Natural Plant Pigments and Derivatives in Functional Foods Developments

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Abstract

Food colour contributes to food acceptability. Hitherto, colours for foods are obtained from artificial sources or chemicals. However, there is a gradual shift in sourcing food colouring materials from artificial sources to natural pigments. This was meant to utilize functional properties in natural pigments such as bioactive activities, anticancer potentials, production of vitamin A, and so on in addition to enhancing consumers' acceptability. Some of the functional compounds in natural pigments are polyphenols, antocyanins, chlophyll a & b, carotenoids, betalains, and so on. These compounds possess potent antioxidants, antidiabetics, vasoprotective, anti-inflammatory, anti-cancer, chemoprotective and anti-neoplastic properties. Carotenes serve as precursor of vitamin A. Isolation and utilization of natural pigments will prevent side effects notable in artificial colouring agents in addition to reducing the prevalence of some diseases like diabetics, cancer and cardiovascular disease. The functionalities of these natural compounds in foods promotes health of the consumers.

Keywords: Antioxidants; Carotenoids; food colours; functional properties; natural pigments; vasoprotective.

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INTRODUCTION

Food Pigments

Food pigments are substance in food that determine colour of food and or can be used to colour foods. Colour of food influence consumer acceptability of a particular food. First colouring agent was produced from natural source (Petropolous *et al*., 2019), example is the pigments from beet root, but was later abandon due to high cost of production, and variation in resulting colour. However, natural source of colour additives is gaining interest nowadays due to several health deteriorating issues resulting from the use of synthetic colouring agents. Pigments of natural source has been reported to contribute to the overall antioxidant capacity in a dose-dependent and compound-specific manner (McGill, 2009; Agcam *et al* 2017; Petropoulos *et al*., 2019). Important compounds in natural pigments are some polyphenols, carotenoids, chlorophylls and betalains (Shoji, 2007; Aberoumand, 2011).

There are other types of pigment made by modification of plant components such as protein, amino acids, lipids and sugars which result in pigments such as caramel, vegetable carbon and Cu-chlorophyllium (Aberoumand 2011).

Polyphenols are secondary metabolites of plants, which are usually classified into non-flavonoids and flavonoids based on their structure. Non-flavonoids are mostly colourless and do not contribute to the pigment in plant while most flavonoids do. Main flavonoids that contribute to pigment are flavonols, flavones and anthocyanin. Flavonols and flavones are yellow whereas anthocyanins can be orange, red, blue or purple in colour. Flavonols and flavones generally have relatively low solubility in water and this reduces its contribution to food colour as compared to anthocyanins (Shoji, 2007). Xanthones and quinones are flavonoids that also exist in plants as minor pigments.

Anthocyanins pigment provide the red, purple, blue, and pink shade of many fruits, vegetables and flowers and participate in various physiological processes including photosynthesis and pollination by attracting pollinators (Menzies *et al*., 2016; Petropoulos *et al*., 2019). Anthocyanins are glycosides and acylglycosides of anthocyanidins. There are about 250 naturally occurring anthocyanins in form of delphinidin, cyanidin, pelargonidin, marvidin and peonidin and all are o-glycosylated with different sugar substitute. The common anthocyanins are 3- or 3,5-glycosylated (Wang *et al*.,1997; Espin *et al*., 2000). A single anthocyanin can produce various tones and strength of colours in different flowers. Anthocyanins has been detected in appreciable quantity in many fruits and vegetables which include.

