Advantages and considerations for the applications of natural food pigments in the food industry

S.J. Ranaweera, A.A.L.T. Ampemohotti, Udara. S. P. R. Arachchige
Faculty of Technology, University of Sri Jayewardenepura, Sri Lanka

Abstract – Color is one of the main sensory attributes which influence product acceptance. To maintain and enhance the color of food products. Imparting colors is essential due to various reasons. Synthetic colors are widely used as they are low cost and they have better stability. However, usage of natural pigments should be promoted as an alternative for the harmful colorants mainly in order to reduce the health risks and for some other benefits. There are so many sources in the surrounding that we can extract those pigments. But these pigments are so sensitive to processing conditions so a proper understanding of their properties is very important to utilize them effectively.

Index Terms— color, pigments , synthetic colors, natural colors, health risks

1 INTRODUCTION

Color is a very important sensory parameter that can easily differentiate the interest, acceptance and the attraction of a food product. Basically, it influences the initial acceptance or the rejection of a product. Pigments are responsible for the color of a product. There are so many synthetic and natural colors available. These colors are important in food processing to replace the color that has been lost during processing, to get a uniform color for the whole batch, to add color to a colorless product, to enhance the strength of the color of a product and etc. Artificial food dyes are not safe for human consumption most of the time. They may cause allergies, irritability, hyperactivity like health issues as well as cancer like very serious problems when they are consumed for a considerable time. It has been proven by several researchers including "the so-called Southampton six" which is done to check the influence on children's oversensitivity by using some colorants [1]. The extraction of natural pigments from food waste and underused commodities is the best solution to reduce these effects by reducing the usage of artificial dyes. On the other hand, it will also help to manage waste as these pigments can be extracted from food waste and by-products in food industries. Most of these materials are neglected and under-utilized. Ancient people only used so many natural sources to derive these colors until the first artificial color was synthesized in 1856 [2].

Food pigments should only add the color to a product and it should not be responsible to change the other sensory parameters of the product like taste, aroma and etc. Therefore the materials which influence the other sensory properties apart from its color like saffron, paprika are not classified as pigments [3]. There are different methods to extract pigments and Solvent extraction is the most popular way to extract natural pigments [4]. The quality of the pigments depends on raw material quality and extraction quality. There are already permitted natural pigments available including flavonoids, anthocyanins, lutein, canthaxanthin, betalains, quinones, cochineal and etc. Additionally, these pigments have health benefits too.

2 DISCUSSION

What you see is the first impression of a product. Colorants play a major role in order to make that appear attractive. Increasing consumer preference towards a particular food product is important in the modern competitive world. Colorants are essential for most of the food industries including bakery and confectionary, Meat and aqua, fats and oil, dairy, spices and condiments, beverage and other processing industries. It plays a major role in maintaining organoleptic properties. Every different color is representing a specific wavelength of the visible electromagnetic spectrum.

- Blue 450–495 nm
- Green: 495–570 nm
- Yellow: 570–590 nm
- Orange: 590–620 nm
- Red: 620–750 nm

We see the color of an object based on the reflected and absorbed colors of it. Pigments are able to absorb and reflect colors. What we see is the reflected color or the color combination [5], [6].

People tend to use different synthetic and natural coloring agents for this purpose. Some colors are changing and fading away. To preserve the desired color though out the shelf life, the addition of colorants is necessary. Manufacturers always tend to use low-cost artificial colors instead of natural pigments even though they are harmful to make more profit. The food colorant market is increasing day by day. It was valued at USD 3.71 billion in 2017 and projected to reach USD 5.12 billion by 2023 [7]. Most of the synthetic colorants hazardous for human health, so it is always better to use naturally extracted colors, especially for food products. Synthetic colors are still using in industries as synthesizing colors artificially required comparatively a low cost than extracting natural pigments and their stability is higher but natural pigments are getting more focused due to the increasing demand as modern consumers are more health-conscious.

