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Medicinal significance, pharmacological activities, and analytical aspects of anthocyanidins 'delphinidin': A concise report

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ABSTRACT

Herbal medicines have been used for the treatment of various disorders in the world since a very early age due to easily available and less side effect. A large number of phytochemicals have been derived directly or indirectly from natural sources in the form of oils, food supplement, neutraceuticals, and colour pigments. Anthocyanins are classes of phytoconstituents mainly responsible for the different colors of plants material. Literature report revealed the presence of different anthocyanidins such as cyanidin, delphinidin, petunidin, peonidin, pelargonidin, malvidin, cyaniding etc. These anthocyanidins showed a wide range of pharmacological activities. Anthocyanins have an attractive profile in the food industry as natural colorants due to its possible health benefits and safety issues compared to the synthetic dye. Delphinidin is an important anthocyanidins mainly present in the epidermal tissues of flowers and fruits. Delphinidin showed various pharmacological activities such as antioxidant, antimutagenesis, anti-inflammatory and antiangiogenic etc. This review was aimed to elaborate the medicinal importance, pharmacological activities and analytical aspects of anthocyanidins 'delphinidin'. This review will be benificial to the scientist, manufacturer and consumers in order to explore the potential health benefits of delphinidin.

1. Introduction

Nature is the source of all the raw materials that we need. In ancient time, most of the drugs were obtained from natural sources as they have fewer side effects and has economical values[1]. Development of different food products in food science and technology is one of the major trends that cover the specific health benefits offered by food ingredients from plants including sterols, carotenoids, polyphenols and anthocyanins[2]. Phytoconstituents present in the plants have been reported to have a wide range of pharmacological activities. Flavonoids (Figure 1) are benzo-c-pirone derivates having 15 carbon atoms skeleton. Different classes of flavonoids viz. flavanones, flavones, flavanols, isoflavonoids, anthocyanins and flavans differ from each other in respect to their structural characteristic around the heterocyclic oxygen ring. Due to the ability to absorb ultraviolet light, they can protect DNA damage and decrease the risk of cardiovascular disease[3]. Catechins, anthocyanidins and their glycosides-anthocyanins are the flavonoidal compounds present in the plant materials and showed health beneficial property. Flavonoids are responsible for the different colours of plant part as shades of yellow, orange and red in flowers. More than 4 000 flavonoids have been reported in the edible plants and are consumed regularly in the human diet. Flavonoids represent one of the most prevalent classes of compounds in vegetables, medicinal herbs, nuts, fruits and beverages such as coffee, tea, and red wine etc[4]. Flavonoids are commonly ingested through different natural sources such as from fruits and vegetables in the diet[5]. Health beneficial properties of flavonoids are mainly due to its antioxidant and chelating abilities. Flavonoids play an important role in protection against ultraviolet radiation, pathogens, and herbivores in the plants. They are used in the food products, cosmetics, and various preparations. Flavonoids have different pharmacological activities such as antioxidant, vasodilatory, anticarcinogenic, antiinflammatory, antibacterial, immune-stimulating, antiallergenic, antiviral,

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estrogenic activity etc[6]. Flavonoid rich medicinal plants are used to prevent or cure diseases in Asian countries, especially in China. Several research studies have been done to know the molecular mechanisms of the therapeutic effect of flavonoids[7]. Anthocyanins (Figure 2) are naturally occurring flavonoid, widely distributed in fruits and vegetables in the daily diet[8]. Anthocyanins are mainly responsible for the different colours such as red, purple, blue, hues etc. in fruits, vegetables, flowers and grains. They play an important role in the prevention of diverse diseases such as cancer, diabetes, mutagenesis, carcinogenesis and cardiovascular diseases. Anthocyanins showed antioxidant, anti-proliferation, anti-angiogenic and anti-inflammatory activity[9-13]. Anthocyanins have been used in the food industry as natural colorants because their vibrant colors[14,15]. Depending on the nutrition customs, the daily intake of anthocyanins in humans has been estimated to range from several milligrams to hundreds of milligrams[9,13].