Chlorophylls are green pigments found in all higher plants which take part in the photosynthesis. Chlorophyll is a macrocyclic tetrapyrrole with coordinated magnesium in the center. There are two types of chlorophyll (chlorophyll a and b) found in green plant (Ngamwonglumlert *et al*., 2015; Rodriguez-amaya, 2018). Chlorophyll a and b contain methyl group (CH_3) and formyl group (CHO) respectively on carbon C-3 of tetrapyrrole ring of the chlorophyll structure. Chlorophyll a appears blue-green and chlorophyll b yellow-green (Rodriguez Amaya, 2018). Derivatives of chlorophyll a and b due to degradation by heat (Rodriguez-Amaya, 2018) are pheophytin (formed by replacement of magnesium atom by hydrogen), pyrophophytin (formed by replacement of carboxymethoxy group at C-10 by hydrogen), chlorophyllide (formed by removal of phytol at C-7), pheophorbide (removal of phytol and magnesium), pyropheophorbide (removal of phytol, magnesium and carboxymethyl group) (Von Elbe and Schwartz, 1996; Rodriguez-Amaya, 2018). Loss of chlorophyll pigment in thermally processed green vegetables has been reported to be due to formation of pheophytin and pyropheophytin derivatives of chlorophyll giving olive brown colour (Ngamwonglumlert *et al*., 2015; Rodriguez-Amaya, 2018). Chlorophyll b has been reported to be more heat stable than chlorophyll a. (Vonelbe and Steven Schwartz 1996). The stability was attributed to electron-withdrawing effect of its C-3 formyl group (Rodriguez Amaya, 2018).

Carotenoids are also part of photosynthetic process and are nature's most widespread pigments. Carotenoids, mostly identified with yellow-orange colour of many plants (Petropoulos *et al.*, 2019) serves as secondary pigments to harvest light energy in all chlorophyll-containing tissues (Ngamwonglumlert *et al*., 2015; Petropoulos *et al*., 2019). Some carotenoids are bound with chlorophyll which gives rise to a variety of attractive colours in plants, fruits and vegetables (Rao and Rao, 2007). Carotenoids are generally of two types, carotenes containing only carbon and hydrogen, and xanthopyll made up of carbon, hydrogen and oxygen (Mortensen, 2006). Common carotenoids in plants are α-carotene, β-carotene, capsanthin, lutein, lycopene, zeaxanthin. Animals obtained carotenoid from plant, human body cannot synthesis carotenoid but are accumulated in some organs and tissues.

Betalains composed of a nitrogenous central structure, betalmic acid, glucosyl derivatives or aminoacid derivatives. Betalmic acid condenses with imino compounds (like cyclo-L-3,4-dihydroxy-phenylalanine) to form variety of colorful pigments (Qaisar *et al*., 2019). Betalain pigment is an important natural pigment earlier developed from beet roots for use in food industry.

Colouring agents and additives from natural source is gaining more interest food industries due to health benefit to be derived from such. There had been increase in research focusing on natural pigments source, extraction, stability during processing, health benefits and limitation to the use of such pigments in food production. Hence, this study is to review some pigments with special emphasis on their functional properties. The sources of such pigments were also reviewed.

FUNCTIONAL FOODS

Functional foods (nutraceuticals) are whole, fortified or enhanced foods that can provide health benefits beyond the provision of essential nutrients (vitamins and nutrients) when they are consumed. In addition to improving the well-being of consumers, they also reduce risks of diseases (Coisson *et al*., 2005). Functional foods have a potentially positive effect on health beyond basic nutrition (Coisson *et al*., 2005). The functionality of functional foods is as a result of the presence of bioactive compounds in them. Bioactive compounds (also known as nutraceuticals) have been defined as essential and nonessential food compounds (carotenoids, essential oils, antioxidants, flavours, pigments, vitamins, polyphenols) that occur naturally and have an effect on human health (Biesalski *et al*., 2009). A vital benefit of nutraceuticals is that they are associated with a lower risk of chronic diseases (Biesalski *et al*., 2009).

Sources of bioactive compounds include, fruits, vegetables, vegetable oils, essential oils, plant by-products, plants, have been discovered to be rich sources of natural bioactive compounds (Awolu, Ojo, Igbe *et al*., 2017; Ajila *et al*., 2007). Other sources are, peels, stems, seeds, shells, bran and residues remaining after extraction of juice, oil, starch and sugar (Awolu *et al*., 2017; Baiano, 2014).

COMMON PLANT PIGMENTS AND FUNCTIONALITIES

Common colourants, their chemical classifications, source and E numbers are presented in Table 1. They include anthocyanins, betalains, caramel, carotenoids, chlorophyll and curcuminoids.

