A Review on Recent Advances on Natural Plant Pigments in Foods: Functions, Extraction, Importance and Challenges

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REVIEW ARTICLE

A Review on Recent Advances on Natural Plant Pigments in Foods: Functions, Extraction, Importance and Challenges

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Abstract

Natural plant pigments have attracted researchers to investigate the application of these dyes in food products. Besides, public awareness of the adverse effects of synthetic dye also increased the demand for natural pigments. Various colours can be obtained from different plants. Interestingly, these pigments are not only beneficial in the appearance of final food products, but they are very advantageous to the plant itself, food and human nutrition. Hence, this article reviews the state-of-the-art establishment of plant pigment application in food products. This review starts with a brief explanation of plant pigment usage in food, followed by clarifications on the functions of six primary plant dyes and the extraction of the natural pigments. The importance of natural pigments is shared. A highlight of future challenges facing the food industry in utilizing natural pigment is also discussed.

Keywords Plant pigment · Natural dye · Natural product · Food product · Extraction

Introduction

The food industry is one of the essential sectors in the world with high demand in global markets. Most of the food products deal with dye either from natural or synthetic pigments. A pigment is a substance occurring in animal tissue, plant or synthetically produced and gives a characteristic colour. Artificial pigments are the most used in cosmetic, food and pharmaceutical industries because of their advantages related to the colour range, price, resistance to oxygen degradation and solubility [8]. However, the current interest focuses

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on the development of food-grade pigments from natural sources due to the undesirable toxic effects, mutagenicity and potential carcinogenicity of artificial dyes [8, 39, 48]. Public's awareness for environmentally benign and non-toxic sustainability in bio-resourced colourants has developed a revolution in natural product research and development [50, 64]. An increasing trend towards replacement of synthetic dyes by natural pigments in the last 35 years has been identified, because of high consumer demand for more natural products, and natural pigments' safety and health benefits [7]. Most natural dyes have inherently antimicrobial and antioxidant properties, and could consequently possess high medicinal activity [27] as shown in Fig. 1. Besides, these dyes consist of various vitamins with different concentrations, depending on the plant source. The use of natural colours is seen as an ecologically sustainable and non-hazardous process [47]. Natural dyes have been applied not only in the food industries, but also in clothing, pharmaceutical and cosmetic sector [33, 51] because of abundance benefits.

In fact, natural pigments are usually more expensive than synthetic and require a larger number of raw materials. This natural source also gives unpleasant aromas and flavours to the products like red beets and red radishes. The pigments are also easier in losing colour or hue alterations due to sensitivity towards oxygen, light and heat. Natural dyes also can be more sensitive to environmental conditions such as various compounds of organics, pH, metal ions or proteins [53]. The drawbacks of natural pigments reveal that synthetic dyes work better and more stable in product development.

With the high demand for food products using plant pigment that promotes health advantages, the identification of the most effective methods for extracting plant dyes has

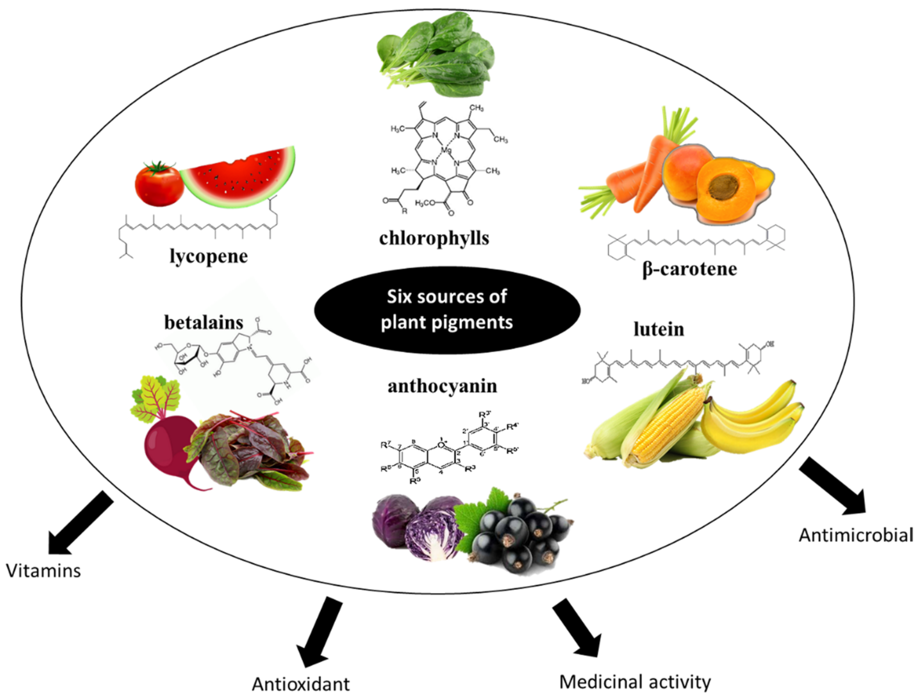

Fig. 1 Main function of six plant pigments

become increasingly important. Traditionally, plant pigments are prepared by boiling the plant part in water using a technique known as tisane or decoction. These types of pigments can be obtained, but these methods are time-consuming and may not be the most effective method for extracting the dye from the plants. This article provides a review of the state-of-the-art establishment of plant pigment application in food products. It also discusses the functions of six commonly used plant pigments in food industries. Besides, this paper explains the extraction of plant pigment with unit operations involved in the extraction process. Importance of natural pigments is also shared. Finally, a highlight of future challenges facing the food industry in applying natural pigments is also presented.

