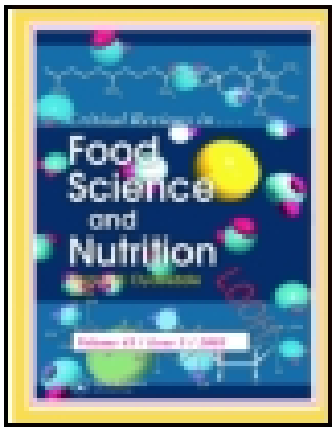

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Health Benefits of Anthocyanins and Their Encapsulation for Potential Use in Food Systems: A Review

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Health benefits of anthocyanins and their encapsulation for potential use in food systems: A review

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Abstract

Anthocyanins are one of the six subgroups of large and widespread group of plant constituents known as flavonoids. They are responsible for the bright attractive orange, red, purple, and blue colors of most fruits, vegetables, flowers and some cereal grains. More than 300 structurally distinct anthocyanins have been identified in nature. Earlier, anthocyanins were only known for their coloring properties but now interest in anthocyanin pigments has intensified because of their possible health benefits as dietary antioxidants, which help to prevent neuronal diseases, cardiovascular illnesses, cancer, diabetes, inflammation and many such others diseases. Ability of anthocyanins to counter oxidants makes them atherosclerosis fighters. Therefore, anthocyanin

rich foods may help boost overall health by offering an array of nutrients. However, the incorporation of anthocyanins into food and medical products is challenging task due to their low stability towards environmental conditions during processing and storage. Encapsulation seems to be an efficient way to introduce such compounds into these products. Encapsulating agents act as a protector coat against ambient adverse conditions such as light, humidity and oxygen. Encapsulated bioactive compounds are easier to handle and offer improved stability. The main objective of this review is to explore health benefits of anthocyanins and their extraction, characterization, encapsulation and delivery.

***Key Words*:** anthocyanins, flavonoids, encapsulation, health benefits, antioxidants, coloring agent

Introduction

Color plays an important role in the acceptability of foods. Colorants are being used in food industry since centuries to enhance or at least restore original appearance of foods or to ensure uniformity, as an indicator of food quality. Color is the first characteristic perceived by the senses. Synthetic colorants have always been a question of controversy regarding their safety. Consumers prefer natural colorants than the synthetic ones as they are increasingly concerned with the safety of synthetic colorants. Therefore, interest in natural colorants has significantly increased as a consequence of both legislative action and consumer awareness. Anthocyanins have a great potential in replacing many of these synthetic colorants.

Anthocyanins (Greek *anthos* = flower and *kianos* = blue) are the common coloring compounds found in a large number of plants (Table 1). Chemically anthocyanins are phenolic compounds belonging to the flavonoids, with two benzene rings joined by a linear three carbon chain, possessing the C6ï C3ï C6 basic skeleton (Wilska, 2007). More than 600 different anthocyanins and their substituents have been reported (Veitch and Grayer, 2008). Anthocyanins are formed by modification of anthocyanidins by glycosyl and aromatic or aliphatic acyl moieties (Castaneda *et al.,* 2009; Oren, 2009). They may be present in leaves, flowers and fruits. Anthocyanins are a group of myriad coloring compounds that represent different colors such as purple, red, blue and orange. They play an important role in the color quality of both fresh and processed fruits, vegetables, and other plants products. Anthocyanins are normally found dissolved uniformly in the vacuolar solution of epidermal cells (Rogez *et al.,* 2011). Anthocyanin-rich extracts are increasingly attractive to the food industry as natural substitutes to synthetic FD&C dyes and lakes, because of their coloring properties (Bueno *et al*., 2012). They

are non- toxic and water soluble which leads to their easy incorporation in food systems and are thus of great interest for their use as natural water soluble colorants (Pazmino *et al.,* 2001[a]). The stability of anthocyanins during processing and storage is an area of concern. Due to their poor stability, they undergo degradation during processing. Incorporation of anthocyanins in different food systems is therefore, a challenging task and encapsulation seems to be a way forward. Anthocyanins find wide application in food and beverage industry. This includes use in products such as syrups, soft and alcoholic drinks, confectionery, sweet dressings, jams, jellies, dairy products, powder mixes and bakery products. They also have potential application in pharmaceutical industry.

