).Phenolic molecules stand out among the antioxidant components present in fruits and vegetables. They are found in fruits, vegetables, leaves, nuts, seeds, and flowers and occur naturally in plants as secondary metabolites. They are an important part of the human diet and have been added to several medicine compositions on purpose(WU et al., 2004).

The most powerful antioxidants in food are phenolic chemicals, which provide a wide range of health benefits(Cox et al., 2005). Plant products antioxidant action is mostly related to phenolic chemicals(Chua et al., 2008). As a result, the therapeutic efficacy of a diet rich in fruits with high levels of natural antioxidants is important(Sokol-Letowska et al., 2007), and their ability to neutralize free radicals (Stratil et al., 2007).Flavonoids, tannins, and phenolic acids are abundant in blueberries, as they are in most berries. Many studies have shown that the presence of such bioactive substances, particularly anthocyanins, in the blueberry offers a number of health benefits(Heinonen et al., 1998, Smith et al., 2000; Seeram, 2008).

Biogenetically, phenolic compounds are generated through two metabolic pathways: the shikimic acid pathway, which produces phenylpropanoids primarily, and the acetic acid process, which produces the simple phenol as the principal result. The majority of plants produce phenolic chemicals.Thephenylpropanoidpathway is involved. When both paths are combined, the result is Flavonoids, the most abundant category of phenolic chemicals in nature, are formed(Sánchez-Moreno, 2002; Hollman, 2001).

Phenolic molecules are necessary for cellular metabolism and function.They play a role in a variety of functions in plants, including sensory characteristics (colour, scent, taste, and astringency), structure, pollination, pest and predator resistance, seed germinative processes after harvesting, growth, development, and reproduction (Tomás-Barberán,2001;Espín, 2001).

The antioxidant activity of food phenolic compounds is of nutritional relevance because it has been linked to the potentiation of human health-promoting benefits through disease prevention (Lampe, 1999).Additionally, due to their pharmacological properties, these chemicals may be employed for medicinal purposes in some situations (Percival, 1998). Because of its toxicity, many phenolic compounds with low molecular weight, such as thymol, are utilised as antiseptics in medicine (Harborne, 1980).

II. NUTRIENT COMPOSITION

Berries have a high concentration of important vitamins, dietary fibre, and minerals. Berries have high sugar content, yet are low in calories and fats. Vitamin C, dietary fibre, potassium, and folates are all found in raspberries, blackberries, and blackcurrants. Vitamin C values in these berries range from 9.7 to 60 mg/100 g, with blueberries having the lowest and strawberries having the highest. Berries including strawberries, blackberries, and raspberries are high in folate (vitamin B9) and potassium. Blackberries and blueberries are high in vitamin K, whereas cranberries are strong in vitamin E. Beta-carotene, lutein, and zeaxanthin are abundant in blackberries. Among these berries, blackcurrants have the highest quantities of calcium, iron, phosphorus, and potassium. (Haytowitz et al., 2018).

Table 1. Nutrient composition (value per 100 g fresh weight)
(Haytowitz, D.B. and Pehrsson, P.R., 2018)

Nutrient	Strawberry	Blackberry	Raspberry	Cranberry	Blueberry	Blackcurrant
Water (g)	90.95	88.15	85.75	87.32	84.21	83.95
Energy (kcal)	32	43	52	46	57	56
Protein (g)	0.67	1.39	1.2	0.46	0.74	1.4
Total lipid (fat) (g)	0.3	0.49	0.65	0.13	0.33	0.2
Carbohydrate (g)	7.68	9.61	11.94	11.97	14.49	13.8
Fiber, total dietary (g)	2	5.3	6.5	3.6	2.4	4.3
Sugars, total (g)	4.89	4.88	4.42	4.27	9.96	7.37
Calcium, Ca (mg)	16	29	25	8	6	33
Iron, Fe (mg)	0.41	0.62	0.69	0.23	0.28	1
Magnesium, Mg (mg)	13	20	22	6	6	13
Phosphorus, P (mg)	24	22	29	11	12	44
Potassium, K (mg)	153	162	151	80	77	275
Sodium, Na (mg)	1	1	1	2	1	1
Zinc, Zn (mg)	0.14	0.53	0.42	0.09	0.16	0.23
Copper, Cu (mg)	0.048	0.165	0.09	0.056	0.057	0.107
Selenium, Se (µg)	0.4	0.4	0.2	0.1	0.1	0.6
Vitamin C (mg)	58.8	21	26.2	14	9.7	41
Thiamin (mg)	0.024	0.02	0.032	0.012	0.037	0.04
Riboflavin (mg)	0.022	0.026	0.038	0.02	0.041	0.05
Niacin (mg)	0.386	0.646	0.598	0.101	0.418	0.1
Vitamin B6 (mg)	0.047	0.03	0.055	0.057	0.052	0.07
Folate, total (µg)	24	25	21	1	6	8
Vitamin A (µg)	1	11	2	3	3	2
Carotene, beta (µg)	7	128	12	38	32	25
Carotene, alpha (µg)	0	0	16	0	0	0
Lutein + zeaxanthin (µg)	26	118	136	91	80	47
Vitamin E (mg)	0.29	1.17	0.87	1.32	0.57	0.1
Vitamin K (phylloquinone) (µg)	2.2	19.8	7.8	5	19.3	11