Functions of Six Natural Pigments

Bioactive compounds are a chemical type that can be found in plants and particular food such as fruit, vegetables and nuts. Bioactive compounds give excellent effects to the body and may promote good health. They exhibit beneficial effects, for example, antimicrobial, antioxidant and induction of enzymes. The bioactive compounds, including pigment, are responsible for giving the smell, flavour and colour of the agricultural commodities [1, 34]. Natural colours are sometimes called 'bio-colours' because of their biological origin [40]. In this paper, the functions of six primary plant pigments (lycopene, β-carotene, betalains, anthocyanin, chlorophylls and lutein) are elaborated. It was found that these pigments were commonly used in the formulation of food products. A brief explanation of the functions of each presented pigment is shown in Table 1.

Lycopene

Lycopene is one of the natural pigments in the large phytochemical family known as carotenoids. Structurally, it consists of eight isoprene units made of carbon and hydrogen, where the chemical formula is $C_{40}H_{56}$ [57]. Lycopene is the most abundant carotenoids that can be found in ripe tomatoes for approximately 80–90% of total pigment contents. Arnao et al. [4] found that the concentration of lycopene is 1.16 times higher than the concentration of ß-carotene in tomato. Lycopene also contains 2.9 times higher than the antioxidant capacity of vitamin C [4]. This pigment was found to be more efficient and powerful antioxidant compared to other carotenoids such as β-carotene and α-carotene due to the presence of 11 conjugated and two non-conjugated double bonds [2, 59] as shown in Fig. 2. These conjugated bonds act as the mediators to antioxidant activities [41, 59].

Lycopene is a red carotenoid pigment that naturally formed in tomatoes, pink grapefruit, watermelon, guava, papaya and other red fruits [57]. The lycopene content in the plant depends on the plant species and the ripeness of the plant part. It also plays a role as an intermediate medium in the biosynthesis of many carotenoids and gives red colours and photoprotection for the plant.

Lycopene is valuable as natural food colouring because of its non-toxicity and intense colour [2]. Its extract can be found commonly in the breakfast cereal, baked goods, dairy products, candy, fruit and vegetable juices and others. Lycopene has been included in food supplement products in a specific value to claim an antioxidant content or other health benefits. The quantity of lycopene in a product varies from 2 mg/1 in bottled water to 130 mg/kg in ready-to-eat cereals (Rath S, Olempska-Beer Z, 2007). The presence of antioxidant in a product is believed to prevent the degradation of the other food components in the same

Table 1 Functions of natural pigments with common plant

Natural pigments	Common plant	Main function
Lycopene (red) $C_{40}H_{56}$	•Tomato •Pink grape fruit •Watermelon •Papaya •Guava	•Antioxidant [13] •Anti-carcinogenic activities [29] •Skin protection [29]
β-Carotene (red–orange) $C_{40}H_{56}$	•Carrots •Apricots •Asparagus •Chinese cabbage •Chilli •Paprika	•Vitamin A [58] •Increase immune system [60] •Inhibit cancer cells [60] •Protect skin against sunburn [60]
Betalains (red-yellow) $C_{24}H_{26}N_2 0_{13}$	•Red beet •Dragon fruit •Swiss chard •Cactus flower	•Defence and resistance towards pathogen resistance [56] •Antioxidant (Manjunath J., Shetty, P.R., Geethalekshm I., 2018) •Chemo-prevention effects [23]
Anthocyanin (red/blue/purple/green) $C_{15}H_{11}O$	•Red cabbage •Elderberry •Black currant •Sweet potato •Purple carrot •Cherry •Red reddish	•Antioxidant [13] •Avoid coronary heart diseases [13] •Strong in bactericidal [13] •Antiviral and fungistatic activities [13] •Protect body against free radicals [13] •Decrease the risk of heart diseases and cancer [13]
Chlorophylls (green) $C_{55}H_{72}O_5N_4MG$	•Green plant •*Aloe vera*	•Improving immune system (Manjunath J., Shetty, P.R., Geethalekshm I., 2018) •High antioxidant (Manjunath J., Shetty, P.R., Geethalekshm I., 2018) •Anti-carcinogen (Manjunath J., Shetty, P.R., Geethalekshm I., 2018)

Table 1 (continued)