Anthocyanins pigments

Anthocyanins are recognized as natural alternatives for dyes, though commercial use as dye may not be economically feasible. Anthocyanins are reported to be used as functional compounds for colouring food and as a potent agent against oxidative stress (Downham and Collins, 2000). It prevented lipid peroxidation of cell (Noda *et al*., 2002). Studies have revealed that anthocyanins possess vasoprotective, anti-inflamatory, anti-cancer, chemoprotective, and anti-neoplastic properties (Awika *et al*., 2004) thereby showing a protective effect against coronary diseases. Researchers has established that natural anthocyanin-based pigments extracted from black-chokeberry (623 μg/mg), black-thorn (151 μg/mg), strawberry (54.8 μg/mg) and elderberry (5 μg/mg) serves as colourant and at the same time possess antiradical properties (Espin *et al*., 2000).

Anthocyanins has been reported to be effective in the treatment of diabetic retinopathy, in fibrocystic disease of the breast in human and in treatment of various microcirculation diseases resulting from capillary fragility (Wang *et al*., 1997). Anthocyanin have increased stability at reduced water activity, therefore, they are suitable for colouring dried and intermediate moisture foods.

Table 1. Major colorants from natural sources (or nature identical): chemical classification sources, colours, and regulatory status in the United States and European Union (Sigurdson *et al*., 2017).

Chemical classification	Additive	Source	Color	Use in the United States	E number
Anthocyanin	Grape skin extract	Grapes (marc from pressing)	Red to purple to blue	Beverage food	E163
	Grape color extract	Concord grapes (*Vitis labrusca*)		Non-beverage	
	Fruit juice	Berries		General	
	Vegetable juice	Carrot, cabbage, and others		General	
Betalain	Beet powder	Beet (*Beta vulgaris*)	Pink to red	General	E162
Caramel	Caramel	Heating of sugars	Brown	General	E150
Carminic acid	Cochineal extract	*Dactylopius coccus*	Orange to red	General	E120
Carotenoid	Annatto	*Bixa orellana* L.	Yellow to orange to red	General	E160b
	Astaxanthin	Synthesized, bacterium (*Paracoccus carotinifaciens*), yeast (*Phaffia rhodozyma*), algae (*Haematococcus pluvialis*)		Fish feed	NA
	β-Carotene	Natural (carrots) or synthesized		General	E160a
	Canthaxanthin	Synthesized		Fish feed and chicken skin	E161g
	Carrot oil	Carrot (*Daucus carota* L.)		General	NA
	Corn endosperm oil	Yellowcorn(*Zea mays*)		Chicken feed	NA
	Paprika (oleoresin)	Paprika (*Capsicum annum* L.)		General	E160c
	Paprika			General	E160c
	Saffron	Stigma (*Crocus sativus* L.)		General	NA
	Tagetes	Aztec marigold (*Tagetes erecta* L.)		Chicken feed	NA
	Tomatolycopene	Tomato (*Solanum lycopersicum*)		General	E160d
	β-Apo-8^{r}-carotenal	Synthesized		General	E160a
Chlorophyll	Sodium copper chlorophyllin	Alfalfa (*Medicago sativa*)	Green	Citrus-based dry beverage mixes	E141
Curcuminoid	Turmeric (oleoresin)	Rhizome (*Curcuma longa* L.)	Yellow	General	E100

Carotenoids pigments

Common carotenoids in plants are α-carotene, β-carotene, capsanthin, lutein, lycopene, zeaxanthin with β-carotene as the most common carotenoid in plant tissue and is commonly used as colourant in foods.

Carotenoid serves as precursor of vitamin A with carotenoids containing β rings having greatest provitamin A activity. Provitamin A carotenoids are converted into retinol and other related retinols, which play important roles in the visual cycle and in gene regulation, in mammals (Roridguez *et al*., 2018). High intake of carotenoids has been reported to promote cognitive function, improve immune system and lower the risk of developing cardiovascular and degenerative chronic diseases such as cancer and macular degeneration (Voutilainen *et al*., 2006; Rao and Rao, 2007; Rodriguez-Amaya, 2018). Action of carotenoids against diseases has been attributed to their antioxidants ability to scavenge free radicals that cause oxidative damage which result from such diseases. Carotenoids have also been reported to possess some non-antioxidants mechanisms such as retinoid-dependent signalling, modulation of carcinogen metabolism, regulation of cell growth, modulation of DNA repair mechanisms (Stahl *et al*., 2002; Rao and Rao, 2007; Rodriguez-Amaya 2018).

