Food Science and Applied Biotechnology, 2024, **7**(2), 353-359

UFT Academic Publishing House, Plovdiv

Food Science and Applied Biotechnology
e-ISSN: 2603-3380

Journal home page: www.ijfsab.com
https://doi.org/10.30721/fsab2024.v7.i2

Mini Review Article

Prunus spp. fruits as practical natural colouring agents in foods

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Abstract

Fruits and vegetables are among the most important phytochemical sources worldwide, which can also provide an anticipated food colour. The sensory perception of the food is directly linked to its colour. Consumers have a specific expectation for the colour of food i.e. desired and vivid ones. Thus, colour additives, both natural and synthetic, are so important to the food industry. Colour additives are able to enhance the sensory attributes lost during processing, and to expand product variety. However, studies report a link between synthetic colours and some health disorders. That is why serious attention is paid to natural dyes. In this context, *Prunus* fruits present an excellent alternative source of natural compounds that enable the production of a wide range of colouring molecules, such as anthocyanins, carotenoids and chlorophylls. Moreover, in addition to their ability to colour, they also contribute by increasing food's bioactive qualities. Carotenoids are the pigments that give the yellow and orange colour to the pulp and skin of apricots and other *Prunus* fruits. Along with them, flavonoids, anthocyanins (purple, blue colours), etc. are also found in prunes, for example. Still, whether the fruit can be used as a reliable source of food colouring is an open question worth answering. Therefore, more research is currently needed to better understand the behaviour of natural compounds during the extraction processes and further incorporation into food matrices. In this regard, scientists add fruits directly in the food in order to avoid extraction and potential loss of bioactive compounds, i.e. natural dyes. Regulation approvals should always be considered as well and it has to be noted that different legislation applies to different countries. In view of the sustainable food cycle provision and the seek for more value-added ingredients, natural dyes ought to be taken into account with priority.

Keywords

value added ingredients, natural sources, bioactive compounds

Abbreviations

EFSA – European Food and Safety Authority; FDA – Food and Drug Administration

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Article history:
Received 26 March 2024
Reviewed 26 March 2024
Accepted 17 April 2024
Available on-line 10 October 2024

https://doi.org/10.30721/fsab2024.v7.i2.381
2024, UFT Academic publishing house, Plovdiv

Introduction

Consumers use colour to assess the quality of products. The colour is associated with not only freshness, maturity state, and safety but also expected taste, especially when food colorants are being used (Figueiredo et al. 2023). For example, the orange colour is constantly linked to the taste of the orange fruit.

Synthetic colours have been long used in various industries but their harmful effects (inability to degrade, health issues, among others) exceed their practical use (Miller et al. 2022). Natural colorants, on the other hand, can not only contribute to the physical appearance of products but also carry important health benefits due to their chemical structure (Shakoor et al. 2022). Colour molecules can be extracted from roots, flowers, leaves, or the whole raw material. Natural colorants belong to chemical structures like anthocyanins, chlorophylls, carotenoids, betalains, phenolic compounds, among others (Singh et al. 2023). Countries with better biodiversity have greater possibilities to produce dyes. Food safety authorities like the EFSA or the FDA are the ones that monitor, regulate, allow or suspend the use of both synthetic and natural dyes.

The genus *Prunus* is known worldwide and can be evaluated as a potential source for natural dyes (Table 1). The genus comprises of some of the well accepted and cherished fruits like cherries, peaches, sour cherries, plums, apricots, and almonds (Popova et al. 2022).

These representatives have been studied for their potential bioactivity and health-promoting properties. Some of the reported compounds include polyphenols, carotenoids, phenolic acids, carbohydrates, among others (Nowicka et al. 2023).

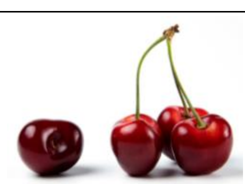
The object of this review is to synthetize the availability of natural colouring compounds as well as to make reference to the potential health benefits as well as to present *Prunus* spp. as possible natural dyes. In addition, some future perspectives in view of the trending research topics will be provided.