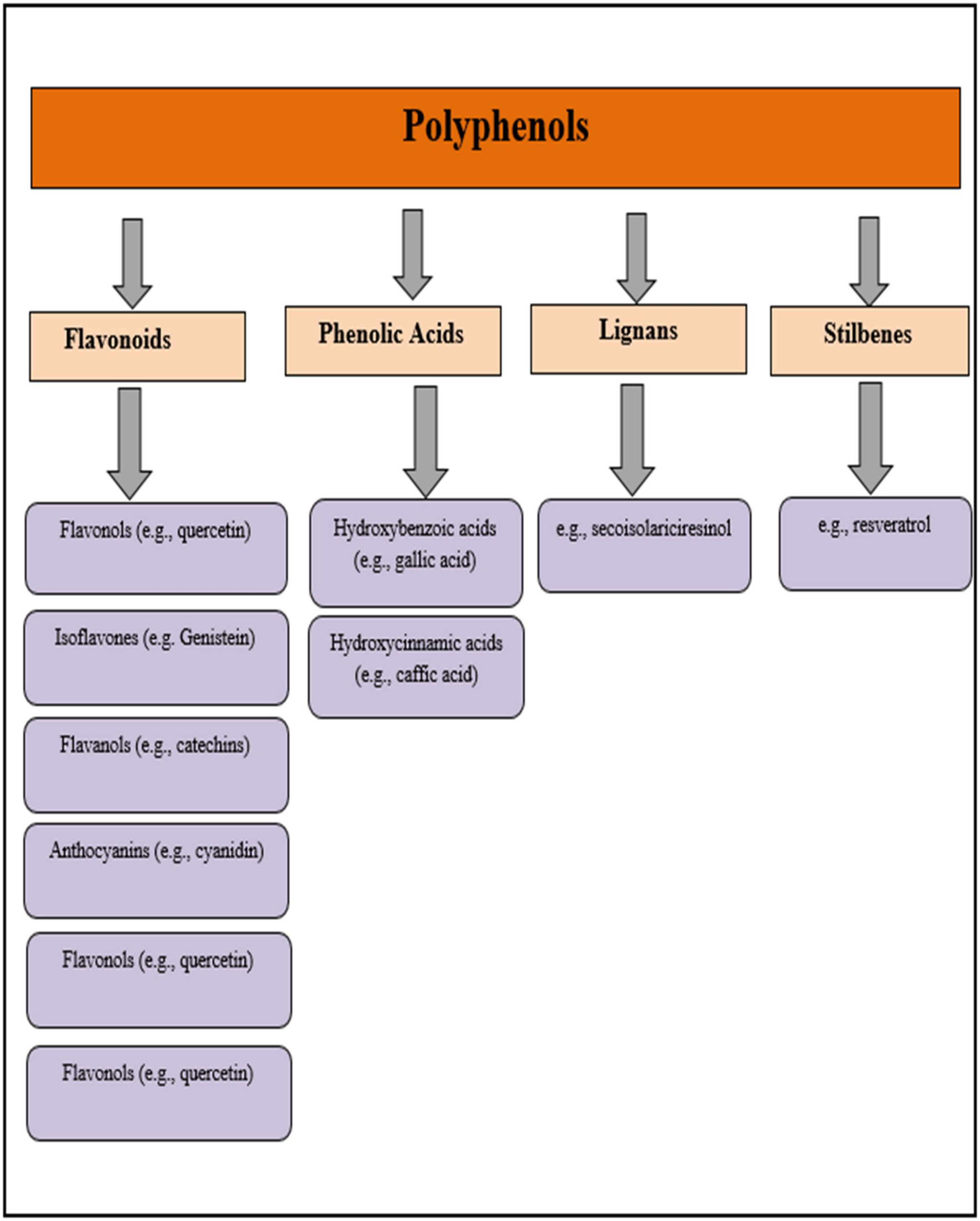

Figure 1: Polyphenols Classes

Fig.1 Classes of Polyphenols

A. Classes of Polyphenols

Berry fruits have a high concentration of phenolic compounds and a diverse range of them. They are represented by phenolic acids (benzoic and cinnamic acid derivatives), tannins, stilbenes, and flavonoids such as anthocyanins, flavonols, and flavanols, which differ in structure and molecular weight (catechins)(Shahidi F et al., 2004,Puupponen-Pimiäet al., 2005, Cieślik et al., 2006).Phenolics are a broad group of secondary metabolites that consist of one or more aromatic rings with varying degrees of hydroxylation, methoxylation, and glycosylation, and contribute to the colour, astringency, and bitterness of fruits (Crozier et al.,2006).

B. Phenolic Acids

Benzoic acids and cinnamic acids, as well as their derivatives, are two types of phenolic acids. The simplest phenolic acids found in nature are benzoic acids, which have seven carbon atoms (C6-C1). Cinnamic acids have nine carbon atoms (C6-C3), while the ones found in vegetables most usually have seven. The presence of a benzenic ring, a carboxylic group, and one or more hydroxyl and/or methoxyl groups in the molecule distinguishes these compounds. Phenolic acids may account for one-third of all phenolic chemicals consumed by humans(Yanget al., 2001).

Although other characteristics contribute to the antioxidant activity of phenolic acids and their esters, this activity is usually determined by the number of hydroxyl groups found in the molecule of these substances and their esters, especially hydroxybenzoic acid, hydroxycinnamic acid, caffeic acid, and chlorogenic acid, and although other characteristics contribute to the antioxidant activity of phenolic acids and their esters, this activity is usually determined by the number of hydroxyl groups found in the molecule of these substances and their Cinnamic acids that have been hydroxylated are more efficient than benzoic acids in general.(Sánchez-Moreno,2002).