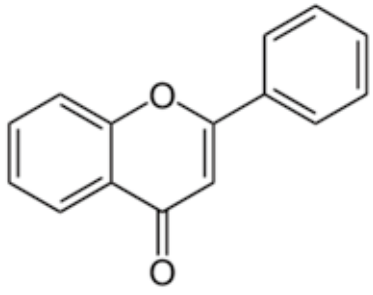

Figure 1. Chemical structure of flavonoid.

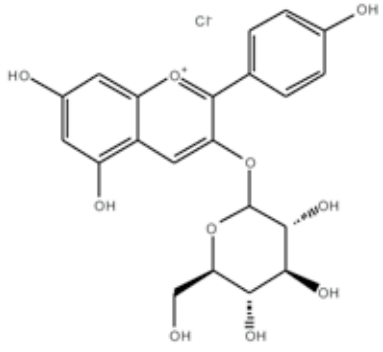

Figure 2. Chemical structure of anthocyanin.

1.1. Anthocyanidins

Polyphenols are one of the major classes of phytochemicals occurring in fruits, vegetables and plant-derived beverages such as tea and wine and have been known for its health beneficial properties. Anthocyanidins (Figure 3) have gained much attention to the scientists over the last decade due to their health aspects and different pharmacological activities[16]. Anthocyanidins mainly comprises delphinidin, cyanidin, petunidin, pelargonidin, peonidin and malvidin etc. representing the aglycons of most anthocyanins in plants[13]. They have a wide range of biological functions and health benefits including anti-oxidative, antiinflammatory and anti-tumor properties[17,18].

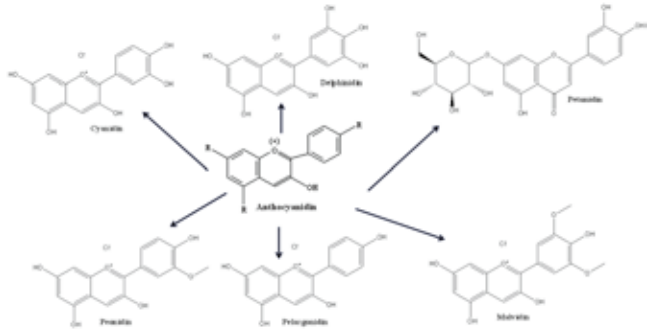

Figure 3. Chemical structure of different anthocyanidine.

1.2. Delphinidin

Delphinidin (2-(3, 4, 5-trihydroxyphenyl)chromenylium-3, 5, 7-triol) (Figure 4), a diphenylpropane-based polyphenolic ring structure present in the vacuolar sap of the epidermal tissues of flowers and fruits. Delphinidin showed antioxidant, antimutagenesis, anti-inflammatory and anti-angiogenic properties. The mode of action of the above mentioned activities of delphinidin are through the vascular endothelial growth factor receptor-2 phosphorylation inhibition, platelet-derived growth factor ligand/receptor signaling, cancer cell proliferation and modulation of Met receptor phosphorylation[16,19-21]. Delphinidin is found in many brightly colored fruits, vegetables and in dietary supplements that are currently consuming as complementary cancer medicine[22].

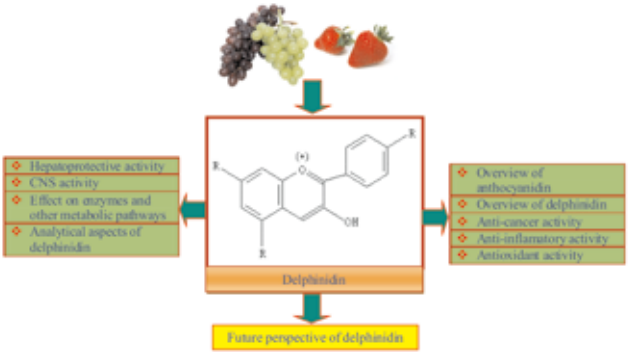

Figure 4. Chemical structure and overview of delphinidin.