Natural pigments	Common plant	Main function
Lutein (yellow) $C_{40}H_{56}O_2$	•Peas •Sweet corn •Sweet peppers •Maize •Kiwi fruits •Orange juices •Grapes •Spinach	•Protect the neural retina [30] •Delaying the retina and lens in age-related eyes diseases and the pigmentary abnormalities [30]

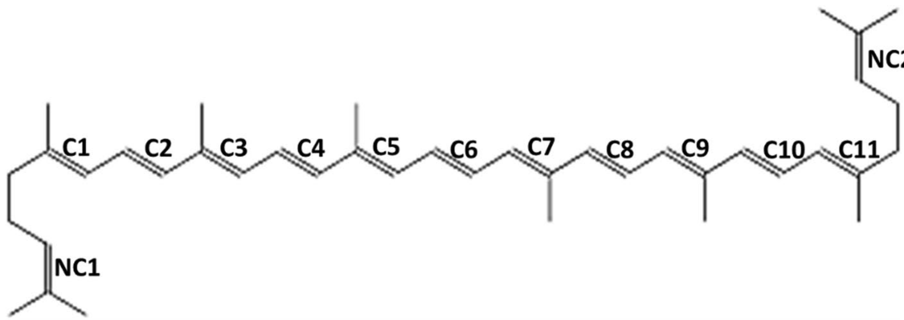

Fig. 2 Chemical structure of lycopene (C denotes for conjugate; NC denotes non-conjugate)

product [13]. Additionally, lycopene has widely been applied as feed additives, nutrient supplement, animal feed supplements, nutraceutical for cosmetic and pharmaceutical [24].

Lycopene also shows the anti-carcinogen activities in reducing the risk to get cancer diseases, especially prostate and breast cancer [15, 43]. Consumption of the tomatoes or tomatoes products in a single serving per daily can protect the DNA from damage that causes in the pathogenesis of cancer [14, 43]. Antioxidants that exist inside of lycopene can act as skin protection due to its efficiency to scavengers of reactive oxygen species (ROS) that induce photo-oxidative damage that causes to the skin ageing and skin cancer [29].

β-Carotene

Carotenoids are useful in maintaining healthy skin due to potent antioxidant and also prevent many diseases such as cancer, muscle degeneration in old age and also cataracts [37]. Besides, carotenoid is an acyclic molecule with five or six C rings on the both, or one ends [52]. The significant carotenoid in carrots and tomatoes is β-carotene [54]. β-Carotene is an isoprenoid compounds and approximately about 600 fat-soluble carotenes found in plant and microorganisms. The chemical formula of β-carotene is $C_{40}H_{56}$ with 536.87 g/mol of molecular weight. β-Carotene is known as an antioxidant that can prevent cellular damage and had a strong antioxidant that can reduce with up to 1000 free radicals per molecule [21]. It is the most studied carotenoid and one of the main carotenoids that can be found in human blood and tissues. It is made of two molecules of retinol, as shown in Fig. 3, and had a maximal pro-vitamin A activity [58].

β-Carotene is the major precursor of carotenoids in the human body. The total of retinol intake is less than one-third in developed countries which is attributed to pro-vitamin A. Vitamin A is vital in normal organogenesis, immune functions, eyesight and also tissue differentiation [55]. The primary sources of β-carotene include carrots, apricots, asparagus, Chinese cabbage, chilli and paprika [21]. Therefore, it is the most abundant form of vitamin A that is easily found in fruits and vegetables. β-Carotene is one of the natural pigments that is synthesized in plants and responsible for the red–orange colour of fruits and vegetables. It also provides important roles for the plant in photoprotective function, especially when photosynthesis occurs; avoids photo-oxidative damage and light-harvesting; and acts in the biosynthesis of phytohormone abscisic acid (ABA). The red–orange colour from β-carotene functions to attract the pollinators due to the brightness [60].