Cinnamic acids are rarely found in plants in their natural state. They're usually in the form of esters, with a cyclic alcohol-acid like quinic acid to make isochlorogenic acid, neochlorogenic acid, criptochlorogenic acid, and chlorogenic acid, as well as a caffeoyl ester, which is the most important combination(Bravo,1998).

Phenolic acids may account for one-third of all phenolic chemicals consumed by humans.(Yang et al., 2001).

C. Flavonoids

Variations in the hydroxylation pattern and oxidation state of the core pyran ring give birth to a diverse spectrum of chemicals, including flavanols, anthocyanidins, anthocyanins, isoflavones, flavones, flavonols, flavanones, and flavanonols. The existence or absence of a double bond between C2 and C3, as well as the production of a carbonyl group by C4, determine the hydroxylation pattern and oxidation state. Flavones, flavonols, flavanones, and flavanonols are the most abundant subgroup of polyphenols, accounting for the bulk of flavonoid compounds (D'Archivio, M et al.2007). Tannins can be separated into two types: hydrolysable tannins and condensed tannins, which are found in complexes with alkaloids, polysaccharides, and proteins (Crozier, A. et al ,2006).

Table 2: Major flavonoid subclasses

Subclass	C2–C3 Bond group	C3 Hydroxyl group	C4 Carbonyl group	Ring B Position	Glycosylation	Notable Examples	Natural Sources	Refrences
Flavones	Present	Absent	Present	C2	Common	Apigenin, Luteolin	Parsley, celery, chamomile	(deLacerda de Oliveira, L et al.2014),(Tsao , 2010).
Flavonols	Present	Present	Present	C2	Common	Quercetin, Kaempferol	Onions, kale, apples	

