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Review Article

Natural Dyes from Plants for Smart Packaging Printing and Applications

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ABSTRACT

More and more people are becoming curious about the benefits of using natural dyes in textiles. Toxic and allergic reactions associated with synthetic dyes have prompted many countries to establish stringent environmental regulations. Natural dyes are more biodegradable and environmentally friendly than synthetic dyes. There are four types of natural dyes: those originating from plants, animals, minerals, and microorganisms. All natural fabrics can be dyed using natural dyes. They can also be used to color synthetic fabrics, according to a recent study. Natural dyes aren't just for textiles; they're used in food, medicine, handicrafts, and leather processing. Many of the plants that provide natural color are also used in traditional medicine. The classification of natural dyes and the numerous sustainability challenges associated with their manufacture and application are reviewed in this paper in an attempt to be comprehensive.

Keywords: Color; Pigment; Natural dyes; Intelligent packaging; Printing; Ecofriendly; Ink

INTRODUCTION

Inks play an important and diverse role in our daily life. Our day begins with newspapers and toiletries and progresses to the breakfast table, which is replete with several ink-labeled, packaged consumer products such as tea or coffee, bread, and butter, and then gradually moving to our workplaces schools or offices where ink is found everywhere, be it books, calendars, photocopies, computer prints, stamps, or even money. Ink is a dissolved or suspended organic or inorganic pigment or dye in a solvent. However, it is considered chemically as a colloidal system of fine pigment particles, either colored or uncolored, scattered in an aqueous or organic solvent. Fruit or vegetable juices, protective secretions from cephalopods like squid, cuttlefish, and octopus, blood from some types of shellfish, and tannin from galls, nuts, or tree bark were said to be the first inks. The first man-made ink is thought to have appeared 4,500 years ago in Egypt and constituted of a mixture of animal or vegetable charcoal (lampblack) and glue [1,2]. Before 2500BC, the earliest black writing inks were suspensions of carbon, mainly lampblack, in water stabilized with a natural gum or compounds such as egg albumen [3].

Modern inks are made up of several different ingredients. They also contain various other substances collectively termed as 'vehicle' in different amounts in addition to the pigment. pH modifiers, humectants to prevent premature drying, polymeric resins to impart binding and other properties, defoamer/antifoaming agents to control foam efficiency, wetting agents such as surfactants to control surface properties, biocides to prevent fungal and bacterial growth that causes fouling, and thickeners or rheology modifiers to control ink application are examples of these [4]. In other words, printing has existed in some form or another for centuries; while the core purposes of decoration and information have remained the same, the printing technique and ink compositions have undergone significant changes [5].

Inks today are divided into two categories: printing and writing inks. Ink for conventional printing, in which a mechanical plate comes into contact with or transfers an image to the paper or item being printed on, is further divided into two subclasses: ink for digital nonimpact printing, which comprises inkjet and electrophotographic technologies. Over 90% of inks are printing inks, which use pigments rather than the dyes used in writing inks to provide color. Organic pigments made consisting of salts of nitrogen-containing compounds (dyes) such as yellow lake, peacock blue, phthalocyanine green, and diarylike orange are mixed with linseed oil, soybean oil, or a heavy petroleum distillate as the solvent (called the vehicle) in color printing inks [6,7].

Chrome Green (Cr_2O_3), Prussian Blue ($Fe_4\{Fe(CN)_6\}_3$), Cadmium Yellow (CdS), and Molybdate Orange are inorganic pigments that are utilized in printing inks to a lesser extent. White pigments, like

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as titanium dioxide, are employed as stand-alone pigments or to tweak the properties of color inks. Carbon black is used to make black ink. A weak solution of the red dye eosin is used in most red writing inks. Substituted triphenylmethane dyes can be used to achieve a blue color. Iron sulphate, gallic and tannic acids, as well as pigments, are found in many permanent writing inks. In most cases, ballpoint ink is a paste containing 40 to 50 percent dye [8,9].

Titanium dioxide rutile and anatase in tetragonal crystalline form are commonly used as pigments in white inks. Because of the known toxicity of heavy metals, several inorganic colors, such as chrome yellow, molybdenum orange, and cadmium red, have been replaced with organic pigments, which have superior light fastness and lower toxicity, because of growing health and environmental concerns. Carbon black has largely supplanted spinel black, rutile black, and iron black in practically all black inks. Waxes, lubricants, surfactants, preservatives, wetting and drying agents, and other additives are used in inks to aid printing and impart any desired qualities [10,11].