2. Pharmacological aspects of delphinidin

2.1. Anti-cancer activity of delphinidin

For the determination of anticancer activity, effect of delphinidin on established breast cancer cell lines of various molecular subtypes were determined. Delphinidin

inhibited proliferation, blocked anchorage-independent growth, and induced apoptosis of ER-positive, triple negative, and HER2-overexpressing breast cancer cell lines. MAPK (mitogen-activated protein kinase) signaling was partially reduced in triple negative cells and ER-negative chemically transformed MCF10A cells after treatment with delphinidin[22]. Anthocyanins have gained much attention due to their wide range of potential health-promoting effect. Mechanisms responsible for the cytoprotective actions of delphinidin and other anthocyanins were investigated. All the tested flavonoids were found to counteract peroxynitrite-induced apoptotic effects on endothelial cells through the inhibition of several crucial signaling cascades. Furthermore epidemiological studies revealed that delphinidin has a beneficial effect on various stages of carcinogenesis[23,24]. In another study, the extent of DNA damage by delphinidin is not affected by the expression of tyrosyl-DNA-phosphodiesterase 1, indicating that the induction of DNA strand breaks is not predominantly topoisomerase-mediated. However, the DNA-damaging properties of delphinidin were decreased by the addition of catalase to the cell culture medium, counteracting delphinidin-mediated hydrogen peroxide formation[25]. In another study, delphinidin inhibits tumor promoter-induced transformation and cyclooxygenase-2 (COX-2) expression in JB6 promotion-sensitive mouse skin epidermal (JB6 P+) cells by directly targeting Raf and mitogen-activated protein kinase (MEK). The activation of activator protein-1 and nuclear factor-kappaB by TPA were found to be dose dependently, moreover it is inhibited by delphinidin treatment[26].

Effect of delphinidin in human colon cancer HCT116 cells was investigated. Delphinidin exhibited decreased cell viability, induction of apoptosis, cleavage of PARP, activation of caspases-3, -8, and -9, increase in Bax with a concomitant decrease in Bcl-2 protein and G2/M phase cell cycle arrest[27]. In another study, Effect of anthocyanidins in primary (Caco-2) and metastatic (LoVo and LoVo/ADR) colorectal cancer cell lines was investigated. Delphinidin showed cytotoxic effect on metastatic cells[18]. Effects of anthocyanins in different modes of cell death in different cancers were investigated. Delphinidin could induce apoptosis in leukemia cells thereby promoting growth retardation in hepatocellular carcinoma cells[19]. Effects of delphinidin on UVB-induced COX-2 upregulation and underlying molecular mechanism were investigated. Delphinidin suppressed UVB-induced COX-2 expression in JB6 P+ mouse epidermal cells. COX-2 promoter activity and PGE (2) production were also suppressed by delphinidin treatment within non-cytotoxic concentrations[28]. Effect of delphinidin treatment to human PCa LNCaP, C4-2, 22Rnu1, and PC3 cells was investigated and found that it exhibited dose-dependent inhibition of cell growth without affecting normal human prostate epithelial cells[29]. Delphinidin induces apoptosis and cell cycle arrest in androgen refractory human PCa 22Rnu1 cells and the effects are concomitant with inhibition of NfkappaB[30].

2.2. Anti-inflamatory activity of delphinidin

Delphinidin (isolated from *Punica granatum* L) specifically inhibited the Histone acetyltransferase (HAT) activities of p300/CBP. It also inhibited p65 acetylation in MH7A cells, a human rheumatoid arthritis synovial cell line. Delphinidin treatment inhibited TNF α -stimulated increases in NF-κB function and expression of NF-κB target genes in these cells. Delphinidin suppressed lipopolysaccharide-induced pro-inflammatory cytokine expression in Jurkat T lymphocytes, demonstrating that HATi efficiently suppresses cytokine-mediated immune responses[31].