Chlorophylls pigments

Artificial chlorophyll pigments, chlorophyllin, is commonly used as food-colouring agents in sugar confectionaries, desserts, sauces and condiments, cheese and soft drinks (Inanc, 2011). Chlorophyll from plant source has been reported to have positive effect when used to treat wound and inflammation. Studies have shown that chlorophyll form complexes with certain chemicals that cause cancer and the complex structure formed interfere with gastrointestinal absorption of potential carcinogen, thereby reducing the amounts of carcinogen substances in susceptible tissue (Breinholt *et al.*, 1995; Egner *et al*., 2003; Cing-Yun *et al*., 2008; Inanc 2011). Several researchers (Hoshina *et al*., 1998; Ferruzzi *et al*., 2002) reported that chlorophyll and its derivatives support antioxidants, however, other researchers reported that antioxidant activity of chlorophyll is light dependent as it has pro-oxidants effects in the presence of light (Wanasundara and shahidi 1998; Inanc 2011). Lanfer-Marquez et al. (2005) reported effective protection of chlorophyll derivatives, pheophorbide b and pheophytin b, against linoleic acid using β-carotene bleaching method compare with BHT. However, when compared with Trolox using DPPH assay, all chlorophyll derivatives were reported to have low antioxidants activity (Lanfer-Marquez et al., 2005). Chlorophyll a pigment showed the weakest antioxidant activity among all the greenish pigments the researchers observed. Other healthy importance of chlorophyll include ability to rejuvenate and energize the body, detoxification of the liver, cleaning of the intestine, ability to normalize blood pressure and ability to combat bad odours, bad breath and body odour due to magnesium it contains. (Ferruzzi *et al*., 2007; Inanc, 2011).

Betalains pigments

Betalains pigments are water soluble and have been reported to maintain their colour over a wide range of pH, from 3 to 7, making it suitable for use in colouring food in the pH range (Aberoumand, 2011; Qaisar *et al.,* 2019). Betalains are of different type which are betanin, betacyanin, amaranthine, betacyanin, betaxanthin, vulgasanthin, gomphrenin. Betanin has been used to colour foods such as youghurt, confectionery, ice creams, syrups etc though the usage is limited by the typical earthy flavour.

Betacyanins type of betalains are the main compound associated with the red colour exhibited by flowers, fruits and other plant tissue (Aberoumand, 2011).

Structure of Betacyanin is made up of glycosides of the aglycones betanidin/isobetanidin. This pigment has been said to be nutritionally importance to reduce the risk of coronary disease.

PLANT SOURCES FOR FUNCTIONAL PLANTS PIGMENTS

Pigments in Sweet Potato

Anthocyanin pigment extracted from sweet potato were more than 15 consisting mainly of peonidin, cyanidin and pelargonidin derivatives (Stinizing *et al*, 2002; Petropoulos, 2019). Purple fleshed sweet potatoes contain acylated anthocyanins making it suitable for use as colourants (Esatbeyoglu *et al*., 2017; Petropoulos et al., 2019). Anthocyanin pigments extracted from sweet potato had no negative flavour and may be used in place of red cabbage (Stinizing *et al*, 2002). Antioxidant activity of sweet potato has been reported to be due to the anthocyanin contents of the plant (Kubow *et al*., 2016). Sun *et al*. (2018) reported a prebiotic-like activity of anthocyanins from sweet potatoes through the modulation of microbiota in the intestine. Anthocyanin from purple potato was reported to inhibit tyrosine kinase activity thereby, said to be effective against colon cancer cells (Mazewski *et al*., 2018).

Teow *et al*. (2007-564) evaluated white, yellow, orange and purple skinned sweet potato for antioxidant capacity by ORAC, DPPH and ABTS. The researchers established that purple and orange sweet potato had detectable total anthocyanin with the purple sweet potato having the highest value. Purple sweet potato also possesses highest hydrophilic antioxidant activity with ORAC assay having the highest value and DPPH having the least value; implying that anthocyanin contribute significantly to antioxidant activity of sweet potato (Teow *et al*., 2007).

Orange fleshed sweet potato had the highest β-carotenoid. Orange sweet potato also possess highest lipophilic antioxidant activity which was related to high level of carotenoids contents.