Flavanones	Absent	Absent	Present	C2	Common	Hesperidin, Naringenin	Citrus fruits (oranges, lemons)	(Reis-Giada, 2014).(de Lacerda de Oliveira et al. 2014).
Flavanonols	Absent	Present	Present	C2	Less Common	Dihydrokaempferol	Tea, grapes, certain fruits	
Anthocyanidins	Present	Variable	Present	C2	Absent	Cyanidin, Delphinidin	Red cabbage, berries	(Reis-Giada, 2014). (Crozier, A. et al ,2006), (Ozcan, T et al ,2014),(He and Giusti, 2009; Lee et al., 2015)
Anthocyanins	Present	Variable	Present	C2	Present	Pelargonidin-3-glucoside	Berries, red grapes, purple corn	
Isoflavones	Present	Absent	Present	C3	Common	Genistein, Daidzein	Soybeans, legumes	(Lattanzio, V. 2013), (Reis-Giada, M.d.L.et al , 2014).

D. Stilbenes
Stilbenes are a class of polyphenolic compounds characterized by a two-carbon methylene bridge connecting two phenyl rings. Although present in relatively small quantities in the human diet, they play a crucial role as antifungal phytoalexins—compounds synthesized by plants in response to stress or pathogen attack. Among stilbenes, resveratrol (3,4′,5-trihydroxystilbene) is the most extensively studied due to its notable antioxidant, anti-inflammatory, and potential anti-cancer properties. While grapes and red wine are prominent sources of resveratrol, certain berries, such as blueberries, cranberries, and mulberries, have also been reported to contain trace amounts of this compound. These berry-derived stilbenes contribute to the overall polyphenolic profile and may enhance the antimicrobial and cardioprotective effects associated with regular berry consumption (Crozier et al. 2005).

E. Lignans
Lignans are plant-based phytoestrogens with antioxidant properties. While flaxseed is the richest source, berries like blueberries, strawberries, and cranberries also contribute small amounts. These lignans are converted in the gut to enterolactone and enterodiol, which may help protect against hormone-related cancers and cardiovascular disease (Adlercreutz et al. 1997).

F. Tannins
Tannins are phenolic compounds with molecular weights between 500 and 3000 Da, primarily classified into hydrolysable tannins (e.g., gallotannins and ellagitannins) and condensed tannins (Chung et al. 1986; Okuda et al. 1995). While phlorotannins are found only in brown seaweeds and are not common in the human diet (Ragan et al. 1986), berries—particularly strawberries, raspberries, and blackberries—are rich in hydrolysable and condensed tannins. These tannins contribute to the antioxidant and antimicrobial properties of berries. Although their antioxidant activity is generally lower than that of flavonoids, highly polymerized tannins can exhibit antioxidant effects up to 15–30 times greater than simple phenols (Bravo 1998; Sánchez-Moreno 2002).

G. Carotenoids
Carotenoids are found in modest amounts in berry fruits (Heinonen MI, et al.1989, .Razungles A, et al,1989, Marinova D, et al.,2007). Chokeberry is one of the most abundant sources of carotenoids, with an average amount of 48.6 mg/kg fresh weight. Lycopene, -carotene, -carotene, -cryptoxanthin, lutein, 5,6-epoxylutein, trans-violaxanthin, cis-violaxanthin, and neoxanthin are all found in chokeberry fruits (Razungles A, et al.,1989).

H. Vitamin C
Ascorbic acid (vitamin C) is a vital water-soluble antioxidant found abundantly in a variety of fresh fruits and vegetables. Chemically known as 2-oxo-L-threo-hexono-1,4-lactone-2,3-enediol, it exists primarily in the forms of L-ascorbic acid and dehydroascorbic acid in the human diet (Naidu 2003). While most plants can synthesize ascorbic acid from D-glucose or D-galactose, humans lack the enzyme L-gulonolactone oxidase and must obtain it from dietary sources. Berries, especially strawberries, blackcurrants, and raspberries, are excellent natural sources of vitamin C, contributing significantly to daily intake and enhancing the antioxidant capacity of berry-based diets.

III. HEALTH-PROMOTING EFFECTS OF BERRY COMPOUNDS

A. Oxidative Stress Suppression
Oxidative stress, which is brought on by high amounts of free radicals, can accelerate ageing and a number of degenerative disorders. Active oxygen radical scavengers including vitamin C, phenolic compounds, flavonoids, and carotenoids interact with antioxidants found in berries.