Other inorganic components, like as clays, act as fillers or extenders, lowering the cost of pigments while also improving ink characteristics. In new silver and gold inks, metallic pigments such as aluminum powder (aluminum bronze) and copper-zinc alloy powder (gold bronze) are employed. Luminescent and pearlescent effects are achieved using a variety of inorganic pigments. Lithography, also known as offset printing, flexography, gravure printing, screen printing, letterpress printing, and digital printing are the main types of printing techniques. The type of printing process especially, how the ink distribution rollers are placed in the printing press determines the composition of printing inks [12,13].

The printing principle can be demonstrated using a simple pad operation with liquid ink that can wet the pad. The pad is initially dipped in a rubber type, which is then wet with ink. It is now pressed against a substrate, like as paper, and an impression is made on it. When in the pad, this ink should remain liquid; however, once cast on the substrate to be printed, it should dry quickly. Although digital printing does not use movable types, the various printing techniques differ in how the type is impregnated with ink. As a result, each operation necessitates ink with different viscosity and drying efficiency, which can be achieved by fine-tuning the composition [14].

A pigment (one of which is carbon black, which is similar to the soot used in 2500 BC), a binder (an oil, resin, or varnish of some type), a solvent, and numerous additives such as drying and chelating agents make up today's printing inks. The specific recipe for a certain ink is determined by the type of surface it will be printed on as well as the printing process employed. The numerous printing procedures are all similar in that ink is put to a plate/cylinder, which is then applied to the printed surface. The plate/cylinder, on the other hand, can be made of metal or rubber, and the image can be raised above the plate's surface, etched into the plate and the excess ink scraped off, or in the plane of the plate but chemically modified to attract the ink. To meet these various situations, different inks are created [15].

GLOBAL MARKET (NATURAL DYES)

The market for natural dyes and pigments in Europe was worth USD 1255 Million in 2020, and it is predicted to increase at a CAGR of 10.1 percent between 2021 and 2028. Increased demand for dyes and pigments in textiles, foods and drinks, paints and coatings, and cosmetic applications are expected to boost market expansion. Furthermore, the negative consequences of making synthetic dyes and pigments, such as pollution of aquatic bodies owing to chemical dumping, have fueled demand for natural dyes and pigments. Because natural dyes and pigments are made from naturally available ingredients, they have a lower reliance on raw materials produced from crude oil resources.

Plant leaves, vegetables, meat, red wine, green tea, fruits, and insects are used to make natural dyes and pigments. These raw materials are then processed to create plant-based, animal-based, and mineral-based dyes, as well as pigments like carotenoids, anthocyanins, betaines, quercetin, chlorophyll, and phycocyanin, which are widely used in printing inks, textiles, food and beverage, cosmetics, and other applications (Figure 1). In 2020, Germany accounted for a large portion of the total revenue for the European natural dyes and pigments market. The rising use of plant and animal-based dyes, as well as natural pigments derived from algae and other fruits and plants, is responsible for this increase (Figure 2).

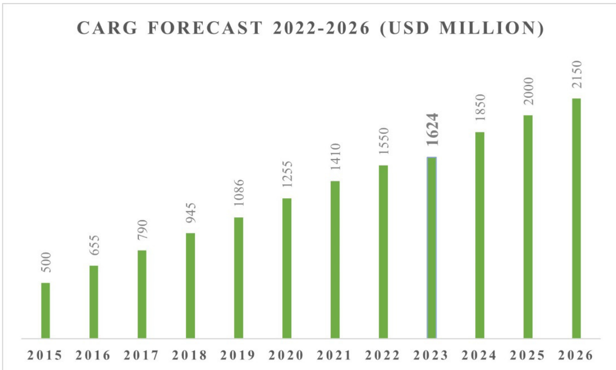

Figure 1: Global market of natural dyes.

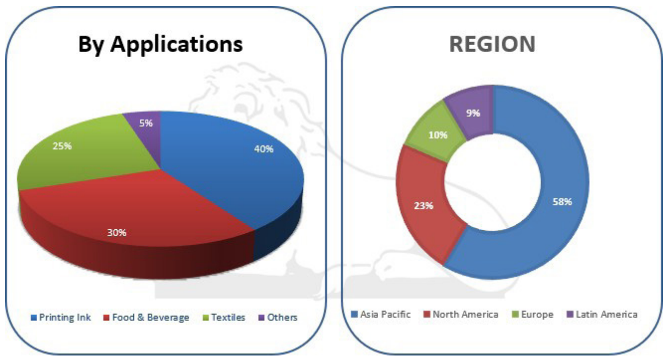

Figure 2: Market of natural dyes by applications and region.