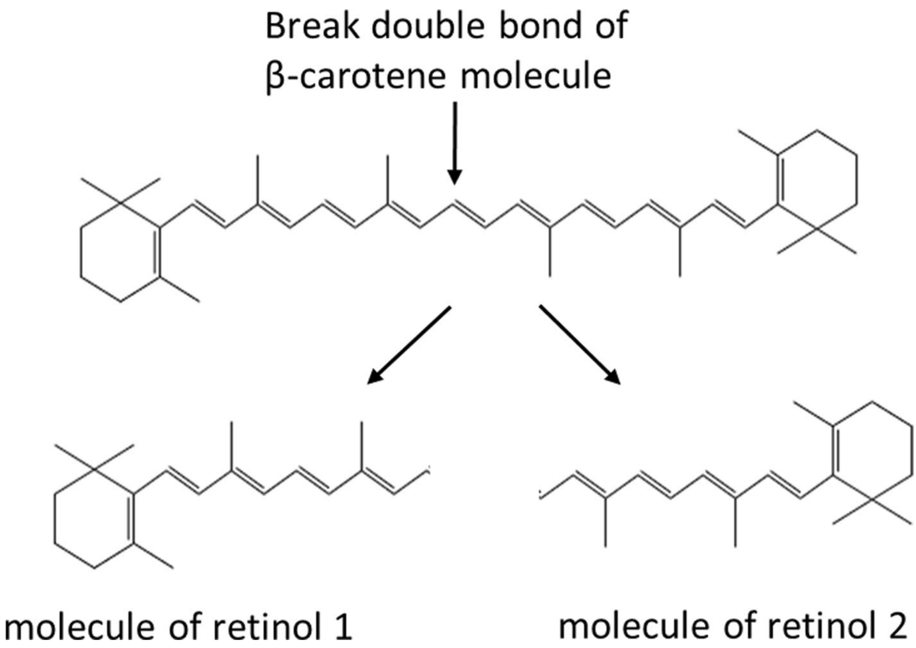

Fig. 3 Chemical structure of β-carotene

In the food industry, β-carotene has been applied as natural food colourants and food fortification. About 5 mg of β-carotene in 1 kg of food is included in a food product either as a coloured or fortified food [20]. Antioxidant that is present in the β-carotene can increase the immune system function; inhibit the growth of specific type of cancer such as lung cancer; and also protect against sunburn [60].

Betalains

Betalain pigment belongs to the group of Caryophyllales. It can be subdivided into red-violet betacyanins or yellow betaxanthins according to its chemical structure [18]. Both groups share the same betalamic acid as the chromophoric unit and structural. The chemical formula of betalains is $C_{24}H_{26}N_{2}0_{13}$ with 550.5 g/mol of molecular weight. It can be found in the edible part of the plants but also in the flowers, leaves, stems and bracts [16]. It is in a range of stable pH from 4 to 6 but degrades by thermal processing (Manjunath J., Shetty, P.R., Geethalekshm I., 2018).

Betalains are a group of red and yellow water-soluble pigments found usually in red beet, dragon fruit, Swiss chard, cactus flower and in some flowers. Betalain extract has traditionally been used as natural colourant mainly in dairy products, beverages, candies and also cattle products [19]. Their application in food is limited due to its sensitivity in a few factors such as pH and temperature. Betalains can be applied in food that has a minimum treatment towards heat and short shelf life and packaged and marketed in a dry state under reduced levels of humidity, light and also oxygen (Manjunath J., Shetty, P.R., Geethalekshm I., 2018).

Betalains show anti-inflammatory, antioxidant, antimicrobial, anti-fungal and rich in nutrients [26]. It is proven that a red beet used the betalain compound to improve the vital defence and to increase the resistance towards pathogen [56]. This compound also helps in increasing the resistance towards the oxidation of low-density lipoproteins, inhibiting the lipid peroxidation and preventing chemo effects [23]. The production of commercial betalains depends not only on efficiency of processing techniques (such as enzymatic control, extraction, purification, concentration and drying operations) but also on the continuous availability of highly pigmented sources [13].

Anthocyanins

Anthocyanins are natural colourant, which belong to the groups of the flavonoid family of secondary metabolite. It can be found in outer cell layers of the plant, such as epidermis and peripheral mesophyll cells (Manjunath J., Shetty, P.R., Geethalekshm I., 2018). Anthocyanins are glycosides of anthocyanidins and sugars. It is highly water-soluble, and because of that, it is extracted using water.

Blue, red, green and purple are the colour pigments of anthocyanin. The colours of anthocyanins are not stable where they change according to the pH. At low pH around 3, the colours of anthocyanins are stronger red. The colour turns into almost colourless at pH 5, while at neutral and alkaline pH, it turns from blue or purple to green colours. Anthocyanin can be found in red cabbage, elderberry, black currant, sweet potato, purple carrot, cherry and red reddish [35].

Anthocyanins act as an antioxidant, defence mechanisms, photoprotection and also other ecological functions for plant. It also helps in reproductive mechanisms such as pollination, antifeedant and seed dispersal [13]. Consumption of this natural pigment brings to low incidences of coronary heart diseases. Anthocyanins are also strong in bactericidal, antiviral and fungistatic activities. The presence of antioxidant prevents the oxidation of ascorbic acid that can protect the body against free radicals, inhibit the oxidative enzymes and decrease the risk of heart diseases and cancer [13].

Anthocyanins have been applied in the food and drink as natural colourants as well as a natural antioxidant. One of the main claims of the food industries nowadays is for natural colourant in replacing the red dyes. It is used broadly as pigments of fruit juices and wines. The most important sources of anthocyanins are the grape pomace that has widely been used in wine production. Up to date, anthocyanin pigment and lees preparation are the only two sources used in human food mainly in the production of beverages and soft drinks that are approved by the Food and Drug Administration (FDA) [62].

Chlorophylls

Chlorophyll is a green pigment that is utilized by all plants for photosynthesis. It is a cyclic tetrapyrrole coordinated in the centre magnesium. There are two forms of chlorophyll which are alpha and beta that are used in the food industry as colourants. Chlorophyll is a lipid-soluble and is extracted with the use of organic solvents. Chlorophyll can be water-soluble in saponification which is called as chlorophyllin [35].