Pigments in Black Sorghum

Sorghum is cereal with significant amount of anthocyanin pigment which compare well to what is found in fruits and vegetables. Significant amount of anthocyanins pigment is concentrated in the bran of black sorghum (Awika, 2004). Anthocyanin contents in the bran was reported to be three to four times the amount in the grains and higher (4.0-9.8mg/g) than anthocyanin level obtained from several commercial sources (usually fruits) except for Elderberry (2.0-10.0 mg/g) which were almost in the same range with sorghum (Awika, 2004).

Several anthocyanin including apigeninidin, apigeninidin-5-glucoside, luteolinidin, luteolinidin-5-glucoside, cyanidin and pelargonidin has been isolated from sorghum. Anthocyanin most commonly found in black sorghum is 3-deoxyanthocynidins and it exist in nature as aglycones (Clifford, 2000) consisting of luteolinidin and apigeninidin. 3-deoxyanthocynidins is said to be stable in acidic solution with improve stability over anthocyanin pigment commonly found in fruits and vegetables due to lack of oxygen at C-3. Awika (2004) recommended extraction of sorghum antioxidant using acidified methanol for high antioxidants activity.

Anthocyanins in black sorghum (3-deoxyanthocynidins) contribute greatly to high antioxidant activities observed in black sorghum and the antioxidant activities were similar to activities of anthocyanins found in fruits and vegetables. Lower quantity of sorghum bran may be required for antioxidant compare with bran of other cereals (wheat, barley, rice) currently use as antioxidant in various food products. The pigment in black sorghum bran due to 3-deoxyanthocyanidin imparts natural dark appealing colour and is more stable than pigment obtained from other source of anthocyanin making resulting colour superior to others (Awika, 2004). Pigment extracted from sorghum bran have been proven to produce acceptable quality colour in bread and cookies (Gordon, 2001; Mitre-Dieste *et al*., 2000)

Pigments in Pomegranate fruit

Major anthocyanin pigments in pomegranate are delphinidin, cyanidin and pelargonidin (Noda *et al*, 2002). The main anthocyanin in the juice is delphinidin-3,5-diglucoside while other anthocyanin such as cyanidin, pelargonidin and even delphinidin 3 and 3,5-glycosylated can be found in the seed coat. Pomegranate extract was reported to show potent radical scavenging activity against superoxide which was reported to be largely due to presence of delphinidin, a major component of pomegranate juice and partly cyanidin which is present in the seed coat (Nodal *et al*, 2002). Nodal et al. (2002) also reported that superoxide radical scavenging activity and H_2O_2-induced lipid peroxidation in rat brain homogenate of anthocyanin were highest in delphinidin, followed by cyanidin and was least in pelargodin. Anthocyanidin was reported not to directly scavenge hydroxyl radical but showed apparent hydroxyl radical scavenging activities which was said to be due to chelating of ferrous ion in the hydroxyl radical of delphinidin and cyanidin (Nodal *et al*.,2002). Anthocynidin in pomegranate extract show superoxide radical scavenging activity value of 16±2 lower scavenging activities when compare to scavenging value of pure dephinidin, cyanidin and pelargonidin which are 1360, 240, and 52 SOD-equivalent units/mg respectively indicating that anthocyanidin in pomegranate did not effectively scavenge nitric oxide (NO) (Nodal et al., 2002)

Pigments in tomatoes

Pigments in tomatoes are chlorophyll, β-carotene and lycopene though the content of this pigment depends on the maturity of tomatoes (Kozukue and Friedman, 2003). Tomato has been reported as the best source of lycopene which is orange in solution. Lycopene has been reported as one of the most effective antioxidants having twice antioxidant activity when compared with β-carotene (Mezzomo and Ferreira, 2016; Clinton S. K., 1998). Boileau et al. (2003) reported that lycopene fed rats show high blood lycopene content with reduced risk of prostate cancer death in rat fed with tomato powder. This may be an indication that consumption of lycopene and tomato products may favourably influence markers of oxidative stress, prostate specific antigen or tissue biomarkers (Chen et al., 2001; Hadly et al., 2003). Studies have also shown that lycopene lower the risk of chronic degenerative disease and cardiovascular disease, as well as, risk of developing prostate, lung and ovarian cancers (Rao, 2002; Cramer et al., 2001). Lycopene pigment mainly from tomato is hardly use commercially as colourant because it is expensive and is more prone to oxidative degradation than β-carotene (Mortensen, 2006).