Chemistry

Anthocyanins are phenolic compounds belonging to the flavonoid family responsible for the color of the petals of flowers and the fruits of a great variety of plants (Strack and Wray, 1989), as well as for the color of products that are made from colored vegetable matrices like wine (Mazza, 1995).

Anthocyanins possess two benzene rings joined by a linear three carbon chain (C2, C3, C4), as represented in Figure. 1. This means they possess C6ï C3ï C6 basic skeleton (Wilska, 2007).

Anthocyanins are chemically glycoside moieties of anthocyanidins derived from the flavylium or 2-phenylbenzopyrilium cation. Out of several anthocyanidins found in nature, six are more common and widespread which include cyanidin, delphinidin, pelargonidin, peonidin, petunidin and malvidin (Table 2). Being polar in nature anthocyanins are soluble in polar solvents such as methanol, ethanol and water. This is the reason why most of the extraction processes are

designed to use such solvents. These solvents are being acidified to stabilize anthocyanins in the flavylium cation.

Anthocyanins show structural variations which are mainly due to differences in the number of -OH moieties in the molecule, the degree of methylation of ï OH moieties, the nature and number of the sugar moiety attached to the aglycone molecule and the specific position of these attachments. Additionally anthocyanins also vary in their quantity depending upon the source in which they are present (Table 3).

Role of anthocyanins in human health

In addition to coloring properties, anthocyanins exhibit strong anti-oxidant activity which helps to prevent neuronal diseases, cardiovascular illnesses, cancer, diabetes, inflammation and many such others diseases. Anthocyanins are reported to have effect on treatment of cancers (Nichenametla *et al.,* 2006) and human nutrition (Stintzing & Carle, 2004). They are reported to be effective in suppressing tumor growth by arresting cell growth between S phase and G2 phase of the cell cycle (Koide *et al.,* 1996). Ability of anthocyanins to counter oxidants makes them atherosclerosis fighters. Anthocyanins are found to relax blood vessels and protect the integrity of the endothelial cells that line the blood vessel walls. Based on animal experiments, strawberry has been shown to have inhibitory effect against esophageal cancer and reverses the neuronal and behavioral aging in these experimental animals (Torronen and Maatta, 2002). This therapeutic activity of strawberries has been correlated with anthocyanin content in these fruits. Other health benefits of anthocyanins include allergy relief, healthy heart (Basu *et al.,* 2010; Wallace, 2011), better eyesight (Ghosh & Konishi, 2007), ulcer treatment and cognitive function (Moskovitz *et al.,* 2002). They have been found to have positive effects in the treatment of various diseases

resulting from capillary fragility (Tamura, *et al.,* 1994). For instance preventing cholesterol-induced atherosclerosis and inhibiting platelet aggregation.

Therefore, due to the interesting coloring and heath properties, researchers are involved in exploring the natural potential of anthocyanins. Large number of reports are found in the literature regarding the techniques for purification and separation of anthocyanins (Blevea *et al.,* 2008), application of anthocyanins in food (Giusti & Wrolstad, 2003), identification and distribution in plants (Matera *et al.,* 2012), stability (Cavalcanti *et al.,* 2011; Durge *et al.,* 2013), quantitative analysis using chromatographic and electrophoretic techniques (Huang *et al.,* 2009) and their degradation kinetics (Reyes *et al.,* 2007)**.**

Bioavailability of anthocyanins

The bioavailability is the proportion of a particular nutrient that is digested, absorbed, and metabolized through normal pathways. Bioavailability of anthocyanins is a major issue regarding their biological effects. To perform their multiple effects the bioavailability of anthocyanins present in different fruits and vegetables is important, but it still remains not so well understood issue. Anthocyanins need to be ingested and distributed within the body successfully. However, as anthocyanins are usually ingested in combination with different food sources, the effect of food matrixes on their absorption makes bioavailability studies more complex.