Chlorophyll helps in improving immune system function. It revives the body system by slowing down the oxidation of LDL (bad cholesterol) that becomes the main factor to cardiovascular disease (Manjunath J., Shetty, P.R., Geethalekshm I., 2018). It also contains a high antioxidant capacity that helps in neutralizing the free radicals and limiting the oxidative damage in the body. Chlorophyll also shows an ability to prevent or decrease cancer or acts as anti-carcinogen. Besides, it facilitates in increasing the uptake of the oxygen in the blood cells.

Chlorophyll can easily be found in all green plants. Foodstuffs that usually used chlorophyll as natural pigment were dairy products, soups and also drinks (Manjunath J., Shetty, P.R., Geethalekshm I., 2018). Chlorophyll is legal in Europe when extracted from edible plants, nettle, grass or alfalfa, silkworm droppings and even mulberry leaves but illegal in the USA.

Lutein

Lutein belongs to the family carotenoids of xanthophyll, and it is one of the significant components for the macular pigment of the retina. Its chemical formula is $C_{40}H_{56}O_2$ with a molecular weight of 568.87 g/mol. Lutein differs from other carotenoids due to its two hydroxyl groups, one for each side, as presented in Fig. 4. Lutein is a plant pigment in bright yellow colour [14].

Lutein exists in leafy vegetables, many fruits and coloured vegetables such as peas, egg yolk, sweet corn and sweet peppers. The plant that contains the highest lutein content is the maize with 60% total weight [14]. Lutein also can be found with a substantial amount together with zeaxanthin in 30–50% in kiwi fruits, orange juices, grapes, spinach and different kinds of squash [14]. Lutein protects the neural retina from the photo-oxidative damage and development of common visual disorder by absorbing the blue light and quenching the ROS due to the presence of powerful antioxidant activities. It also helps in delaying the retina and lens in age-related eye diseases and the pigmentary abnormalities [30].

Lutein is essential in photoprotection of plant. It is crucial in quenching of the chlorophyll states, stabilization of antenna proteins and light-harvesting to transfer the excitation energy towards chlorophyll (Manjunath J., Shetty, P.R., Geethalekshm I., 2018). Lutein has been used as the additive in bakery products to increase the bioavailability of lutein, especially in the human body [44]. But, lutein is prohibited in the USA as food colourant except for chicken feed [35].

Extraction of Plant Pigment

Natural dyes are extracted from different parts of plants including bark, leaf, root, fruits or seeds and flower that contain colouring materials [27]. The discussions on unit operations and the basic principle involved in the extraction of pigment are emphasized in this section.

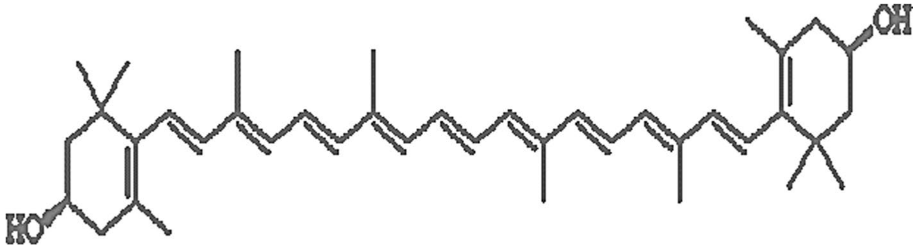

Fig. 4 Chemical structure of the lutein

Unit Operations for Solvent Extraction of Plant Pigment

Unit operations involve a physical change or chemical transformation of one material into the desired product. In a process, several unit operations are needed starting from raw materials into the final product. Solvent extraction of plant pigment also requires several unit operations such as drying, extraction, filtration and evaporation. The extraction process is divided into three main stages which are before, during and after the extraction process, while four unit operations involved as exhibited in Fig. 5.

Before an extraction starts, the fresh plant part will be dried to remove the water content in the plant. It is also as a precaution step to maintain the sample from any microbial activities, thus increasing the sample shelf life. Drying is the first unit operation used in the extraction process of plant pigment. The dried sample then will be used in the second unit operation, which is extraction. In this unit operation, the solvent will be mixed with the dried sample. Any additional factors or forces such as heat, pressure, microwave and ultrasonic can be applied in this extraction unit operation. Typically, the forces are needed to reduce the extraction time as well as to get higher extraction yield [10, 38]. After the extraction process completes, the filtration unit operation is necessary to separate solid residual biomass and liquid plant pigment with solvent. In this stage, typically, filter paper can be used to separate the liquid and solid forms. Final unit operation in this process is evaporation, where the purpose is to remove all the solvent from the liquid mixture of solvent and plant pigment [5]. Rotary evaporator equipment is utilized to remove the solvent at an appropriate temperature. At this stage, the temperature selection is critical to ensure that the pigment is not vaporizing together with the solvent. This pigment then can be applied in the formulation of cosmetic, food and pharmaceutical products.