Pigments in Red Pepper (Capsicum)

Red pepper is known to impact red colour and pungency to food items (Arimboor *et al*., 2014). Pigments found in red pepper include capsanthin, capsorubin, betacarotene, betacryptoxanthin and zeaxanthin with capsanthin and capsorubin been the most dominant pigments in red ripe pepper (Deli *et al*., 2001; Marin *et al*, 2004; Kim *et al*.,2016; Hassan *et al*., 2019). Carotenoids, especially capsanthin, content of red pepper significantly increase with fruit ripening (Hassan *et al*., 2019). Capsanthin accounts for almost 80% of total carotenoids in red pepper and possesses higher bioaccessibility and stability than other carotenoids of red ripe pepper (Pugliese *et al*., 2013; Hassan *et al*., 2019). Carotenoids pigments of red pepper has been reported to possess good antioxidants activity with increasing activity at advance stages of ripening (Cervantes-Paz *et al*., 2012; Hassan *et al*., 2019).

Capsanthin and capsorubin are the most powerful antioxidant pigments in red pepper. Capsorubin and capsanthin are reported to possess stronger lipid peroxidation than β-carotene (Maoka *et al*., 2002) while capsorubin have relatively higher antioxidant activity than capsanthin (Nishino *et al*., 2015).

High level of the capsanthin and beta-carotene has been reported to possess stronger antioxidant activity in term of DPPH free radicals scavenging and reducing power activities (Bae *et al*., 2012; Hassan *et al*., 2019). Free radical scavenging activity of red pepper is dependent of the ratio and constituent of the carotenoids. Thermal treatment of pepper during postharvest handling and processing also influence antioxidants activity of the carotenoid pigments present (Hassan *et al*., 2019; Cervantes-Paz *et al*., 2014; Topuz *et al*., 2011; Sayin and Arslan, 2015; Ornelas-Paz et al., 2013). Studies have also shown that carotenoid pigments of red pepper especially capsanthin possess antiadipogenic, antiobesity activities. Jo *et al*., (2017) reported capsanthin of red ripe pepper to have potential insulin sensitizing activity in high fat diet-induced obesity mouse models. Antiadipogenic activity of capsanthin in red pepper was reported to be superior to activity observed in other carotenoids pigments including capsorubin, betacarotene, betacryptoxanthin and zeaxanthin (Jo *et al*., (2017). Commercial natural pigment made from capsanthin and other carotenoid pigments of pepper is called paprika. Paprika pigment is commonly used as flavouring and colouring agents in food industries with little or no side effects (Palma and Robert, 2019). Paprika pigment is cheaper, more stable and produce similar colour shade as lycopene (Mortensen, 2006).

Pigments in palm fruits

Carotenoids and chlorophyll are the pigments found in oil palm fruits depending on the age of maturity (Sundram *et al*.,2003). Red palm oil is extracted from palm fruit with carotenes, lycopene and Xanthophylls as the carotenoid pigments. However, carotenes (β and α carotene) is the major carotenoid pigment in palm oil which contribute about 90% of the total carotenoids (Mortensen, 2006; Yap *et a*l., 1997) making palm oil the richest source of carotene among other vegetable oils. Carotene pigments imparts an orange-red colour to crude palm oil. Provitamin A activity of palm oil is reported to be 15 and 300 times more retinol equivalents than carrot and tomato respectively (Sundram *et al*., 2003). Studies has shown that carotene in palm oil has chemopreventive activities against a number of human cancer cells including breast, pancreatic and gastric cancer cells (Nesaretnam *et al*., 2002; Sundram *et al*., 2003).

Studies also exist on inhibitory effect of palm carotene against liver, lung and skin tumor with α-carotene showing higher activity than β-carotene (Nishino *et al*., 1992). However, these chemopreventive activity of carotene in palm oil could not be attributed to synthetic carotene (Sundram *et al*., 2003). Palm oil carotene has also shown high antioxidant activity with different antioxidant assays in dose dependant manner (001-0.1%).