The antioxidant content of berries is four times higher than that of other fruits and vegetables.Ten times the quantity of veggies Studies have demonstrated the antioxidant qualities of strawberries.Their capacity is closely linked to the quantity of vitamin C and phenolic chemicals they contain. (Baby B.et al., 2018).In strawberries, vitamin C is the most important antioxidant, followed by anthocyanins.hydroxycinnamic acids (mostly p-coumaric acid derivatives and flavanols) are next (Tulipani, S et al, 2008). Strawberry eating boosts antioxidant capacity in the blood and lowers oxidative stress.Increases serum vitamin C levels and decreases plasma protein levels (Romandini, S et al.,2013, Henning, S.M.et al.,2008).

B. Antimicrobial Properties

Berries have shown significant antimicrobial potential against a variety of pathogenic microorganisms, making them promising natural agents for infection control. Polyphenols, particularly anthocyanins and ellagitannins present in berries such as blueberries, blackberries, and raspberries, have been found to disrupt bacterial cell walls, inhibit biofilm formation, and interfere with bacterial adhesion to host tissues.

For instance, blueberry extracts have demonstrated strong inhibitory effects on Escherichia coli and Staphylococcus aureus through mechanisms involving membrane destabilization and oxidative damage (Seeram et al., 2006; Wu et al., 2004). Similarly, cranberry and blueberry polyphenols have been reported to reduce Helicobacter pylori colonization in gastric mucosa, potentially by blocking bacterial adhesion receptors (Zhang et al., 2008; Zunino et al., 2012). Gooseberries and mulberries, rich in gallic acid and flavonoids, have also been observed to exert broad-spectrum antimicrobial activity, particularly against Gram-negative strains (Skrovankova et al., 2015). These findings highlight the therapeutic value of berry-derived compounds in managing infections and mitigating antibiotic resistance.

C. Neuroprotective Effects of Berry Polyphenols

In a study with rats, (Duffy et al., 2008) confirmed that supplementing the diet with 2% blueberry extract for 8 weeks protected them from neurodegeneration and cognitive deficits caused by excitotoxicity and oxidative stress. This study found evidence that supplementing with blueberry extract can help prevent or treat Alzheimer's disease, as well as possibly other neurodegenerative disorders. It was also discovered that the extract can help slow down degenerative processes induced by oxidative or inflammatory processes.

A key factor is oxidative stress, which causes damage to brain macromolecules.

In neurodegenerative illnesses, this is a process. Alzheimer's disease is a widespread neurodegenerative illness that affects up to 18 million individuals globally. Polyphenols have a significant antioxidative capacity, hence they may protect against neurological illnesses if consumed(Letenneur L, et al.,2007)When compared to those who drank less or did not drink at all, those who drank three to four glasses of wine per day had an 80% lower incidence of dementia and Alzheimer's disease(Scarmeas N, et al.,2007).

Resveratrol, which is prevalent in wine, scavenges O2 - and OH• free radicals in vitro, as well as lipid hydroperoxyl free radicals; this potent antioxidant activity is likely to be implicated in the protective effect of moderate red wine consumption against dementia in the elderly.

In a model of Alzheimer's disease, resveratrol suppresses nuclear factor B signalling and so protects against microglia-dependent - amyloid toxicity, and this activity is linked to SIRT-1 activation(MarkusMA,et al.,2008). It was discovered that drinking high-polyphenol fruit and vegetable juices at least three times a week may help to prevent the beginning of Alzheimer's disease(Dai Q,et al.,2006) Polyphenols found in fruits and vegetables appear to be valuable potential neuroprotective agents due to their capacity to inhibit oxidative stress(Singh M,et al .,2008).

D. Anticancer Properties

The antioxidant impact of berries coincides with its anticancer potential, according to studies in vitro and in vivo (Castro, D.et.al.,2015 ,Skrovankova, S.et.al 2015).Scavenging reactive oxygen species is part of the antioxidant process.ROS are reactive oxygen species (ROS) that cause oxidative damage to biological macromolecules like DNA and RNA. DNA and RNA are two types of genetic material.

The accumulation of oxidative DNA damage aids in the genesis of cancer. oxidative stress is one of the major causes of tumours, and as a result, oxidative stress is one of the major causes of cancer.