Health defects of synthetic colors:

The utilization of artificial food ingredients including these colors is responsible for the increasing rates of motel diseases like cancers and chronic diseases.

- Some colors are manufactured by using harmful chemicals such as heavy metals such as arsenic, a lead that can cause life-threatening diseases [8].
- After doing several experiments on lab animals, FDA found that some of the synthetic colors may cause cancer.

  Eg: Blue 1(Brilliant blue FCF),Blue 2 (Indigotine), Green 3(Fast green FCF),Red 40 (Allura red AC), Yellow 5 (Tartrazine), Yellow 6 (Sunset yellow FCF)
- Yellow 5, Yellow 6, red 40 colors contain carcinogenic compounds.
- Cause hyperactive in children Caffeine is known as a widely using colorant in soft drinks and it causes heart defects.

Natural pigments:

Most of the natural pigments are extracted from plant materials such as fruits, flowers, leaves, stems, roots as they produce an ample amount of different pigments. Especially most of the flowers are enrich with different colors of pigments and food wastes like peel, pulps, seeds also contain a huge amount of pigments. Besides animal by-products such as blood and microbial products be used for this. These natural pigments will support to make organic products without any detrimental effects. As natural colors are very sensitive, they should be treated to preserve (Table 1).

Table 1. Natural sources for pigment extraction [9]

Native name of the plant	Botanical name	Important part	Color that can be extracted
Hibiscus	Hibiscus rosasinnsis	Flower	Red
Lotus	Nymphaea nouchali	Flower	Pink
Manel	Nymphaea stellata	Flower	Blue
Katarolu	Clitoria ternate	Flower	Blue
Rathmal	Ixora spp	Flower	Red
Ranawara	Cassia auriculata	Flower	Yellow
Mango	Mangifera indica	Fruit	Yellow
Pineapple	Ananas sativum	Fruit	Light yellow
Sapathilla	Achras zapota	Fruit	Yellow
Beet	Beta vulgaris	Yam	Red
Carrot	Dacus carotova	Yam	Yellow
Iramusu	Hemidesmum indicus	Stem	Pink
Kotalahimbutu	Salacia reticulate	Stem	Pink
Wing bean	Delichos lablab	Flower	Blue
Beli	Hibiscus tiliaceus	Flower	Yellow
Babila	Sida cordifolia	Flower	Yellow
Mae	Vigna sinensis	Flower	Blue
Thora	Caesallpinoide	Flower	Yellow
Erabadu	Erythrina indica	Flower	Red
Panithora	Cassia oxidentalis	Flower	Yellow
Nidikumba	Mimosa pudica	Flower	Pink
Sweet potato	Impomoea batatas	Flower	Yellow
Katuikiliya	Acanthus ilicifolis	Flower	Blue
Sun flower	Helianthus zinica	Flower	Yellow
Monarakudumbiya	Vernonia cinerea	Flower	Pink
Thampala	Amaranthus	Leaves	Red

Bovitia	Osbekiya	Fruit	Purple
Eraminia	Zizyphus	Fruit	Red
Buthsarana	Cana	Flower	Red
Delum	Punica granatum	Fruit	Pink
Brinjal	Solanum melongena	Flower	Purple
Papaya	Carica papaya	Fruit	Yellow
Passion fruit		Fruit	Yellow
Kekatiya	Apanogetone	Flower	Blue