β and α-carotene has shown effective reducing activity and lipid peroxidation with DPPH, superoxide radical scavenger and Metal chelator while only 0.1% concentration was effective using ABTS assay. 0.1% activity inhibit almost 50% lipid peroxidation in lipophilic medium indicating palm carotene can act as substantial chemoprotective agents and prevent harmful physiological activities (Gupta and Ghosh, 2013).

Pigments in beet roots

Betanin from red beet root is marketed as E-162 in the European Union and is commonly used as red food colourant. Studies revealed that betalains from beet roots, identified as betanin, possessed high antiradical effect and antioxidant activity which is stronger than catechin (Kanner et al., 1994).

Betanin at very low concentration was found to inhibit peroxidation and low-density lipoprotein (LDL) oxidation was found to be better than that of catechin. However, there was a conflicting result on antioxidant activity of betalain from beet root according to Zakharova and Petrova (1998). this was reported by Cai et al., (2003) to be due to different purification procedure for betalains samples and antioxidants activity assessment methods. Betalain is said to be good electron donour, made up of monoglucosylated O-diphenol group and a cyclic amine group in their structure. Increase in the number of hydroxyl groups (-OH) or amine group in the molecular structure was said to lead to higher antioxidant activity. The position of the hydroxyl group and glycosylation of aglycon in the chemical structure is also of great importance in determining the activity level. (Kanner et al., 2001; Cai et al., 2003).

Pigments in Amaranthaceae plants

Plants of Amaranthaceae family has been reported to possess total of 16 red-violet betacyanins and three yellow betaxanthins (Cai *et al*., 2003). Evaluating antioxidant activity of these series of betalain from amaranthaceae family using DPPH showed that all betalains exhibited stronger antioxidative power than ascorbic acid. The study also revealed that red-violet gomphrenin type betacyanins and three betaxanthins from amaranthaceae plant have higher antiradical activity than catechin; and are highly efficient natural antioxidants. DPPH radical scavenging activity of the betalain compounds from amaranthacea family was due to different structural features of betalain compounds with their ability to donate hydrogen ion (Cai et al., 2003).

Betacyanin and betaxanthin (from Amaranthus) were also found to have high potential not only as food colourant but as antioxidant which could be a substitute for betalain from beet root (Kanner et al., 2001; Cai et al., 2003). Sarker et al., (2020) reported that green morphological type of amaranth possesses remarkable amount of several pigments which include carotenoids, chlorophyll a, chlorophyll b, betalain and betacyanin. The pigments were said to have strong antioxidants activity and contribute significantly to the antioxidant activity of green morphological type amaranth (Sarker et al., 2020).

In the same vain, red morphological type amaranth was said to contain abundant pigments as found in green morphological amaranths with the addition of betaxanthin, anthocyanin, and amaranthine (Sarker and Oba, 2019). These pigments were said to detoxify free radicals in human body therefore acts as potent antioxidants (Wagnet et al., 2015; Sarker and Oba, 2019). Protection of carotenoids, betalains, betacyanin and betaxanthins against lung and skin cancers and cardiovascular diseases has also been reported which give room for their use as additive and colouring agents in cosmetic products, drugs and food (Isabeller et al., 2010; Sarker and Oba, 2019).

Sarker and Oba (2019) stated that significant positive correlation exists between all the pigments found in red morphological type amaranths and TAC ($ABTS^+$), TFC, TPC, TAC (DPPH) which was an indication of strong antioxidants activity of the pigments.

Tumeric pigments

Turmeric has brilliant yellow pigment called curcuminoids. Curcuminoids consist of curcumin and its derivatives- demethoxycurcumin, 5-methoxycurcumimg and dihydrocurcumin which are found to be natural antioxidants (Prasad and Aggarwal, 2011). Turmeric is commonly used as spice at household level to impart yellow colour. Curcumitable 1n extracted from turmeric can be used as preservative, colouring and flavouring agents in the food industry, as well as, a substitute for synthetic colouring agents. Curcumin from turmeric has been reported to have some pharmacological activities including inhibition of various cancer cells, improving colon health and cardiovascular system (Shalaby and Amin, 2018).