2.3. Antioxidant activity of delphinidin

Effects of delphinidin against oxidized low-density lipoprotein (oxLDL) -induced damage in human umbilical vein endothelial cells (HUVECs) was investigated. Delphinidin was found to markedly restore the oxLDL-induced viability loss in HUVECs in a concentration-dependent manner[32]. In another study, density functional theory calculations were done to evaluate the antioxidant activity of delphinidin. One-step H atom transfer rather than sequential proton loss-electron transfer or electron transfer-proton transfer would be the most favored mechanisms for explaining the antioxidant activity of delphinidin in nonpolar solvents as well as in aqueous solution[33]. Delphindin enhanced the levels of p27, suppressed by hydrogen peroxide in the tested cell line. Hydrogen peroxide and delphinidin seem to regulate intracellular levels of p27 through the regulating HIF-1 level that is in turn, governed by its upstream regulators comprising of PI3K/Akt/mTOR signaling pathway[34]. In another study, anthocyanidins showed significant scavenging activity against different free radicals including delphinidin that was found to be the most active in the tested concentration[35].

2.4. Hepatoprotective activity of delphinidin

The hepatoprotective effects of delphinidin in carbon tetrachloride (CCl (4)) -induced liver fibrosis in mice was investigated. Delphinidin has successfully attenuated oxidative stress, increased matrix metalloproteinase-9 and metallothionein I/II expression and restored hepatic architecture. The therapeutic effect of delphinidin is

mainly attributed to hepatic stellate cells (HSC) inactivation and down-regulation of fibrogenic stimuli with strong enhancement of hepatic regenerative power[16].

2.5. CNS activity of delphinidin

Neuroprotective effects of delphinidin against abeta-induced toxicity were investigated. Delphinidin rescued PC12 cells from abeta by attenuating the elevation of intracellular calcium levels and tau phosphorylation[36]. Effect of delphinidin isolated from *Vaccinium myrtillus* on retinal ganglion cells (RGCs) against retinal damage were investigated *in-vitro* and *in-vivo*. Delphinidin significantly inhibited SIN-1-induced neurotoxicity and radical activation in RGC-5 and inhibited lipid peroxidation in mouse forebrain homogenates in a concentration dependant manner[37]. Neuronal SNARE proteins mediate neurotransmitter release at the synapse by facilitating the fusion of vesicles with the presynaptic plasma membrane. SNARE zippering can be modulated in the midways by wedging with small hydrophobic molecules where as delphinidin and cyanidin inhibited N-terminal nucleation of SNARE zippering[38].

2.6. Effect of delphinidin on enzymes and other metabolic pathways

The effect of delphinidin on human Glyoxalase I (GLO I) were investigated and exhibited the most potent inhibitory effect on human Glyoxalase I (GLO I) revealing its potential for the development of novel GLO I inhibitory anticancer drugs[20]. Delphinidin affects the catalytic activity of topoisomerase-II alpha in a redox-independent manner. Delphinidin also diminished the DNA-damaging properties of topoisomerase II poisons in HT29 cells without affecting the level of sites sensitivity to formamidopyrimidine-DNA-glycosylase[39]. Delphinidin was found to have *Schistosoma mansoni* NAD (+) catabolizing enzyme (SmNACE) inhibitory potential in a sensitive and robust fluorometric high-throughput screening assay[40]. Delphinidin inhibited TNF-alpha-induced COX-2 expression in JB6 P+ mouse epidermal (JB6 P+) cells in another study. Delphinidin inhibited the TNF-alpha-induced phosphorylations of JNK, p38 MAP kinase, Akt, p90RSK, MSK1, and ERK, and subsequently blocked the activation of the eukaryotic transcription factors AP-1 and NF-kappaB[41]. Effect of delphinidin (Dp) using soybean lipoxygenase-1 and human neutrophil granulocyte 5-lipoxygenase were investigated and found that Dp 3-O-glucoside (Dp3glc) and Dp 3-O-galactoside (Dp3gal) revealed the most effective soybean lipoxygenase-1 inhibition[42]. Alpha isoform of estrogen receptor (ERalpha) deficient mice were used to determine the endothelium-dependent vasorelaxation effect of delphinidin. Delphinidin is able to induce endothelial vasodilation in aorta from ERalpha Wild-Type but not from Knock-Out mice, by activation of nitric oxide (NO) pathway in endothelial cells[43]. Competitive radioligand binding assays to identified delphinidin as ligands with moderate affinity to human cannabinoid receptor 1 were also investigated in another study[44]. In another study, anthocyanins and anthocyanidins were exposed to the human efflux transporters multidrug resistance protein 1 (MDR1) and breast cancer resistance protein (BCRP), using dye efflux, ATPase and, for BCRP, vesicular transport assays. Results showed that delphinidin interacted with the BCRP transporter[45]. In another study, delphinidin was found to strongly inhibit the protein tyrosine kinase activity of receptor tyrosine kinases at low micromolar concentrations[46]. In another study, photometric assay was used to screen the inhibitory ability of delphinidin against phospholipase enzyme[47].