Basic Principle of Extraction

Plant pigments are normally extracted using a solvent such as water, ethanol and methanol. The solvent in the extraction process functions as a transfer medium of pigment compound from plant cell to the liquid solvent. The transfer process involves several steps where it starts as soon as the plant part is soaked in the solvent. The first step entails the penetration of the solvent into the plant cell because of the different solvent concentrations between cell and solvent medium, as shown in Fig. 6. The plant part used is generally in a dried form, as a precaution to extend the storage time of the plant before the extraction process. As a result of dried plant sample, solvent quickly diffuses into the plant cell to replenish the loss of water. The diffusion process initially is slow and requires time to complete the soaking

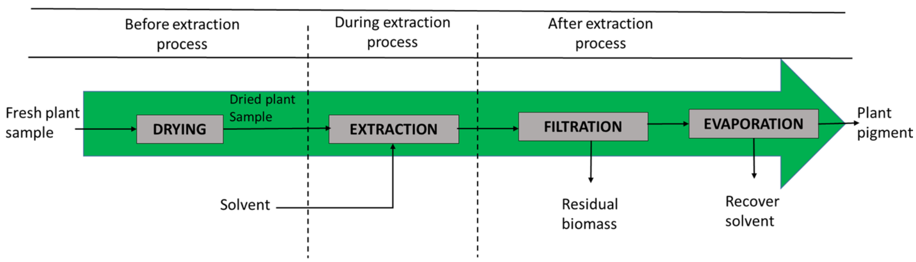

Fig. 5 Unit operations for solvent extraction of plant pigment

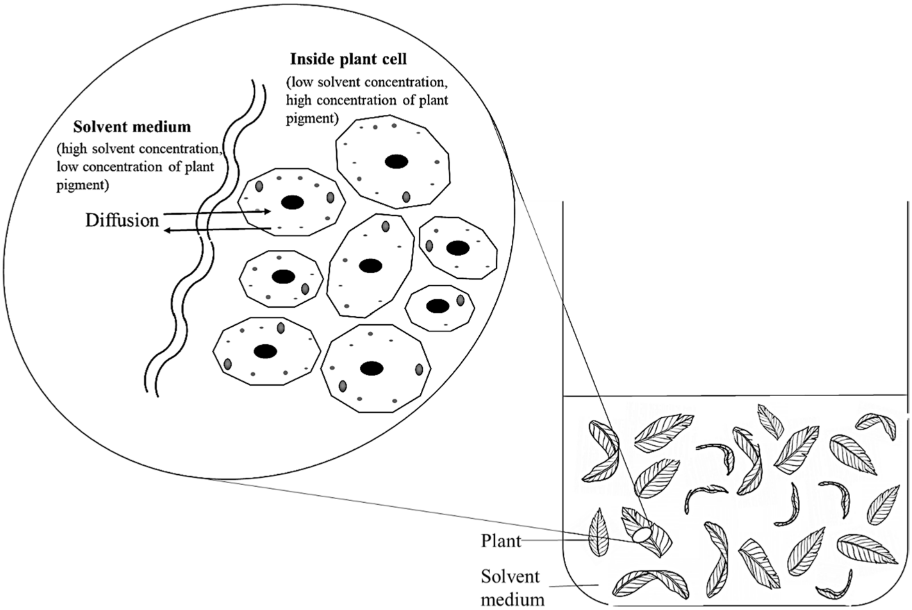

Fig. 6 Initial penetration of solvent into the plant cell

process [46, 61]. However, any force factor, such as heat, can be used to accelerate this process. Expansion of plant material size occurs because of the diffusion process, which makes the extraction of plant pigment easier. At this stage, the plant pigment dissolves in the solvent before it diffuses out from the cell to the solvent medium. At the end of the extraction process, the solvent is removed by evaporating the solvent from the pigment-solvent mixture. Any factors that enhance the diffusivity and solubility of solvent–solute (plant pigment) interaction help in reducing extraction time, hence increasing the efficiency of the process [6]. Elsevier). Table 2 presents the previous works on the extraction methods of the pigmented plants with the solvents used. This table reveals that the most used solvents in extracting plant pigments are water and aqueous alcohol.

Importance of Natural Pigments

Vegetables are rich in vitamins, especially vitamins A and C, and minerals including iron, magnesium, calcium and potassium. Further processing of vegetables provides a range of useful materials, including starch and sugar, that is added to food products (Bruce, 2013). Non-food products such as cosmetic products also have been made from herbals and vegetable origin as one of its ingredients. In addition, the popularity of the use of plant active compounds as cosmetic products ingredients had increased due to its benefits in protecting and curing the skin [49]. Most of the pigments applied in cosmetic products come from consumable sources such as vegetables and fruits.

Application of the plant pigments in cosmetic products is increasing due to the higher demand of consumers on the natural ingredient in cosmetic products. Colours are the main component of the cosmetic product, especially for the application in the face, nail and hair. A natural pigment can be obtained from a plant with various colours.