Various studies have been carried out to investigate the bioavailability of anthocyanins (Clifford, 2000; McGhie & Walten, 2007). The bioavailability of anthocyanins is less than 1% (Bub *et al.,* 2001; Matsumoto, et al., 2001; Manach *et al.,* 2005) Anthocyanins containing different glycosides have different bioavaliabilities. In general, non-acylated anthocyanins are better absorbed than acylated ones (Tsuda, *et al.,* 1996; Zhang, *et al.,* 2005).

Bub *et al.* (2001) while studying malvidin-3-glucoside (M3G), an anthocyanin, occurring in red wine and red grape juice reported that M3G is poorly absorbed and not anthocyanins themselves rather yet not defined anthocyanin metabolites or other polyphenols might be responsible for the observed antioxidant and health effects. Anthocyanins are rapidly absorbed and eliminated and that they are absorbed with poor efficiency (Manach *et al.,* 2005). As such, continuous intake of anthocyanins may be needed for their systemic benefits.

Extraction of anthocyanins

Various methods are available for the extraction of active components from plant sources. However, the selection of suitable method depends on many factors such as the economic viability and appropriateness of the process to the particular circumstance.

Anthocyanins are polar molecules, extracted from various fruits and vegetables and more interestingly they can be obtained from otherwise waste materials as well (Clifford, 2000). Aqueous mixtures of ethanol, methanol or acetone are used for anthocyanin extraction (Kahkonen *et al.,* 2001). As per the previous literature available, anthocyanins are most commonly being extracted by solvent extraction method and more particularly by using HCl and methanol (Durana *et al.,* 2011). The extraction may be enhanced by using agitation or stirring techniques. The extract so obtained can then be filtered and vacuum-concentrated using rotary evaporator. In order to avoid thermal degradation of anthocyanins, membrane technologies such as ultrafiltration and nanofiltration can be used for their concentration which gives concentrate of similar quality as the initial extract (Cisse *et al*., 2011). They also concluded that membrane processes could be of great interest to pre-concentrate the extracts without thermal damage before final concentration (vacuum evaporation, osmotic evaporation) or spray drying. However,

further research is needed to better explore the potential of membrane processes as attractive alternatives for producing concentrate of anthocyanin extract and to evaluate economy of the process at industrial scale.

Radish anthocyanins were extracted by using acidified methanol (concentrated HCl/methanol = 0.01:100 ml) (Jing *et al.,* 2012). Recently the Aqueous two-phase extraction (ATPE) was used for the extraction or isolation of natural products from crude extracts, such as betalains (Chethana *et al.,* 2007) in case of mulberry. ATPE is recognized as an effective, versatile and important emerging technique for the downstream processing of biomolecules. Aqueous two-phase extraction has recently been used in case of anthocyanins extraction from mulberry. The extract showed a relatively high antioxidant activity compared with conventional extraction without affecting the composition of the anthocyanin mixture (Wu *et al.,* 2011).

Supercritical fluid extraction (SFE) can act as a potential alternative to organic solvent extraction, a commonly used method for extraction of these compounds. Supercritical fluid extraction (SFE) can be highly beneficial as it is rapid and automatically controlled process. SFE methods are selective and they do not require the use of large quantities of toxic solvents. One more advantage is the absence of light and air during the extraction and hence there is a reduction in the degradation processes during extraction as compared to the conventional extraction techniques. However, due to the polarity of anthocyanins the extraction of anthocyanins by SFE method using CO_2 requires high pressures and high percentage of an organic co-solvent (Mantell *et al.,* 2003).

Anthocyanins can also be extracted by microwave-assisted extraction procedure. In case of microwave-assisted extraction (MAE), the energy from microwaves gives rise to molecular

movements and rotation of liquids with a permanent dipole. This in turn gives rise to rapid heating of the material. Microwave-assisted extraction leads to improved efficiency, low solvent consumption and reduced extraction time. Yang and Zhai (2010) carried out microwave-assisted extraction of anthocyanins from purple corn (Zea mays L.) cob and concluded that the microwave assisted extraction was highly efficient and rapid in comparison with the conventional solvent extraction Similar results were reported by Liazid *et al.,* (2011) and Zou *et al.,* (2012) for microwave assisted extraction of anthocyanins from grape skin and mulberry respectively.