Antiangiogenic properties and antioxidant activities of delphinidin form *Vaccinium myrtillus* were investigated. These anthocyanidins concentration-dependently inhibited vascular endothelial growth factor (VEGF)-induced tube formation in a co-culture of human umbilical vein endothelial cells (HUVECs) and fibroblasts[48]. Effect of delphinidin as a inhibitors of spermidine-induced pro-Plasma hyaluronan-binding protein (PHBP) autoactivation were investigated and was found to be potent and selective, and did not inhibit heparin-induced pro-PHBP[49]. In another study, delphinidin chloride showed instability in the Dulbecco's modified Eagle's medium (DMEM), RPMI 1640 (RPMI) and Minimal Essential Medium Eagle (MEM)) culture media's[50]. The absorption and metabolism of the 3-monoglucosides of delphinidin in healthy human subjects were investigated to examine the effect of red wine extract on plasma antioxidant status and on monocyte chemoattractant protein 1 production[51]. In another study, a scheme of genetic control of anthocyanidin biosynthesis in sweet pea flowers is proposed by the Gene E1 is involved in the biosynthesis of trihydroxylated delphinidin[52]. In another study it was found that delphinidin had a strong interaction with soybean seed ferritin[53].

3. Analytical aspects of delphinidin

For the analysis of flavonoidal compounds, different analytical techniques have been developed and mentioned in the literature. Among the analytical methods, liquid chromatography-tandem mass spectrometry (LC-MS/MS), high-performance liquid chromatography (HPLC), high-

performance liquid chromatography-mass spectrometry (HPLC-MS) is commonest. These techniques are mainly used for the separation, identification and quantitative analysis of different samples. These techniques may be used to solve many qualitative and quantitative analytical problems in a wide range of fields, including medicine, pharmaceuticals, chemistry, biochemistry, food analysis, toxicology and environmental analysis etc. Analysis of Concord grape juice by HPLC with electrospray ionization-mass spectrometer coupled with photodiode array detection (ESI-MS, PDA), and fluorescence detection resulted in the identification and quantification of 60 flavonoids including delphinidin was found to be present in the tested samples[54]. Chromatographic analysis of grape extracts by high-performance liquid chromatography-mass spectrometry identified different anthocyanins including delphinidin is one of the main constituents in the grape extracts[55]. Bilberries (*Vaccinium myrtillus* L.) from seven locations and highbush blueberries (*Vaccinium corymbosum* L.) from one location in Slovenia were analyzed through LC-MS/MS method in respects to their delphinidin content[56]. The influence of a wide range of temperature regimes on pomegranates was investigated. Reversed phase-high-performance liquid chromatography (RP-HPLC) analysis of the pomegranates revealed mono- and diglucosylated delphinidins and cyanidins is the major components in the samples[57]. In another study, the influence of growing season (winter vs summer) on the synthesis and accumulation of phenolic compounds (delphinidin) was studied in five grape cultivars for three consecutive years [58]. For the determination of the aglycon forms of the anthocyanins delphinidin in red wine, high-performance liquid chromatography with diode array detection techniques were used in another study[59].

Table1

Analytical techniques for the determination of delphinidin in various samples.