The market is divided into five regions: North America, Europe, Asia Pacific, Latin America, and the Middle East and Africa (MEA). The North American continent is further divided into countries such as the United States and Canada. The European continent is divided into the United Kingdom, France, Germany, Italy, Spain, Russia, and the Rest of Europe. China, Japan, South Korea, India, Australia, Southeast Asia, and the Rest of Asia Pacific make up Asia Pacific. The Latin America region is separated into Brazil, Mexico, and the rest of Latin America, while the Middle East and Africa region is divided into GCC, Turkey, South Africa, and the rest of MEA [16,17].

The market has been divided into two types of applications: Printing ink, food beverage, textiles, and others. Because of its extensive use in various packaged goods, the food category held a major proportion of the market and is expected to continue to do so by 2026. Furthermore, strict laws regulating food colorants are likely to boost the segment's expansion [18].

COMPOSITIONS OF PRINTING INKS

Pigments: Pigments are the most important component of ink, accounting for almost half of its cost. A pigment is a particulate substance - colored, black, white, or fluorescent - that affects the look of an item through selective light absorption and/or scattering. It appears in ink as a colloidal solution that maintains a crystal or particle structure throughout the coloring or printing process. The Organic Pigment Identification System number is commonly used to identify organic pigments in modern inks. It displays the pigment's color shade or hue, as well as structural and historical characteristics (sequence of synthesis). Pigments give the ink its color and provide gloss, abrasion resistance, and resistance to light, heat, solvents, and other factors. Extenders and opacifiers are also employed as special pigments. Opacifiers are white pigments that make the paint opaque so that the surface beneath it cannot be seen. Extenders are translucent pigments that make the colors of other pigments appear less vivid (Figure 3) [19].

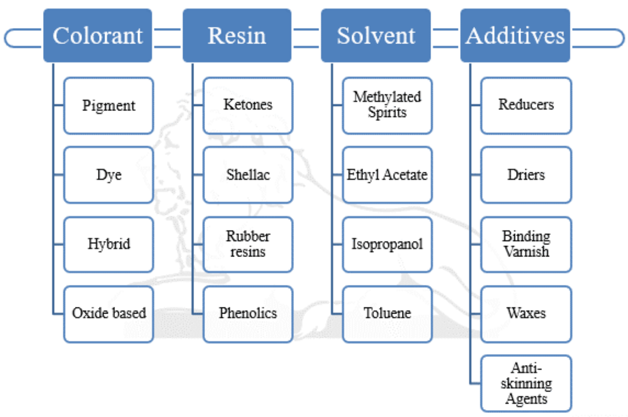

Figure 3: Composition of printing links.

Types of pigments: Different types of pigments are available in market Pigments, along with dyestuffs, are perhaps the most essential components in printing ink formulation since they transmit the ink's visual identity and invariably comprise the majority of the ink's component. Pigments and soluble dyes both change the reflectivity of a substrate to give it color. Insolubility is a critical feature of pigments, which are multimolecular crystalline structures built to an optimal particle-size distribution. When applied to a substrate in a vehicle, they either stay on the surface or fill up spaces in paper or other uneven surfaces (Table 1) [20].

Table 1: Sources of pigments.

Pigments	Sources
Yellow	Mono Azo, Di arylide, Iron Oxide, Tartrazine Lake, Chrome, Cadmium.
Orange	DNA Orange, Pyrazalone, Di arylide, F2G, Benzimidazole, Peri none.
Red	Naphthol, Toluidine, Chlorinated Para, Carmine F.B, Bordeaux FRR.
Green	PMTA, PMTA Vivid, Phthalocyanine.
Blue	PMTA Victoria, Phthalocyanine Alpha, NCNF, NC Beta, Ultramarine.
Violet	PMTA Rhodamine, Methyl, Ultramarine, Di oxazine, Crystal CFA.
Brown	Brown Iron Oxides, Diazo, Chromium Antimony Titanium Buff Rutile.
Black	Lamp Black, Carbon Blacks, Furnace, Channel Black, Black Iron Oxide.
White	Zinc, Lithopone, Titanium Dioxide Anatase, sulphide, Calcium Carbonate.
Pearlescent	Titanium Treated Micas
Metallic	Aluminum, Copper, Bronze.
Fluorescent	These comprise various yellows, oranges, reds, greens, and a blue.