Increasing the rate of carcinogenesis (Sosa, V.et.al,2013). Strawberry extract has been shown to drastically reduce tumour growth. volume and lengthen the longevity of the mouse model (Somasagara, R.R.et.al,2012). Strawberry bioactive chemicals in a mouse model of azoxymethane/dextran sodium sulfate-induced colon carcinogenesis (Shi, N.et.al,2012)model Strawberry also has an anti-proliferative impact, according to an in vitro study.

On human colon, prostate, and oral cell lines, extracts with ellagic acid (Zhang, Y.et.al,2008). An ingestion weighing 60 gper day of freeze-dried strawberry powder reduced histological grade levels of several pro-inflammatory proteins in premalignant lesions in more than Esophageal dysplasia affects 80 percent of patients (Chen, T.et al,2012).

Anthocyanins from blackberries inhibited cancer cell growth by modifying cellular signalling pathways, such as modulating the expression of activating protein-1 (AP-1) and nuclear factor-kB (NF-kB), two essential proteins that coordinate cell proliferation, vascular endothelial cell proliferation, and vascular endothelial cell proliferation.

COX-2, and growth factor (Duthie, S.J,et al.2007). Furthermore, blackberry quercetin is a powerful antioxidant.Experimental animal models and human cancer cell lines revealed anti-carcinogenic capabilities (HT29 and Caco-2) (Agullo, G.et.al,2007).

(Seeram et al. 2006) studied the ability of blueberry extracts to inhibit tumour cell proliferation in the oral cavity, breast, colon, and prostate, concluding that the activity was dose-dependent and different among cell types. Furthermore, the extracts induced apoptosis in colon cancer cell cultures.

The effect of blueberry juice on cell death and cell cycle interruption in human cancer cells of the stomach, breast, prostate, and intestine was studied by (Boivin et al.2007). These researchers discovered that juice, particularly juice from cultivars of the "lowbush" group, had a strong capacity for suppressing cell proliferation. More than caspase-dependent apoptosis, the mechanism of action appears to be connected to cell cycle disruption.

Polyphenols affect pro-carcinogen metabolism through regulating the expression of cytochrome P450 enzymes involved in their conversion to carcinogens. They may also make it easier for them to be excreted by upping the expression of phase II conjugating enzymes.

The toxicity of polyphenols may be to blame for the stimulation of phase II enzymes (ScalbertA,atal,2005). In the body, polyphenols can create potentially hazardous quinones, which are also substrates for these enzymes. Polyphenol consumption could then activate these enzymes for self-detoxication, resulting in a general improvement in our defences against hazardous xenobiotics. (Talalay P, et al 1988).

Teacatechins in the form of capsules have been shown to have cancer-preventive effect in males with high-grade prostatic intraepithelial neoplasia (PIN) by blocking the conversion of high-grade PIN to cancer (Khan N et al, 2005).

E. Regulation of Blood Pressure

Polyphenols and flavonoids have been shown to be helpful in the treatment of cardiovascular illnesses, such as hypertension. Anthocyanins and anthocyanin-rich berry eating have been linked to a considerable reduction in blood pressure in some studies(Clark, J.L.et al., 2015, Vendrame, S.et al., 2019). After 12 days of ingestion of a blackcurrant extract containing either 105, 210, or 315 mg/day of anthocyanins, a group of 15 athletes with the two higher anthocyanin doses showed a substantial decrease in arterial pressure (Cook, M.D.et al., 2017).

During an eight-week study, 45 prehypertensive participants were given black raspberry powder, and the group receiving 2.5 g raspberry powder per day saw a significant decrease in systolic blood pressure (SBP) (Jeong, H.S.et al.,2016). Zhu and colleagues (Zhu, Y.et al., 2017)conducted a meta-analysis of various randomised clinical studies and found no significant effect of blueberry eating on either systolic or diastolic blood pressure.

For six weeks, older adults were given either whole wild blueberry powder (1 to 2 g per day) or 200 mg of blueberry extract (2.7, 5.4, or 14 mg anthocyanin content). The extract, which provided a larger dose of anthocyanins than whole berry powder, resulted in a significant reduction in SBP (Whyte, A.R.et al., 2018).