S.N.	Samples	Methods	References
1.	Pink and red grape	CIELAB system and high-performance liquid chromatography (HPLC)-mass spectrometry (MS) coupled with photodiode array detection.	[84]
2.	*Prunus cerasus* L	High-performance liquid chromatography (HPLC).	[85]
3.	Muscadine grapes	High-performance liquid chromatography-mass spectrometry (HPLC-MS) with electrospray ionization.	[86]
4.	*Vaccinium myrtillus* L	High performance liquid chromatography (HPLC).	[87]
5.	*Cynara scolymus* L	High-pressure liquid chromatography-diode array detector-electrospray ionisation/ion trap mass spectrometry (HPLC-DAD-ESI/MSn).	[88]
6.	Peas, faba beans, broad beans, red beans, adzuki beans, vetch, red lentils, green lentils, hazelnuts, walnuts	High-performance liquid chromatography (HPLC) method.	[89]
7.	Method for anthocyanin identification	High-performance liquid chromatography (HPLC) coupled with tandems mass spectrometry (MS/MS) and photo-diode array detection (PDA).	[90]
8.	Common foods in the United States	High-performance liquid chromatography-electrospray ionization-tandem mass spectrometry.	[91]
9.	Grape juices	Ion trap liquid chromatography-mass spectrometry.	[92]
10.	*Vitis vinifera*, *Vitis amurensis*, *Vitis cinerea* and *Vitis X champinii*	High-performance liquid chromatography coupled to mass spectrometry (LC-MS) and NMR spectroscopy (LC-NMR).	[93]
11.	*Canarium odontophyllum* Miq	Rreversed phase high-performance liquid chromatography coupled with diode array detector.	[94]
12.	Blueberry	High-performance liquid chromatography-mass spectrometry (HPLC-MS).	[95]
13.	Blueberries	Liquid chromatography-mass spectrometry and UV-visible spectroscopy.	[96]
14.	*Anacardium occidentale*	Liquid chromatography, with diode array detection and electrospray ionization mass spectrometry (LC-DAD-ESI/MS).	[97]
15.	Grape skin	High-pressure liquid chromatography-diode array detector-electrospray ionisation/ion trap mass spectrometry (HPLC-DAD-ESI/MSn).	[98]
16.	*Dracocephalum moldavica* L. and *D. ruyschiana* L.	High-performance liquid chromatography (HPLC).	[99]
17.	Bilberry (*Vaccinium myrtillus*), black currant (*Ribes nigrum*), strawberry (*Fragaria ananassa* cv. Jonsok), and Cabernet sauvignon (*Vitis vinifera*)	High-performance liquid chromatographic (HPLC).	[100]
18.	Grape skins	Matrix-assisted laser desorption ionization mass spectrometry (MALDI-MS).	[101]

Pomegranate juice has been analyzed for its flavanol-anthocyanin content using reversed-phase liquid chromatography with diode array detection, coupled to mass spectrometry (ion trap) with electrospray ionization (HPLC-DAD-ESI/MS(n)), operating in positive ion mode. Results showed that delphinidin was found to be present in the tested sample[60]. Phenolic composition of seed coat, cotyledon and embryonic axe fractions of *Cicer arietinum* L. and *Macrotyloma uniflorum* L. were analyzed through HPLC method. Results showed that all the tested samples contain delphinidin[61].

Phenol compositions of the cell walls of banana fruits were determined in another study. Delphinidin was found to be present in the insoluble cell wall fraction of banana fruits[62]. Total phenolics and proanthocyanidins content were determined in natural populations of pasture species at defined phenological phases and in different plant organs and also in pathogen-infected plants. The result showed that, delphinidin was found to be present in the tested samples[63]. The flavonoids anthocyanins and flavonols in *Vaccinium uliginosum* L. were studied from 15 populations in Finland. Four anthocyanidin xylosides and 14 flavonol glycosides were identified through HPLC-ESI-MS. Further delphinidin were also quantified by HPLC-DAD in the tested samples[64].