These pigments can be extracted by using several methods as bellow [10],

- Pure water extraction: Flower petals can be added to water and boil to dissolve the pigments in the water and they should be treated with citric or ascorbic acids to prevent the discoloration. It is an economical, safe method.
- Ethanol extraction: 90% of ethyl alcohol can be used for this. Crushed plant materials should be added to ethanol and leave it for some time to extract the pigments. A small amount of ascorbic acid(0.5%) should be added to avoid discolorations. Finally, the solution should be evaporated using the soxhlet apparatus. This method is important to extract both water-soluble and insoluble pigments. For the drying process, water bath drying or dehumidification drying can be used. Dehumidification gives brighter colors. This method is especially important to extract water-insoluble pigments as yellow pigments.
- Yeast added extraction: Initially, the plant materials should be boiled. Before adding yeast that should be cool down. Yeast will be digesting the monosaccharide and it will help to maintain the color during drying.
- Soxhlet extraction
- Microwave-assisted extraction (MAE)
- Ultrasound-assisted extraction (UAE)
- Pressurized fluid extraction (PFE)
- Enzyme-assisted extraction (EAE)
- Solid phase micro extraction (SPME)
- Membrane extraction (ME)

Importance of natural extraction of pigments:

- To face the increasing demand successfully
- Reduce the waste and utilize by products effectively
- To manufacture "safe to use " food products
- Additional nutritional benefits .(anti oxidants, anthocyanin, vitamins.)
- Higher medicinal value
- Non allergic

- Eco friendly
- Expand the export market
- High consumer acceptability.

But anyway there are also limitations of natural pigments that we should consider when using such as,

- Limited availability of souses and Some sources are seasonal
- Low concentration
- Quality varies with the source
- Sensitive to processing conditions such as pH, temperature, light and etc**.**
- Higher material usage**.**

To overcome the above limitations, different tips can be suggested.
It can use recombinant DNA technology to create microbes that can produce natural pigments by them self. The growth conditions can be handled by the manufacturer, So it will not be seasonal anymore. Mild processing conditions may reduce the cost [11].

Also, extensive processing conditions should be avoided. The colorants can be added in the final stages at mild conditions. Utilize waste which is generating in larger amounts in food industries as the extraction materials. The processor must have enough knowledge about all the optimum conditions for the extraction and preservation of those pigments can use a proper package to avoid subjecting to undesirable environmental conditions.

Natural food pigments

- Flavonoids- Water soluble
    - Anthocyanins (Red, Blue and purple)
    - Chalcons (Yellow)
    - Aurones (Yellow)
    - Flavones (Cream color)

- Carotenoid (Red, Orange, Yellow) -Fat soluble
    - Carotenes (Red, Orange)
    - Xanthophylls (Yellow, Orange, Red)
- Chlorophylls (Green)
- Betalains (Bluish pink color)- Water soluble

Application of natural pigments in food industry

Understanding the chemical and physical properties of plant pigments is essential before any application. Because of the brightness, intensity and most importantly the color stability is affected by environmental conditions including temperature, pH, oxygen, etc. Effect of pH on the color of pigments should be highly considered as the food products are acidic, alkaline or neutral and that cannot be avoided even the harmful effect of other processing conditions can be avoided by some alternative actions.

The adverse effects of temperature can be avoided and controlled by adding the colorant after cooling. But the effect of pH is hard to control as the final pH of a standard product is constant. Anthocyanin changes its color based on the pH. It appears as red in acidic conditions, Blue at less acidic conditions and violet/purple at neutral conditions. Changes in some food pigments in different pH values have been already found in the research carried out [9]**.** The red color extracted from the hibiscus flower is very bright at acidic conditions and it is turning into brown color when the pH is increased. Blue color extracted from the Clitoria flower shows a dark blue color when it is low acidic and turns in to brownish color at high acidic pH. Yellow color extracted from the cassia flower appears as yellow in high acidic pH and turned brownish yellow around 5.2 pH and again turned into dark yellow in low acidic conditions. When applying pigments for food products, solubility is also should be considered as they effectively mix and give a uniform color (Table 2). Because even the flavonoids, betalains like pigments are water-soluble and carotenoid like pigments are fat-soluble. So for a product containing more fat, Carotenoids can be successfully used than other flavonoids like water-soluble pigments [12].