Ultrasound-assisted extraction (UAE) is another potential alternative to time consuming and comparatively low efficient conventional solvent extraction method. Ultrasound-assisted extraction makes use of acoustic cavitations which cause molecular movement of solvent and sample. UAE also has more or less same advantages over conventional solvent extraction method as mentioned in case of MAE. In addition to this such techniques also achieve high level of automation and increased yield of the target compound in comparison to conventional extraction techniques. Chen *et al.,* (2007) carried out ultrasound-assisted extraction of anthocyanins from red raspberries and optimized the process conditions by using Response surface methodology (RSM). In addition to being more efficient than conventional solvent extraction process, UAE is efficient and rapid method to extract anthocyanins. This can be due to the strong disruption of fruit tissue structure under ultrasonic acoustic cavitation (Chen *et al.,* 2007).

Characterization of anthocyanins

Characterization of anthocyanins can be carried out by variety of methods developed so for. Some commonly used techniques include high-performance liquid chromatography (HPLC), thin layer chromatography, nuclear magnetic resonance (NMR) spectroscopy, mass spectroscopy, Electrospray ionization mass spectroscopy (ESI), and liquid chromatographyï mass spectrometry (LC/MS).

In general, anthocyanins are purified by using C_{18} columns or by C_{18} solid phase extraction (SPE) cartridges. Then they can be analyzed by HPLC. Prior to this, anthocyanins are to be extracted. For extraction of anthocyanins the raw material is first ground. The ground material is treated with suitable solvents and the mixture is filtered through a Buchner funnel or Whatman filter papers. It is then concentrated by rotary evaporator at 30°C. This will yield a crude extract which is loaded on a C_{18} solid phase extraction cartridge. The loaded cartridge is then washed with suitable solvents. The solvent fraction containing the anthocyanins is evaporated to dryness on a rotary evaporator. The anthocyanins are resolubilized in an appropriate solvent and filtered through a Millipore filter (0.45 pm) prior to high performance liquid chromatography (HPLC). Identification of these anthocyanins can be made according to their HPLC retention times, elution order and comparison with authentic standards. This process is summarized in a flow sheet as described in Figure 2.

Vareed *et al.,* (2005) quantified anthocyanins from various species of genus *Cornus* by using HPLC. *Cornus* plants are widely grown as ornamentals throughout the United States.

Anthocyanins were extracted and separated by reverse-phase high-performance liquid chromatography and Sephadex LH 20 chromatography from the flowers of pomegranate (Zhang *et al.,* 2011). They identified two anthocyanins namely pelargonidin 3,5-diglucoside and

pelargonidin 3-glucoside. These two anthocyanins were identified from pomegranate flowers for the first time.

Characterization and quantification of anthocyanins in black and green tea products processed from some selected tea cultivars have been reported by Kerio *et al.,* (2012). They found that green tea contains significantly higher anthocyanin content than that of black tea. This can be due to the degradation of anthocyanins during the (fermentation) process of black tea manufacture.

Lee and Choung (2011) identified and characterised seven anthocyanins from *Liriope platyphylla* fruits by reversed-phase C18 column chromatography, NMR spectroscopy, and HPLC-DAD-ESI/MS analysis.

Stability of anthocyanins

Some limitations that have restricted the use of natural colorants in food systems are their relatively low stability to several processing conditions, formulation and storage conditions, and that they may impart undesirable odor or flavor characteristics to the final product. However, most of the foods that are natural sources of anthocyanins are often processed by subjecting them to severe temperature, pressure, and pH conditions which may result in loss of these naturally occurring pigments or at least reduce their antioxidant potential. The isolated anthocyanins are highly unstable and very susceptible to degradation (Giusti & Wrolstad, 2003). The stability of anthocyanins is affected by several factors such as pH, storage temperature, chemical structure, concentration, light, oxygen, solvents, the presence of enzymes, flavonoids, proteins and metallic ions (Rein, 2005). However, the chemical structure of anthocyanins is believed to be a major factor influencing the stability of these pigments.