Dyes: A dye is a colored material that has a specific affinity for the substrate to which it is applied. The dye is usually applied in an aqueous solution, and it may be necessary to add a mordant to improve the fiber's fastness. There are 2 primary kinds of dyes, such as:

1) Natural dyes 2) Synthetic dyes.

Natural Dyes: Natural resources are primarily used to produce these colors. These are made of renewable materials.

Synthetic Dyes: These colors are made from a variety of chemicals, man-made materials, and other ingredients. Color's role in textile products cannot be overstated. Since the dawn of history, colors have captivated humans. Since the dawn of time, natural vegetable dyes have been a part of human life. The usage of these colors may be seen in Egyptian mummies and documents from the Mughal period. Natural dye use has been declining since the development of synthetic dyes in 1856 [21,22].

Classifications of dyes

Difference between pigment and dye: The primary distinction is that dyes are soluble, but pigments are insoluble and must be suspended in a medium or binder. This is owing to the fact that dyes and pigments have different particle sizes, which impacts how they function. Consider the difference between a pinhead (dye) and a football (pigment) particle (pigment). Because dyes are soluble and pigments are not, you might image dye particles dissolving in water whereas pigment particles need to be suspended in a binder - think of salt in water (dye) or pebbles in water (pigment). The salt dissolves in the water, forming a solution, while the rocks sink to the bottom, forming a suspension (Figures 4 and 6) [23].

Another distinction is bonding qualities; whereas a dye may chemically attach itself to a substrate on a molecular level, becoming a part of the material, pigments require the binder or carrier to acts as a glue that is painted on the substrate and surrounds the pigment, holding it in place. As a result, dyes become a part of the material, while pigments are layered on top (Figures 7 and 8) [24].

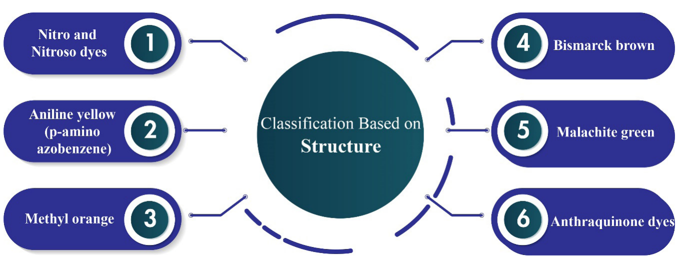

Figure 4: Classification based on structure.

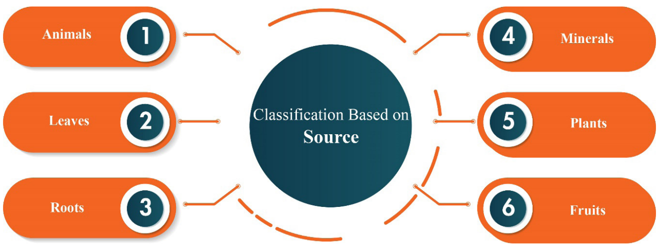

Figure 5: Classification based on structure.

Figure 6: Classification based on structure.

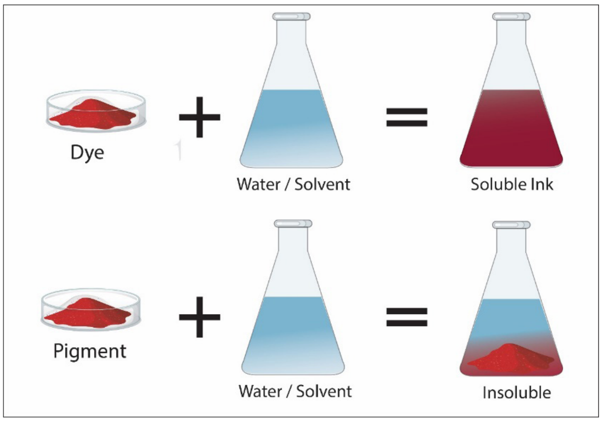

Figure 7: Difference between pigment and dye based on solubility.

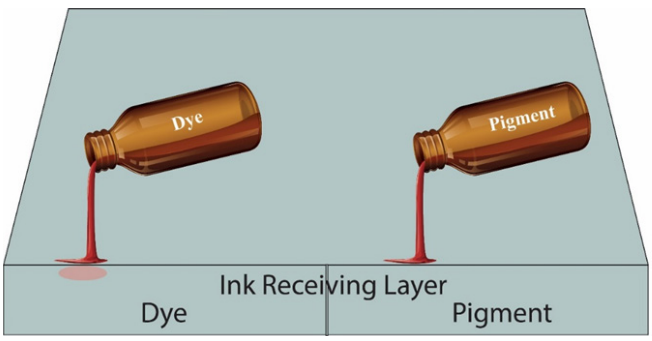

Figure 8: Difference between pigment and dye based on receptivity.