Table 2. Applications of pigments

Color	Pigments	Sources	Applied products
Red	Anthocyanins	grape color or skin, vegetable juice (Carrot, cabbage) fruit juice (blue berries, black berries, rasp berries, strawberries),red wines, cereals. Flowers, Mushrooms	Beverages like mixed fruit juice , yogurts, and dry mixes.
	Betalains	Red beet	yogurt, confectionaries, ice cream, syrups, and sausages
	carotenoid	tomato, watermelon, guava, and pink fruit	meat products, soups, pickles, and snacks.
	Carminic acid	cochineal insects (*Dactylopius coccus)*	Beverages(alcoholic and soft drinks), bakery, dairy products, jams, and confectioneries.
	Monascus	Fermentation of rice with Monascus spp.yeast	meat and sausage
Orange-Yellow	Carotenoid (α-, β-, γ-carotene, lycopene, capsanthin, and bixin, crocin)	Turmeric, Saffron, Carrot, Paprika, Tomato	margarines, baked goods, compound coatings, dry beverage mixes, ice cream, panned candies, sauces, seasonings, soups, frostings, dairy, and cereal , desserts, jams, creams, pastries
Purple	Anthocyanin	Red cabbage, purple sweet potato, and purple carrot, Egg plant	Purple color jam, jelly like products, confectionary products, beverages, yoghurt

Blue	Anthocyanins	Blue berry, black berry, Blue corn	Confectionary products and ice creams, mixed fruit juice.
Green	Chlorophyll	Plants (peppermint, pistachio, common or stinging nettl), algae, and bacteria	Citrus based dry beverage mixtures.

Examples for successful applications:

Betalains which are mainly extracted from red beet and cactus pear are normally stable at a wide range of pH 3-7. So they are comparatively low dependent on the pH but it depends on temperature, light, oxygen, and other components in food. They are most commonly used in low temperature and low acidic dairy products like ice cream [13]. Betalains are better to use with products having a low shelf life, low-temperature processing, and storage. To increase the stability of betalains an opaque packaging can be used and some of the food additives are important as following,

- Preservatives
- Gums- pectin, locust bean gum
- Antioxidants - ascorbic acid
- chelating agents-EDTA, citric acid [14]

Carotenoid is lipid-soluble and highly unsaturated pigments. So they are very sensitive to oxidation [15]. Processing and storage conditions must be maintained as light, moisture, temperature, enzymes, metals, peroxides may accelerate the color loss by oxidation. Chlorophyll is highly unstable and loses its color easily [16].

Anthocyanins are very important as it gives Red, Blue, and purple which are considered as very important colors it changes the color based on the pH. Normally red is the most widely used color in the food industry in order to stimulate the appetite [17]. It is used in different products and the color appears based on the pH.

Eg:

It can be used for yogurt-like products which have low pH values to give reddish color. Can use to impart blue color to icing in confectionery products as acing have low acidity and anthocyanin remains blue in low acidic mediums.

But this color stability also depends on the source it has been extracted.

Eg:

Blue color which is extracting from the Clitoria flower turns brown when the pH is very low (3.0-3.5) so it can be applied for wood apple jams, nectar-like low pH products as they required to be the dark brown color as ripening wood apple should be that color. But red color extracted from the Hibiscus flower will turn bright red-orange color around 3.5-4.0 pH levels. So it is desirable when added into fruit nectar.

Pigments that are extremely sensitive to high-temperature levels such as chlorophyll must be added to cold foods and also should add after the processing stages which uses high temperatures such as pasteurization, sterilization. Carotenoid is resistant to high heat processing as well as freezing conditions [18]. Curcumin

like carotenoid pigments that are extracted from turmeric is highly resistant to temperatures up to 120 0C and also stable at acidic conditions (pH 2.5-6.5) **[3].**

3 Conclusion

Application of plant pigments can successfully be used to reduce the usage of harmful synthetic pigments which cause serious health defects. There are a large number of natural sources that can be used to extract pigments with different hues. The extraction of pigments from natural sources is a challenging process. Their properties should be understood before using them as they are very sensitive to processing and environmental conditions. Even the same pigment which is extracted from different sources do not have the same stability on each of the processing conditions. Additionally, natural pigments also have so many health benefits. These natural colorants can be considered as a gift from nature. These pigments help to produce organic products. By increasing the application of them in the food industry may reduce the rate of motel diseases which is increasing day by day because the main cause for them is assumed as a high intake of unsafe food. These pigments can be successfully utilized only by focusing on the properties of each pigment when using them as different pigments are sensitive for different processing conditions and they may change or fade the color of it if not properly used. So that will then be a total waste.