The thermal stability of radish anthocyanin extracts from Tou Xin Hong area was investigated at 90 and 100 °C for 24 h. Multiple acylation with hydroxycinnamic acids contributed to remarkable stability of radish anthocyanins towards heat in an acidic environment (Jing *et al.,* 2012).

Pelargonidin 3-glucoside is the major anthocyanin present in strawberries and is responsible for their attractive, bright red color. The stability of pelargonidin-based anthocyanins at varying water activity levels was investigated by Garzon and Wrolstad (2001). According to their study, anthocyanin degradation followed first order kinetics and their degree of degradation increased with water activity. It was also observed that half lives of the anthocyanins ranged from 56 to 934 days.

Idham *et al.,* (2012) studied the degradation kinetics and color stability of Spray-dried encapsulated anthocyanins from *Hibiscus sabdariffa* concluding that encapsulation of anthocyanins with polysaccharides followed by appropriate processing may enhance the stability of anthocyanins for efficient utilization in food systems. They observed that combination of maltodextrin and gum arabic had the highest encapsulation efficiencies.

The presence of ascorbic acid has been shown to have a negative impact on anthocyanin stability. High ascorbic acid content has been found to be the main cause of the low stability of anthocyanin extracts from acerola (Veridiana *et al.,* 2006). Acerola is one of the rich and natural sources of ascorbic acid and thus, its influence on the stability of anthocyanins from acerola extracts has been determined and compared to those from acai, which contain no ascorbic acid. They also observed that the color fading was becoming more prominent as higher level of ascorbic acid was added to acai anthocyanin solutions.

Stability of anthocyanins from black carrot in various fruit juices and nectars was investigated by Kirca *et al.,* (2005). Anthocyanin degradation, in all colored juices and nectars, followed first-order reaction kinetics.

Encapsulation of anthocyanins

Although anthocyanins posses potential health-promoting properties and are regarded as promising natural food colorants, their unstable nature unfortunately acts as an obstacle in their practical applications. Anthocyanins possess low stability towards environmental conditions during processing and/or storage. The isolated anthocyanins are highly unstable and very susceptible to degradation (Giusti & Wrolstad, 2003). Therefore, use of anthocyanin pigments in foods has been hampered by their poor stability and in turn their incorporation into food and medical products appears to be a challenging task. Encapsulation seems to be an efficient way to introduce such compounds into these products. Encapsulating agents act as a protecting coat against ambient adverse conditions, such as light, humidity and oxygen. Encapsulated bioactive compounds are easier to handle and offer improved stability. Encapsulation techniques have already been in wide use to reduce interactions of food and medicinal components with environmental factors, such as temperature, light, moisture and oxygen.

Microencapsulation may be a useful method to protect sensitive food ingredients such as anthocyanins until they reach the target organ. Maltodextrin is often used as a wall material for microencapsulation. Idham *et al.,* (2012) observed that microencapsulation of anthocyanins with a combination of maltodextrin and gum arabic resulted in the highest encapsulation efficiencies. They also reported that combination of maltodextrin and gum arabic as wall material gave the longest shelf life and the smallest change in the pigment color. To encapsulate anthocyanins and

betacyanins, maltodextrin with dextrose equivalents between 10 and 25 have been used (Ersus and Yurdagel, 2007). Berg *et al.,* (2012) carried out microencapsulation of anthocyanins and investigated influence of different pectins on powder characteristics of microencapsulated anthocyanins.

Different techniques that are used for microencapsulation include spray drying, coacervation ï phase separation process, pan coating process, solvent evaporation process, air suspension process, interfacial polymerization, and multi orifice centrifugal process.