Natural Colouring Compounds

The colouring compounds present in *Prunus* spp. fruits are not exclusive to the genus. Some of the most common natural colorants in fruits, in general, are carotenoids, flavonoids, anthocyanidins (Lu et al. 2021).

Flavonoids can be divided into flavonols, flavanols, flavanones, flavones, isoflavones, and anthocyanins (Akhlaghi and Foshati 2017). Flavonoids possess various biological activities (Liga et al. 2023). The colour of flavonoid pigments varies from white-cream to orange-red and purple-blue (Miao et al. 2022). Anthocyanins are glycosylated forms of aglycones, and a class of water-soluble flavonoids (Mattioli et al. 2020). They can exhibit red, blue and purple colours. Their colour is pH dependent, meaning that in an acidic pH (pH < 3) cyanidin will be red to orange, while in pH > 11 it will appear blue-green. Appropriate extraction techniques should be used in order to enhance their stability and application (Guo et al. 2022). Different approaches have been used in order to recover anthocyanin pigments (Tan et al. 2022). Some of the frequently used extraction methods include ultrasonic assisted extraction, microwave assisted extraction, supercritical carbon dioxide extraction and combined methods (Tan et al. 2022). Alcohols like methanol and ethanol, along with acidified water or ethanol are some of the most common solvents for the anthocyanin recovery (Muangrat et al. 2017). Anthocyanins are vacuolar pigments and are also reported for their antioxidant properties (Tena and Asuero 2020). They can be found in various representatives of the genus *Prunus* (Mollaamin et al. 2022; Liao et al. 2023). Pelargonidin and cyanidin 3-glucoside have been reported in cherry jams (Swami et al. 2020). The brownish coloration of prune juice is a result of the reaction between phenolic compounds and anthocyanins (Swami et al. 2020). Carotenoids can be responsible for yellow, orange, and red colours (González-Peña et al. 2023). They are classified into carotenes and xanthophylls (Schawartz et al. 2017). Research showed that apricots accumulate more carotenoids compared to other *Prunus* representatives (Han et al. 2020). A total of twelve carotenoids were detected in *Prunus* species, *i.e.* violaxanthin, luteoxanthin, antheroxanthin, lutein, zeaxanthin, β-cryptoxanthin, β-carotene, among others (Han et al. 2020). Carotenoids extract well in polar solvents (Saini et al. 2022). Oxygen concentration, pH-values, light and temperature are some of the most important parameters for the effective carotenoid pigment extraction (Flieger et al. 2018).

Table 1. *Prunus* spp. representatives and their dying compounds

Representative	Chemical class	Compounds	Extraction solvents and techniques	Potential beneficial properties	References
 ***Prunus persica* L.**	Carotenoids flavonoids anthocyanidins	α-carotene, β-carotene, β-cryptoxanthin, lycopene, lutein, and zeaxanthin	hexane, petroleum ether, acetone, ethanol, methanol; liquid-liquid extraction, solid-liquid extraction, Soxhlet extraction ultrasonic extraction	antioxidant propensity, various anti-inflammatory actions cardiovascular health, cancer and neurodegenerative protection	(Cheng et al. 2020; Molina et al. 2023)
 ***Prunus armeniaca* L.**	carotenoids flavonoids chlorophylls	Lutein; α-carotene, β-carotene, γ-carotene, lycopene, and cryptoxanthin; β-cryptoxanthin, phytoene, phytofluene and zeaxanthin quercetin, kaempferol and rutin Chlorophyll a and b	acetone; n-hexane: acetone; heat reflux extraction	antioxidant activity; degenerative diseases protection; cardiovascular health	(Ali et al. 2015; Makrygiann et al. 2022)
 ***Prunus domestica* L.**	anthocyanin carotenoids	cyanidin-3-rutinoside, cyanidin-3-glucoside and peonidin-3-rutinoside	methanol, ethanol, acidified water; thermo stated cell extraction	preventing inflammation, hypertension control, thrombotic risk management, and cancer prevention	(Zbrzeźniak et al. 2015; Han et al. 2020; Liao et al. 2023)
 ***Prunus avium* L.**	carotenoids flavonoids anthocyanins	Lutein; Zeaxanthin; α-Carotene; β-Carotene; quercetin-3-O-rutinoside; kaempferol; cyanidin-3-O-rutinoside	acetone; ethanol; methanol; UAE	modulation of the antioxidant response; protect against oxidative damage	(Średnicka-Tober et al. 2019)