A systematic evaluation of the degradation of anthocyanins and anthocyanidins including delphinidin of *Vaccinium corymbosum* L. was performed through an HPLC/DAD method[65]. Structures of anthocyanins present in Eugenia jambolana fruit collected in the U.S.A. and India were determined using a combination of HPLC-UV, tandem LC-MS, and NMR techniques. Results indicated that the delphinidin is one of the phytoconstituents present in the tested samples[66]. HPLC analysis with a gradient elution technique using formic acid and methanol-acetonitrile as the mobile phase coupled with LC/MS was used for the determination of flavonoidal compound in the bilberry extract. Results showed that all the tested samples contain considerable amount of delphinidin[67]. The stability of total anthocyanin in different packaging such as glass and carton were investigated. The degradation rate of total anthocyanin was 22% higher in carton packaging compare to the glass bottle[68]. The effects of temperature, extraction duration, and use of ultrasound-assisted extraction on the juice yield, total phenols and anthocyanin content of aqueous extracts of black currants were investigated using delphinidin as a marker phytoconstituents[69].

In another study, extraction process of *Vaccinium uliginosum* L was optimized for the delphinidin contents[70]. Furthermore some of the analytical techniques in reference to the determination of the delphinidin in different samples were presented in the Table 1.

4. Future perspective of delphinidin

Nature plays an important role in our life as we get all the raw materials for food, cloth and even the drugs for the treatment of different diseases from natural sources. To maintain proper growth, the pharmaceutical industries need to innovate and access to high output rate on low-cost materials with reasonable safety. The combination of modern chemistry with bio-based starting materials can be the scope of revolutionizing pharmaceutical industries. Emphasis should be given to increase the productivity and enhancement of delphinidin content to meet the industry demand due to its significant contribution in the human health. There is still scope in advancement of techniques for the extraction of higher contents of delphinidin and reduce its cost. For the production of the highest level of delphinidin, tissue culture techniques could be the right option in the future. Delphinidin plays a significant role in the human health, so more investigation should be performed regarding general health beneficial property including its uses as nutraceutical and food supplement in the future. However more study should be performed to determine its safety profile prior to its uses. In regards to its safety profile, case study data should be collected to know its effect on human beings as well as other creature. In this context, both preclinical and clinical are warranted to be carried out to explore the hidden potential of delphinidin in curing various diseases.

5. Conclusion

Herbal medicines are popular for the treatment of various ailments in the world due to believe on its fewer side effects. Many synthetic and natural compounds have been derived from different natural sources such as plants, minerals and organic matter[71-73]. World Health Organization (WHO) has also been listed many plant materials for its medicinal properties in the world[74,75]. Phytochemicals are compounds that occur naturally in plants and are responsible for different color, flavor and smell of plant material. They form part of a plant's natural defense mechanism against various diseases. Natural products such as pure phytoconstituents and plant extracts offer limitless opportunities for new drug development due to the unmatched availability of chemical diversity. Plants play an important role in the medicinal preparations, both preventive and curative[76]. For the past few years there has been an exponential growth in the field

of herbal medicine and these drugs are gaining popularity both in developing and developed countries because of their natural origin and less side effects. Many traditional medicines in use are derived from medicinal plants, minerals and organic matter. Several medicinal plants have been used as dietary adjunct and in the treatment of numerous diseases without proper knowledge of their function[77]. The international market of herbal medicines is estimated to be $ 60 billion and the value of medicinal plants related trade in India is of the order of $ 5.5 billion. Further the role of medicinal plants and traditional medicinal system for developing new drug is incontestable[78]. Quality evaluation of herbal preparation is a fundamental requirement of the industry and other organization dealing with Ayurvedic and herbal products. The growing use of herbal products needs to develop standards for quality products. According to WHO guidelines, an herbal product needs to be standardized about safety before releasing it into the market[79-83].

In the present manuscript, data were collected in reference to pharmacological activities, analytical aspects and health beneficial properties of the delphinidin. From the overall data presented in this article, it was found that delphinidin has a very impressive phytopharmacological profile and could be used for the development of new molecule for the treatment of various disorders including its health beneficial aspects in the future.

Conflict of interest statement

The authors report no conflict of interest.

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