REFERENCES

[1] D. McCann, A. Barrett, A. Cooper, D. Crumpler, L. Dalen, K. Grimshaw, E. Kitchin, K. Lok, L. Porteous, E. Prince, E. Sonuga-Barke, J.O. Warner, J. Stevenson, Food additives and hyperactive behaviour in 3 and 8/9 year old children in the community. The Lancet, 2007.

[2] A. Burrows, Palette of our palates: a brief history of food coloring and its regulation. Compr. Rev. Food Sci. Food Saf. 8(4):394–408, 2009.

[3] M.J. Scotter, Food colour additives of natural origin. In: (ed.), Colour additives for foods and beverages, 3-34, 2015.

[4] S. Presilski, N. Presilska, D. Tomovska, Effects of extraction, conventional processing and storage on natural anthocyanins, J. Food Processing and Technology, Vol. 7, 2: 551, 2016.

[5] F. D. Vargas and O. P. Lopez, Natural colorants for Food and Nutraceutical uses, CRC press, Washington DC PP 7, 2003.

[6] A.G. Newsome, C.A. Culver, R.B.V. Bremen, Nature's palette: the search for natural blue colorants. J. Agric. Food Chem. 62:6498–511, 2014.

[7] https://www.marketsandmarkets.com/Market-Reports/food-colors-market-36725323.html

[**8**] C. Potera, DIET AND NUTRITION: The Artificial Food Dye Blues. Environ Health Perspect. 118(10), 2010.

[9] S.B. Navaratne, Plant pigments for food, 2015.

[10 M.J.]Navas, A.M. Jimenez-Moreno, J. Martin Bueno, P. Saez-Plaza, A.G. Asuero, Analysis and anti oxidant capacity of anthocyanin pigments. Part III: An introduction to sample preparation and extraction.Crit.Rev.Anal.Chem. 42: 284-312, 2012.

[11] V.K. Joshi, D. Attri, A. Bala, S. Bhushan, Microbial pigments. Indian J. Biotechnol. 2:362–69, 2003.

[12] N. Galaffu, K. Bortlik, M, Michel, An industry perspective on natural food colour stability. In: M. J. Scotter (ed.), Colour additives for foods and beverages, Woodhead Publ. Ser. Food Sci. Technol. Nutr., 279. DOI: 10.1016/B978-1-78242-011-8.00005-2, 2015.

[13 F.C.]Stinting, R. Carle, Functional properties of anthocyanins and betalains in plants, food, and in human nutrition. Trends Food Sci. Technol. 15(1):19–38, 2004.

[14] K.M. Herbach, F.C. Stintzing, R. Carle, Betalainst ability and degradation: structural and chromatic aspects. J. Food Sci. 71(4):R41–50, 2006.

[15] D.B. Rodriguez-Amaya, Natural food pigments and colorants. Curr. Opin. Food Sci. 7:20–26, 2016.

[16] A.M. Humphrey, Chlorophyll as a color and functional ingredient. J. Food Sci. 69(5):C422–25, 2004.

[17] S. Singh, Impact of color on marketing. Manag. Decis. 44(6):783–89, 2006.

[18] F. Delgado-Vargas, A.R. Jiménez, O. Paredes-López, Natural pigments: carotenoid, anthocyanins, and betalains – characteristics, biosynthesis, processing, and stability. Critic. Rev. Food Sci. Nutr., 40, 3, 173–289. 2000.