F. Antidiabetic Effects of Berry Phytochemicals

With the onset of hyperglycemia and eventually diabetes, impaired glucose metabolism leads to significant physiological imbalances. Diabetes mellitus, broadly classified into type 1 and type 2, is associated with several biochemical and metabolic alterations in the body (Rizvi et al., 2001; Rizvi et al., 2005). Over time, chronic hyperglycemia results in various complications, including retinopathy (leading to vision impairment or blindness), nephropathy (kidney dysfunction), and neuropathy, which may cause autonomic disturbances, foot ulcers, sexual dysfunction, and even amputations.

Recent studies have documented the anti-diabetic potential of dietary polyphenols, particularly anthocyanin-rich berries such as blueberries, blackberries, gooseberries, and mulberries. These berries are rich sources of flavonoids like catechins, quercetin, and anthocyanins, which exhibit hypoglycemic properties through multiple mechanisms. For instance, polyphenols from these berries may modulate glycemic control by inhibiting carbohydrate-digesting enzymes like α-amylase and α-glucosidase, thereby reducing postprandial glucose absorption (Matsui et al., 2002).

Specifically, studies have shown that diacetylated anthocyanins—present in many pigmented berries—exert hypoglycemic effects when maltose is used as a carbohydrate source, likely due to the inhibition of α-glucosidase activity in the intestinal mucosa.

Additionally, catechins derived from berries such as gooseberries and mulberries have been reported to inhibit sucrase and amylase at dietary doses above 50 mg/kg, thereby slowing down glucose release and absorption. These findings collectively suggest that regular consumption of polyphenol-rich berries may offer protective effects against the development and progression of diabetes, supporting their inclusion in functional diets for diabetic management.

With the beginning of hyperglycemia and, eventually, diabetes, impaired glucose metabolism causes physiological imbalance. Diabetes is divided into two types: type 1 and type 2.

Several physiological indicators have been found to be related in studies. In diabetic situations, the body's chemistry changes (Rizvi SI et al.,2001,2005) In the long run Diabetes has a number of side effects, including the progression of certain diseases. Complements like retinopathy, which affects the eyes and can lead to blindness.

Nephropathy, a condition in which the kidneys' functions are disrupted or agitated, as well as neuropathy, which is linked to an increased risk of amputations, foot ulcers, and other symptoms of autonomic dysfunction, sexual dysfunctions are included. The anti-diabetic effect has been documented in a number of researches.

The anti-diabetic properties of tea catechins have been studied (Rizvi SI et al ,2005, Rizvi S I et al,2001) Polyphenols may influence glycemia through a variety of methods, including inhibiting glucose absorption in the gut or peripheral tissue uptake. At a 10 mg/kg food intake, diacetylatedanthocyanins had hypoglycemic effects with maltose as a glucose source, but not with sucrose or glucose (Matsui T, et al ,2002).

This shows that the inhibition of -glucosidase in the gastrointestinal mucosa is the cause of these effects. Catechin was found to inhibit -amylase and sucrase in rats at doses of about 50 mg/kg diet or higher.

G. Anti-Obesity Effects of Berry Phytochemicals

Obesity is difficult to cure and is a leading cause of diabetes and cardiovascular disease. Natural plant extracts have been proposed as an option for long-term weight control (178 Song, Y.et al.,2013), because pharmacological therapy of obesity causes many adverse effects and has little long-term efficacy.

C57BL/6J mice fed a high-fat diet with anthocyanins were found to be less obese than mice fed a high-fat diet without anthocyanins (Tsuda, T et al., 2003). Weight gain and fat accumulation in mice fed a high-fat diet were not affected by blueberry juice or freeze-dried blueberries. Anthocyanin extracts from blueberries, on the other hand, lowered body weight and fat formation considerably (Prior, R.L.et al., 2010).

The anthocyanins in blueberries promoted the transcription of the peroxisome proliferator-activated receptor (PPAR, which participates in energy homeostasis regulation) (Seymour, E.M et al., 2010), which is linked to improved insulin resistance, fat stimulation metabolism, and fat storage inhibition.

H. Cardiovascular Disease

Blueberry phenolic compounds revealed the role in the decrease of one of the risk factors for cardiovascular disease. Supplementing swine with blueberry extract (Vacciniumcorymbosum cv. Jersey) lowered total cholesterol, LDL, and HDL levels, according to a study. The biggest reduction was shown with blueberry at a concentration of 2%, with total cholesterol, LDL, and HDL lowered by 11.7 percent, 15.1 percent, and 8.3 percent, respectively(Kalt, W et al.,1997).