Rauf et al., (2018) in their review established from various studies that curcumin, yellow pigment from turmeric has numerous pharmacological activities including anticancer (Liu Wang et al., 2017), antidiabetic (Wang et al., 2017), cardiovascular protective (Li et al., 2017), antiobesity (Ding et al., 2016), antimicrobial (Sarker et al., 2016), wound healing (Hussain et al., 2017), and nephroprotective (Hashish and Elgami, 2016) activities. Curcumin is reported to have strong antioxidant activity which protect from reproductive and respiratory disorders (Radaeva et al., 2004; Gan et al., 2016).

Pigments due to chemical reaction of plant components

Brown Pigment Formation in honey

Turkmen et al., (2006) reported the effect of heating on honey and established that antioxidant activity and brown pigment formation in honey is time and temperature dependent. Heating at 70^oC favours antioxidant activity and brown pigment formation than heating at lower temperatures. The studies also establish strong relationship between antioxidant activity and brown pigment formation at different temperature. Antioxidant activity was linear with increase in time and Brown pigment formation at 50 and 60^oC but the increase was logarithmic at 70^oC. The behaviour was attributed to the formation of different compounds following different pathway during non-enzymatic browning reactions as a result of composition of the product and processing conditions (Manzocco et al., 2001; Vav Boekel, 2001 Turkmen et al., 2006).

Limitations of natural pigments

The application of anthocyanin as food colourant and functional ingredients may be limited to acid foods due to its sensitivity to oxidation, bleaching by Sulphur dioxide and variation with pH. Anthocyanins are also limited by their low stability and interaction with other ingredients in the food matrix (Qasir *et al*., 2019).

Anthocyanins can be affected by the co-existence of other polyphenols and metal ions. Likewise, betalains and chlorophylls are sensitive to light, heat, pH change and oxygen which in turn had adverse effect on the food in which it added during processing, storage and consumer evaluation after storage. Chlorophylls hydrolyze in the acidic medium to give a brown colouration (Qasir et al., 2019). Degradation of chlorophyll usually occur during ripening of fruits, senescence of green vegetables and thermal processing (Rodriguez Amaya, 2018).

Carotenoids is moderately heat stable and subject to loss of colour by oxidation during processing and storage (Arimboor, 2014). Lower pH, presence of oxygen, catalytic metal, oxidative enzymes and unsaturated lipids in food also cause carotenoid degradation (Boon et al., 2010; Gao and Kispert, 2003).

Curcumin usually extracted from turmeric is also limited by its spicy, curry flavour. Some of these pigments also possess earthy flavour which limited their application to some food and additional processing may also be required to remove the flavour. Betanin form beet root possess earthy flavour, riboflavin have bitter taste and curcumin may need to be debittered to avoid its odour and taste. Generally, Sigurdson et al., (2017) also stated that lower stability, weaker tinctorial strength, interactions with food ingredients and inability to match desired hue are all factors that can affect application of natural pigments. Availability of all these pigment for commercial purpose in food industry and the tone of colour obtained is largely dependent on the availability of the source materials and method of extraction of the pigment to obtain pure substance and pH of the food they are in (Qasir et al., 2019).

However, recent studies have shown that acylation of anthocyanin and copigmentation interactions with colourless molecules in solution with anthocyanin can be used to stabilize and strengthen the colour of anthocyanins thereby improving its application (Sigurdson et al, 2017; Malien-Aubert et al., 2012; Paccheco-Palencia and Talcott, 2010). Bioavailability of carotenoids in food is affected by factors such as food matrix characteristics, properties of co-ingested food, generic profile of the host (Fernandez-Garcia et al., 2012). Carotenoids are resistance to heating, sterilization and freezing (Qasir et al., 2019) and are oil soluble.

CONCLUSIONS

Some of the sources and benefits of natural pigments were highlighted. A vital benefit of natural pigments is that they are readily available locally at cheap costs. Some of the raw materials highlighted were sweet potato, black sorghum, pomegranate fruits, tomatoes, beet roots and palm fruits. They are rich sources of polyphenols (flavonoids, flavonones), antocyanins (glycosides, acylglycosides), chlorophyll a&b, carotenoids (carotenes, xanthophyll) and betalains. These compounds are potent antihypertensive, antidiabetics, anticancer, anti-inflamatory and vasoprotective compounds, valuable in fighting coronary diseases.

Conflict of interest Statement

Authors declare there are no conflict of interest

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