These are basic criteria; therefore, a dye may require a mordant to assist it bind depending on the material or dye. Their light fastness qualities are one of the behavioral distinctions (the level at which they fade when exposed to light). Pigments are more resistant to fading than dyes, which are more susceptible to fading or bleaching produced by ultraviolet light from the sun. Sunlight (UV rays) can damage a dye molecule's electrical connection and cause it to lose its color, which is why dyes fade; think a pair of denim jeans fading or a spot of wallpaper where a hanging picture used to be. Some people will use dyes specifically for this purpose and appreciate the natural fading process, while others will need a more permanent color [25].

Resins: Resins are primarily binders, binding the ink's other elements together to form a film and binding the ink to the paper. They also contribute to qualities like gloss and heat, chemical, and water resistance. There are many different resins utilized, and most inks employ more than one resin. The most common resins are Acrylics, Ketones, Alkyds, Maleic, Cellulose derivates, Formaldehydes, Rubber Resins-1 and Phenolics-2.

In the production of printing inks, two forms of rubber resin are used; chlorinated rubber and cyclized rubber. Chlorinating a solution or an emulsion of natural rubber produces chlorinated rubber. Cyclized rubber is made by reducing the saturation of natural rubber by treating it with an acid catalyst. These are made by heating as per substituted phenol (benzyl alcohol) in the presence of an alkaline catalyst with aqueous formaldehyde. The qualities of the finished resin are determined by the type of phenol used, the catalyst utilized, the component molar ratios, and the reactor conditions [26].

Solvents: Solvents are aimed at keeping ink liquid from the time it is applied to the printing plate or cylinder to the time it is transferred to the printed surface. To let the image to dry and bond to the surface, the solvent must separate from the ink body at this point. Some printing techniques (such as gravure and flexographic) necessitate a fast-evaporating solvent. Some of the solvents which are used in printing ink are: Ethyl acetate, Isopropanol-propyl acetate, Cyclohexanone, Butoxyethanol, Aromatic distillates, Butyrolactone [27].

Additives: Additives are used to change the formulation's ultimate qualities. (i) Plasticizers, which improve the flexibility of the printed film; e.g., Dibutyl phthalate (ii) Wax, which improves rubbing resistance; e.g., Carnauba-an exudate from the leaves of Copernicia prunifera consisting of esters of hydroxylated unsaturated fatty acids with at least twelve carbon atoms in the acid chain. (iii) Drier, which catalysis the oxidation reaction in inks that dry by oxidation; e.g., cobalt, manganese, or zirconium salts or soaps (iv) Chelating agent, which enhances the viscosity of the ink (aluminum chelate) and facilitates adhesion (titanium chelate) (vi) Surfactants, which improve wetting of either the pigment or the substrate by reacting with free radicals formed during auto-oxidation and preventing them from reacting further; e.g., eugenol (v) Antioxidant, which delays the onset of oxidation polymerization by reacting with free radicals formed during auto-oxidation and preventing them from reacting further; e.g., eugenol (vii) They act as stabilizers for the dispersion of pigments. (viii) Defoamer, which reduces the surface tension in water-based inks so that stable bubbles cannot occur; e.g., hydrocarbon emulsions (ix) Humectants, which prevent premature drying (x) pH modifiers (typically amine derivatives) and biocides and bacteriostats [28,29].

PROBLEMS WITH USING CONVENTIONAL INKS

Toxicity can be a major issue and it can cause allergies such as contact dermatitis and respiratory diseases, allergic reactions in the eyes, skin irritation, and irritation to mucous membrane and the upper respiratory tract. It can be harmful to human health and also to our environment and it is also not biodegradable nor eco-friendly.

NATURAL DYES (A SUSTAINABLE OPTION)

Synthetic dyes have a number of advantages over natural dyes, including shade consistency and color brilliance. Natural colorants are once again becoming popular around the world, and in the current climate of Eco preservation, they have enormous commercial potential. There is also an increasing understanding of their non-hazardous nature.