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Additionally mechanical treatment for the disruption of the thick cell walls and appropriate solvents are recommended for better pigment recovery (Gu et al. 2008). Oxidation is the primary cause for the loss of carotenoids (Ribeiro et al. 2018). Chlorophylls are green oil-soluble pigments (Ebrahimi et al. 2023). Their stability is dependent on pH fluctuation, temperature, and storage duration (Kwartiningsih et al. 2021). Some of the reported effective extraction techniques include enzyme-assisted extraction, supercritical fluid CO_2, methanol extraction (Lu et al. 2014). The bioactivity of chlorophylls has been confirmed by researchers (Martins et al. 2023).

Applications

Many branches of the food industry benefit from both natural and synthetic colorants. The colour of ice cream and yogurt is due to colorants. If natural ones are considered research shows that betalains can be used (Lis and Bartuzi 2023). Anthocyanins can be founding as pigments in beverages, desserts, ice cream, and dairy products (de Mejia et al. 2020). Beverages are an example of food products that most other need colorants. The popular "vitamin waters" are most often coloured. Bakery products are other examples of the existence of food dyes. The colour of bakery products is linked to the Maillard reaction but the presence of another colour can contribute to the sensory profile in terms of not only colour and appearance but also aroma (Luzardo-Ocampo et al. 2021). There are examples of the microencapsulation techniques for the colouring of jelly candies (Dewi et al. 2018). Confectionary is a sector of the food industry with high demand for colouring agents (Suryanarayana et al. 2017). Yogurt and flavoured milks are coloured due to the expectations of the consumer. For example, a strawberry yogurt should be pink, and chocolate milk should be brown. Cheeses also take advantage of natural colorants (Sharma et al. 2020). Furthermore, meat products are a niche for natural colorants not only because of potential colour loss, during processing, but also because of the antioxidant properties of natural dyes like carotenoids (Hamdi et al. 2018). Lasty, coloured pasta has recently gained popularity (Porto Dalla Costa et al. 2016). It is often green, orange and red with reference to tomato, carrot and spinach.

Conclusions and Future Perspectives

Natural pigments in fruit are not only powerful antioxidants but also bear potential health benefits. Living in the era of synthetic pollution, the seek for natural ingredients has become even more valuable. Natural pigments are renewable, non-toxic but their bio accessibility and availability is still to be thoroughly researched. Colour will always be one of the most important attributes of food. Contemporary research design is turning to replacing synthetic dyes with natural as much as possible, because of their harmful nature. The spread of bio dyes can potentially expand biodiversity and thriving availability of native cultivars. The use of fruit waste for colouring can contribute to the sustainability cycle and zero-waste policy. However, research is looking into the possibility of allergies due to natural dyes interactions in the body (Lis and Bartuzi 2023). Additionally, the stability of the colour is sometimes challenging.

Natural pigments should be carefully regulated with safe dosages so that they can act as an enhancer to food quality and not a deteriorator of consumer's experience. This calls for the expansion of research on the topic of plant beneficial metabolites, their extraction, and incorporation in food matrices without loss of their activities like antibacterial, anti-inflammatory, cardioprotective, neuro-protective, and other properties.

Acknowledgements

This work was supported by the Bulgarian National Science Fund, project no. КП-06-Н67/2 (granted to Aneta Popova). The authors would like to acknowledge prof. Argir Zhivondov for actively working on expanding plumcot varieties in Bulgaria, and registering the "Stendesto".

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