Table 2 Previous works on the extraction methods of the pigmented plants with the solvents used

Plant	Extraction method	Solvent used
Eggplant	Maceration	Aqueous methanol (Lakshmi, 2014) Aqueous methanol (Garcia-Salas et al., 2010)
Blackberry	Maceration	Aqueous methanol (Lakshmi, 2014)
Purple grape	Maceration	Water (Boo et al., 2012)
Red cabbage	Maceration	Water (Boo et al., 2012)
Avocado	Maceration	Isopropyl alcohol and ethyl acetate (Sutheimer et al., 2015)
Kiwi	Maceration Lyophilized water extract Ultrasonic bath extraction	Aqueous methanol (Sutheimer et al., 2015) Water (Bursal and Gülçin, 2011) Aqueous ethanol (Park et al., 2013)
Cucumber	Ultrasonic bath extraction Maceration	Aqueous methanol (Abu-Reidah et al., 2012) Dimethyl sulfoxide (DMSO) (Garcia-Salas et al., 2010)
Spinach	Ultrasonic bath extraction	Aqueous methanol (Altemimi et al., 2015)
Orange	Maceration	Hexane (Lakshmi, 2014)
Carrot	Maceration	Hexane (Lakshmi, 2014) Ethanol mix with citric acid (Assous et al., 2014)
Pumpkin	Maceration	Hexane (Lakshmi, 2014)
Pineapple	Maceration	Hexane (Lakshmi, 2014)
Cranberry	Ultrasonic bath extraction	Methanol (Biswas, 2013)
Dragon fruit	Ultrasonic bath extraction Maceration (shaking incubator)	Aqueous methanol (Moo-huchin et al., n.d.) Water (Ramli et al., 2014)
Strawberry	Maceration Maceration and centrifuge	Acetone mix with acetic acid (Kajdžanoska et al., 2011) Aqueous methanol (De Souza et al., 2014)
Pomegranate	Maceration	Methanol (Elfalleh et al., 2011) Aqueous ethanol (Sood and Gupta, 2015)

Common pigments that have been used as ingredients in cosmetic products are anthocyanin (from the grapes, blueberry, plum, purple cabbage and blackberry), chlorophyll (from the avocado, cucumber, spinach, broccoli, lettuce and kiwi), anthoxanthins (from cauliflower, potato, ginger, onions and banana), carotenoids (from papaya, pineapple, pumpkin, carrot and orange) and lycopene (from beetroot, tomato, strawberry, watermelon and pomegranate) [9].

Anthocyanin has been applied in the lipstick [63], lip care [31] and skin care products [45] due to its bioactive compounds and attractive purple-blue colour. Chlorophyll pigment from cucumber and avocado has been utilized in skincare and skin protection [11, 36]. Anthoxanthins that give white-tan colour have been applied in the skin care products [17] such as lotion and sunblock cream. Some of the natural skincare and hair care products include carotenoid pigment as one of the ingredients in the formulations [17]. Red colour pigment form lycopene was found to be used in the lipstick product as it gives impressive red towards the products (Adeel et al., n.d.,[12].

The effectiveness of natural cosmetic products must be tested before it is marketed. The testing is important to ensure the suitability of the product towards human skin; the safety of the product, which will not harm to skin and environment; and the shelf life of the product. The sensory analysis also is an important test for a cosmetic product to test consumer acceptance towards the new product. Table 3 shows cosmetic products using plant pigment with the testing conducted to the products. There are an infinite number

Table 3 Cosmetic products using plant pigment with the testing

Product	Plant/active ingredient	Testing	References
Lip balm	Carrot/carotenoids	Homogeneity test, appearance test, pH test, topical test, irritation test	Anisa et al. (2019)
Lip balm	Strawberry, dragon fruit, pomegranate	Melting point test, stability test, moisture analysis, colour intensity, sensory test and also microbial test	Yusof et al. (2018)
Topical ream	*Calendula officinalis* flower	Stability test, pH test, Burchard test, viscosity test, panel test, dermatological test	Akhtar et al. (2011)
Lotion	Lemon	pH test, viscosity test, sensitivity test, washability test, appearance and emulsion type test	Gyawali et al. (2016)
Moisturizer	*Aloe vera*	pH test, acid value test, saponification value test, viscosity test, spreadability test, layer thickness test, microbial test and skin sensitivity test	Kapoor and Saraf (2010)
Lipstick	Herbal	Melting point, breaking point, force of application, surface anomalies, pH parameters, skin irritation test	Chaudhari et al. [9]
Lipstick	Tomato	Colour, melting point, breaking point, force application, surface anomalies, ageing stability, solubility test, pH parameter, skin irritation test, perfume stability	Dhakal et al. (2016)
Lipstick	Carrot	pH, breaking point, force of application, melting point, hedonic test, perfume stability, irritation open patch test	Hayati and Chabib (2016)
Lotion	Tomato	Determination of pH, drug content, stability test, clinical test, skin irritation test, anti-ageing activity evaluation	Shahtalebi et al. (2015)

of products that have been formulated using plant pigment. However, there is only limited data published on product formulation and testing.