Polyphenol consumption has been shown in a number of studies to reduce the risk of coronary heart disease(Renaud, S et al., 1992, Dubick, MA et al., 2001, NardiniM,et al., 2001).Atherosclerosis is a long-term inflammatory condition that affects the arteries. in the prone-to-lesion areas of medium-sized arteries Atherosclerotic For decades, lesions may be present yet clinically quiet. Activating and causing pathological disorders, such as acute myocardial infarction, unstable angina, or sudden cardiac death are all symptoms of acute myocardial infarction. Death(Vita JA,et al.,2005). Polyphenols are powerful inhibitors of LDL oxidation, which is thought to be a crucial factor in heart disease.

There are more methods that Polyphenols have been linked to a reduction in the risk of cardiovascular disease. Antioxidant, anti-platelet, and anti-inflammatory properties as well as enhancing endothelial function and raising HDL Polyphenols may also help to maintain atheroma stability.(García-Lafuente A et al.,2009).

IV. CONCLUSION

Berries have emerged as exceptional functional foods due to their rich composition of bioactive compounds, including phenolic acids, flavonoids, tannins, stilbenes, lignans, carotenoids, and essential vitamins such as vitamin C.

These constituents not only contribute to the vibrant colors and appealing sensory properties of berries but also offer a wide array of health-promoting benefits. Numerous in vitro, in vivo, and epidemiological studies have demonstrated that regular consumption of berries is associated with reduced risk of chronic diseases such as cardiovascular disorders, certain types of cancer, neurodegenerative diseases, metabolic syndrome, diabetes, and obesity. Among the most studied bioactives in berries are anthocyanins, ellagitannins, and flavonols, which possess strong antioxidant, anti-inflammatory, antimicrobial, anti-carcinogenic, and neuroprotective properties.

These compounds help combat oxidative stress, one of the central mechanisms in the pathogenesis of many chronic diseases. Additionally, berries influence key molecular pathways, including those related to inflammation, cell proliferation, apoptosis, glucose metabolism, and lipid regulation. Notably, the interactions between berry-derived polyphenols and the gut microbiota have also garnered increasing attention, as they play a critical role in modulating the bioavailability and systemic effects of these compounds.

From a nutritional standpoint, berries are low in calories yet high in fiber, vitamins (particularly vitamin C, K, and folate), and minerals such as potassium and iron, making them ideal components of a balanced and health-supportive diet. Their role in improving cardiovascular health, reducing blood pressure, enhancing insulin sensitivity, and promoting gut health makes them valuable not only for the general population but also for individuals at risk of or living with chronic conditions.

Despite the promising findings, several research gaps remain. Many of the health claims are based on preclinical studies, and there is a pressing need for well-designed, randomized, placebo-controlled human trials to validate these effects. Standardization of berry extracts, identification of active compounds, optimization of extraction methods, and investigation into synergistic interactions among phytochemicals are crucial for advancing our understanding.

Furthermore, inter-individual differences in metabolism, gut microbiota composition, and genetic factors should be considered to personalize dietary recommendations involving berries.

In conclusion, berries hold significant promise as both preventive and therapeutic agents due to their multifaceted bioactive profiles. Their incorporation into daily diets can serve as a natural, accessible, and flavourful strategy to promote health and reduce disease risk. With increasing scientific interest and public awareness, future research should aim to translate laboratory findings into clinical applications, ensuring that berry-derived compounds are effectively utilized in the prevention and management of modern lifestyle-related diseases. Thus, berries are not only nutritional treasures but also potential contributors to the development of next-generation functional foods and nutraceuticals.

However, no adverse or toxic effects (i.e., chemical, haematological, or urinary effect) have been linked to the consumption of berries, berry juices, or other extracts, particularly aronia berries and aronia products, in vivo or in vitro (Kulling and Rawel, 2008), suggesting that the phenolic antioxidants found in berries are natural gifts for human health. However, the phenolic component content of berries and berry products is not always fully defined, and more research is needed to determine the therapeutic levels of various berry products for future clinical trials.

Furthermore, more research is needed to fully comprehend the favourable benefits described thus far from a mechanistic standpoint. As a result, more emphasis should be placed on the establishment of well-controlled and high-quality clinical trials.

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