Spray drying is commonly applied method for the microencapsulation of extracted plant phenolics, like anthocyanins. Polysaccharides such as maltodextrin, inulin, gum Arabic, tapioca starch, citrus fibre and other matrix materials like glucose syrup and soy protein isolate are mainly used as matrix materials. Starches being widely available can be used for containment of flavor essences and other components by spray drying in a manner that will provide an oxidative protection and for a controlled release over defined period of time (Wani *et al*., 2012). The use of natural polymers as coating material can enhance the anthocyanin stability and can help in controlled release of these functional ingredients in the human body for more efficient nutraceutical usage. By means of spray drying method, the encapsulated plant phenolics are stabilized against degradation due to the impact of oxygen and light during dry storage. Previous studies show that encapsulation conditions such as gelling agent and technique applied can directly influence the anthocyanin degradation.

Encapsulation by freeze-drying of Roselle (*Hibiscus sabdariffa*) anthocyanins using different coating materials such as maltodextrin, trehalose and gum Arabic has been reported (Gradinaru

et al. 2003; Duangmal *et al*. 2008; Selim *et al*. 2008). However, the freeze-drying method is costlier than spray-drying (Diaz *et al*. 2006).

Coacervation is an expensive process and has recently been used for food grade encapsulation only. This process was developed in the 1950ôs as a means of providing a two ink system for carbonless copy paper (Shahidi and Han, 1993). Coacervation consists of three steps which must be carried under continuous agitation. First step is formation of three immiscible phases ï a liquid manufacturing vehicle phase, a core material phase, and a coating material phase. Second step involves deposition of the liquid polymer coating upon the core material followed by rigidization of the coating usually by thermal or cross-linking techniques to form self-sustaining microcapsules, which is the final step of coacervation.

Pan coating process, an oldest industrial procedure for forming small and coated particles has got wide applications in pharmaceutical industry. In this process the particles are tumbled in a pan while the coating material is applied slowly (Tiwari *et al.,* 2010).

In air-suspension coating process solid particulate core materials is dispersed in a supporting air stream followed by spray coating these air suspended particles. Air-suspension techniques can be effectively applied to core materials comprised of micron or submicron particles, but agglomeration of the particles to large size may occur (Bansode *et al.,* 2010).

In solvent evaporation process microcapsule coating is dissolved in a volatile solvent which is immiscible with the liquid manufacturing vehicle phase. A core material to be microencapsulated is dispersed in the coating polymer solution. This core-coating mixture is dispersed in the liquid manufacturing vehicle phase to obtain the appropriate size microcapsules (Dubey *et al.,* 2009).

Interfacial polymerization is characterized by the polycondensation of two reactants which meet at an interface and react rapidly. Therefore, the technique is based on the polymerization of the reactive monomers which form capsule shell on the surface of the droplet or particle. The substances used are multifunctional monomers (Agnihotri *et al.,* 2012). Polymerization occurs on the interface formed by the dispersed core material and continuous phase.

Encapsulation of anthocyanins by techniques other than spray drying still remains an unexplored area and is therefore, a promising area of research.

Conclusion

Anthocyanins are important components present naturally in most of the fruits, vegetables and in some cereals. In addition to the coloring properties they provide a number of health benefits but are very sensitive to environmental conditions during processing and storage. Encapsulation can be used to improve stability of anthocyanins. Till now no substantial work has been done on microencapsulation of anthocyanins. Only a few researchers have worked on this area and use of spray drying method for encapsulation has been reported. However, use of other techniques for encapsulation of anthocyanins is still an unexplored field of research. Researchers have also used maltodextrin as the coating material for microencapsulation of anthocyanins. Different coating materials can be exploited to with stand different conditions of processing and for target delivery of anthocyanins. Therefore, ample opportunities exist to explore this field of research and to take it from its infancy to a well examined stage.