Challenges for the Food Industry

Nowadays, consumers more demand in searching and using the food products that are made of natural ingredients due to not harmful to the health [28]. The Natural Products Association (NPA), USA, listed a guideline on the natural product labelling. Therefore, the all-natural products must follow the guidelines [25]. Firstly, the product must contain at least 95% natural ingredients (genuinely natural ingredients or ingredients that are derived from natural sources) and contain no ingredients linked with potential suspected human health risks. It also must not be processed in ways that significantly or adversely alter the purity of its natural ingredients, including ingredients derived from purposeful, a renewable source found in nature, minimally processed. The avoidance of the use of synthetic or harsh chemicals so as not to dilute the material as purity and contain non-natural ingredients only where viable natural alternatives are unavailable and only when they pose no potentially suspected human health risks.

The abundance of natural food products in the market is awe-inspiring. However, some of the product has been sold without performing any physicochemical tests that are very crucial as it is consumed by the users. The chemically derived ingredients in food products such as methylcyclopropene gas (this gas is pumped into crates of apples to stop the ethylene production from the apple, where the ethylene increases the fruit's ripen rates); benzoic acid (this preservative is commonly applied to various foods such as low-sugar products, drinks, meats and cereals to retard or prevent the food spoilage caused by chemical changes); butylated hydroxyanisole (BHA) and butylated hydroxytoluene (BHT) (these antioxidants are the most commonly found in sausages, crackers, dried meats, cereals and other foods with added fats to act as a preservative and delaying rancidity); and many more will cause bad reactions to the health such as cancer, a possible human carcinogen, hyperactivity in children and asthma. The food manufacturer uses these chemicals because they are cheaper than natural ingredients and easy to get. Besides, the formulated products such as food supplements that use chemically derived ingredients will give sound effects to the users quickly and adverse results in long-term usage. These functional effects are the main point for the manufacturer to make the product became saleable and trending.

Despite of the benefits, natural pigments are scarce because of their limited sources, poor stability and high cost [7]. The natural pigments are unstable as they are susceptible towards oxygen, light and heat that cause the loss of colour and hue alteration. In natural pigment production, a huge number of plants needed could contribute to more expensive raw materials. In addition, the extraction of season flowers to obtain the flower pigment also consumes a long cycle to get the new sources. Besides, many natural pigments are illegal to be applied in food products. A list of approved colourants has been published by the FDA and EU [32], where the dye that is not listed is considered an illegal colour because the source is doubt or either it comes from plants or not.

In addition, it is challenging to reproduce natural pigments where only skilled workmanship can handle these natural pigments. An appropriate and standardized extraction method must be developed without sacrificing the required quality of the pigment before it is applied in the food product formulation. Moreover, the extraction of the pigments requires time-consuming, and the pigments are not stable where the colour changing can occur when exposed to the sun, sweat and air [22]. The appropriate extraction, identification and finishing techniques need to be derived from the current scientific studies to obtain stable pigment with acceptable colourfastness behaviour [27]. There is a requirement to develop a sustainable, cost-effective process of the production of plant pigment to compete and replace the synthetic ones due to the high cost of the currently available technologies for the industrial scale of pigment production [3].

Another issue that needs to be focused on utilizing the natural ingredients is to find the best supplier with good quality of sources, procedures and services; that is hygienic in processing; and that eliminates cross-contamination. Risk in contamination of microorganisms during processing should not be ruled out. An official guideline regarding safety assessment towards natural food product industry was very limited due to different uses of natural ingredients from plant. A proper measure of different cases is needed for better evaluation of safety [31]. New food products in Malaysia must get approval from the Good Manufacturing Practise (GMP) and Halal certificate from JAKIM [42]. In the USA, the certificates include the Consumer Product Safety Commission (CPSC) for product safety, Customs and Border Protection (CBP) for country origin if imported products, Environmental Protection Agency (EPA) for environmental protection act, Federal Trade Commission (FTC) for unfair trade practices and product performance claims, Food and Drug Administration (FDA) for cosmetic regulation and United States Department of Agriculture (USDA) for organic claims (States, n.d.).

Conclusion

The demand for natural food products has increased with the raised awareness of possible side effects of using products made from chemicals. Plant pigment is one of the important ingredients in natural food products as some products normally need colours. Extraction of this plant pigment must be carefully done to ensure the desired colour of the pigment is obtained. Appropriate solvents and cost-effective extraction processes must be chosen to get the pigment. Thus, the required steps involved in each unit operation of extraction of plant pigment must be applied. The pigment can be preserved when it is dried in powder form. The pigment then can be utilized in the food product formulation where the product must be certified by the government where the food products are produced. Besides, the acceptability of the product by the consumer might also be tested in a sensory test. There are several key players in the global organic pigments market such as Trust Chem Co. Ltd (China), Sudarshan Chemical Industries Ltd. (India), BASF (Germany), Ferro Corporation (USA), Clariant (Switzerland) and Heubach GmbH (Germany).

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