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Table 1: Major anthocyanins from selected plant sources

Plant source	**Anthocyanins**
Apple, elderberry, blackberry, pear, peach, fig, cherry, red onion, red cabbage, rhubarb, gooseberry	Cyanidin
Banana, red radish, strawberry, potato	Pelargonidin
Pomegranate, black currant, gooseberry, purple carrot, blood orange, egg plant, green bean	Cyanidin and delphinidin
Pomegranate, passion fruit, eggplant, green bean	Delphinidin
Plum, sweet cherry, purple sweet potato	Cyanidin and peonidin
Mango	Peonidin
Bilberry, red grape	Petunidn and malvidin

Adapted from: (Bueno *et al.,* 2012)

Table 2: Six common anthocyanins found in nature

Anthocyanidin	**R1**	**R2**	**R3**
Cyanidin	OH	OH	H
Delphinidin	OH	OH	OH
Malvidin	OCH3	OH	OCH3
Pelargonidin	H	OH	H
Peonidin	OCH3	OH	H
Petunidin	OCH3	OH	OH

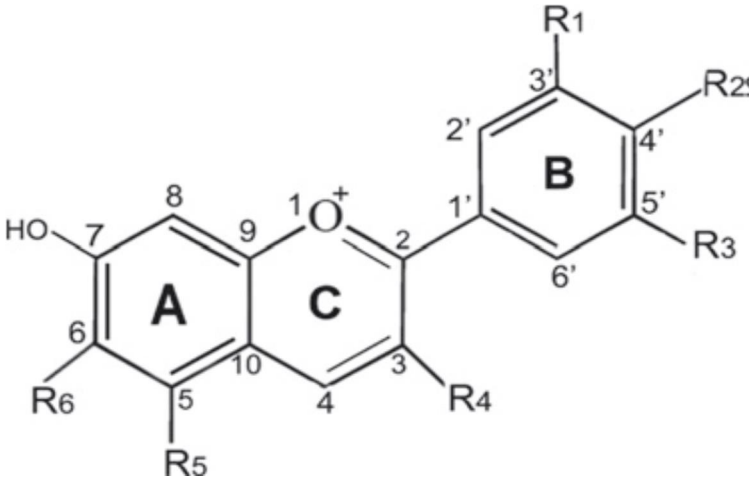
Adapted from: (Kerio *et al.,* 2012)

Table 3: Quantity of anthocyanins reported from different sources.

Name of source	Content /range	Reference
Purple-skinned Jumbo	4.10 (mg/g)	Huang *et al.,* (2009)
Cowart muscadine	2.60 (mg/ g)	Huang *et al.,* (2009)
Banana bracts	32ï 250 (mg/100 g)	Pazmino *et al.,* (2001)[b]
Red radish	154 (mg/100 g)	Giusti & Wrolstad (1996)
Different Chinese radish cultivars	63.77ï 160.74 (mg/100 g)	Jing *et al.,* (2012)
Red wine grapes	30 to 750 (mg/100 g)	Mazza & Miniati (1993).
Strawberry	13ï 315 (mg/100 g)	Silva *et al.,* (2007)
Fresh blackberries	75 mg/100 g	(Ju *et al.,* 2005; Ngo *et al.,* 2007).
A hybrid of fresh strawberries	71.8 mg/100 g	(Ju *et al.,* 2005; Ngo, *et al.,* 2007).
Capulin	31.7 (mg/100 g)	Ordaz *et al.,* (1999)
Black raspberries	145ï 607 (mg/100 g)	Tian *et al.,* (2006)
Acerola pulp	7.21 (mg/100 g)	Rosso & Mercadante (2007).
Acai pulp	282.5 (mg/100 g)	Rosso & Mercadante (2007).

Roselle	230 (mg/100 g)	Tsai *et al.,* (2002)
Corncobs	290ï 1323 (mg/100 g)	Jing and Giusti (2005)
Berries	23.7 (mg/100 g)	Longo and Vasapollo (2006)
Kokum	1000ï 2400 (mg/100 g)	Nayak *et al.,* (2010).
Red onion	219±34 (mg/100 g)	Donner *et al.,* (*1997*)
Grape peel powder	171.42 (mg/100 g)	Ma *et al.,* (2012)
Black rice cultivars	79.5ï 473.7 (mg/100 g)	Chen *et al.,* (2012)
Red rice	7.9ï 34.4 (mg/100 g)	Chen *et al.,* (2012)

Figure 1: Basic structure of anthocyanins



Adapted from: (Yi *et al.,* 2009)**.**

Figure 2: General extraction and identification procedure for anthocyanins.