National and international awareness of natural resource depletion, ecological imbalance, pollution, and our tainted environment as a result of the widespread use of harmful chemicals, notably synthetic colors, has compelled us to consider safer alternatives. These features have broadened the range of natural dye applications. Synthetic colors are poisonous and detrimental to both human skin and the environment. As a result, numerous European countries have banned their use. This necessitates the reintroduction of natural dyes for textile dyeing. Natural dyes are environmentally friendly and biodegradable. Growing plants for the purpose of obtaining natural dyes encourages forestation, which leads to greater ecological balance [30].

According to a survey by the German ministry of food, agriculture, and forestry, 90,000 tonnes of dyes can be produced annually. Natural dye manufacture necessitates the use of agricultural grounds. It is projected that around 250-500 million acres of land will be needed to generate the 100 million tonnes of plant material required to make one million tonnes of natural colors. This land demand equates to 10-20% of the total area grown for grain around the world. Natural dyes are heavily imported into the United States. The total annual import of coloring matter of vegetable or animal origin for these dyes is around 3500 tonnes, or roughly 0.4 percent of the synthetic dyes [31].

For the year 1999, EU countries imported 5300 tonnes of natural dyes. This makes up 0.53 percent of the synthetic dyes on the market. Aside from that, many countries generate natural dyes for local consumption, which may amount to roughly 1000 tonnes.

The Allergo Company is a significant manufacturer of natural dyes. It has set a goal of replacing around 1% of synthetic dyes globally. According to their projections, they will need 0.2% of the total cropland accessible. Some of the challenges that have been examined in making natural dyes an economically viable alternative to synthetic dyes include the growing of raw materials, the development of dying equipment to satisfy industrial requirements, and the transfer of technology to big textile mills [32].

It has created extraction methods that result in pure liquid dye. The dye powder is then made from the liquids. The waste material generated during the extraction is recycled and used as a carbon supplement in the composting process. It has also created an environmentally friendly mordant. Only five dyes are being produced by the company. Osage orange, cochineal, madder, catch, and indigo are some of these.

Another important natural dye manufacturer is Alps Industries. This company makes 300 tonnes of natural dye each year. The company has launched a $1 million R&D project to develop "totally eco-friendly natural dyes" (Table 2).

The major goal of this three-year research and development project is to create at least six fully standardized natural colors from the following raw materials: pomegranate peel, Harada gallnuts, Catechu, Annatto, Madder, Ratan jot, and Himalayan rhubarb. Apart from this, numerous companies specialize in single colors like indigo, lac, cochineal, and catch [33].

Different methods of extraction for natural dyes

Extraction of Red beets were chopped into small pieces and and blended individually at 200 rpm in ethanol and water (1:2). The betaine dye was absorbed into the solvent. These solvents were extracted using an evaporator, centrifugation, and drying in a vacuum oven (Table 3 and Figure 9).

Table 2: Extraction of dyes from different sources.

Image	Sources	Nature		
		Acidic	Initial	Alkaline
	Butterfly Pea	Red	Blue	Blue
	Red Rose	Pink	Red	Yellow
	Allamanda	Brown	Brown	Yellow
	Pomegranate	Light Orange	Dark Brown	Light Brown
	Grape	Pink	Light Purple	Green Yellow
	Turmeric	Yellow	Yellow	Orange
	Red Cabbage	Red	Blue	Orange-Yellow
	Black Bean	Red	Violet	Green-Yellow
	Purple Potato	Pink	Pink	Green

Table 3: Different Methods of Extraction for Natural Dyes.

Extraction Method	Remarks
Aqueous Extraction	An ancient and traditional method. The powdered source is soaked in water, boiled and filtered the liquid.
Ultrasonic Extraction	High power in low-frequency ultrasound waves is used to extract the dye. The powder form of the plant with a mixture of ethanol and water is placed in the ultrasonic bath and sonicated, filtering the liquid dye.
Solvent Extraction	The most effective technique for natural dye extraction. Ethanol, methanol, acetone, petroleum ether, chloroform and such organic solvents are used in the extraction process.
Microwave Assisted	The procedure of Microwave-Assisted Extraction (MAE) involves heating solvents in contact with a sample to separate analytes from the sample matrix into the solvent.
Alkali or Acid Extraction	We get the maximum color yield and boosts up because of the hydrolysis of glucosides.
Enzymatic Extraction and Fermentation	The advantages of the enzyme extraction approach include softer extraction conditions and consistent physical and chemical characteristics of active components.
Supercritical Co2 Extraction	The most complicated process which has benefits from both liquids and gases, high density and viscosity, lower surface tension, and increased solubility, all of which increase quickly with pressure.

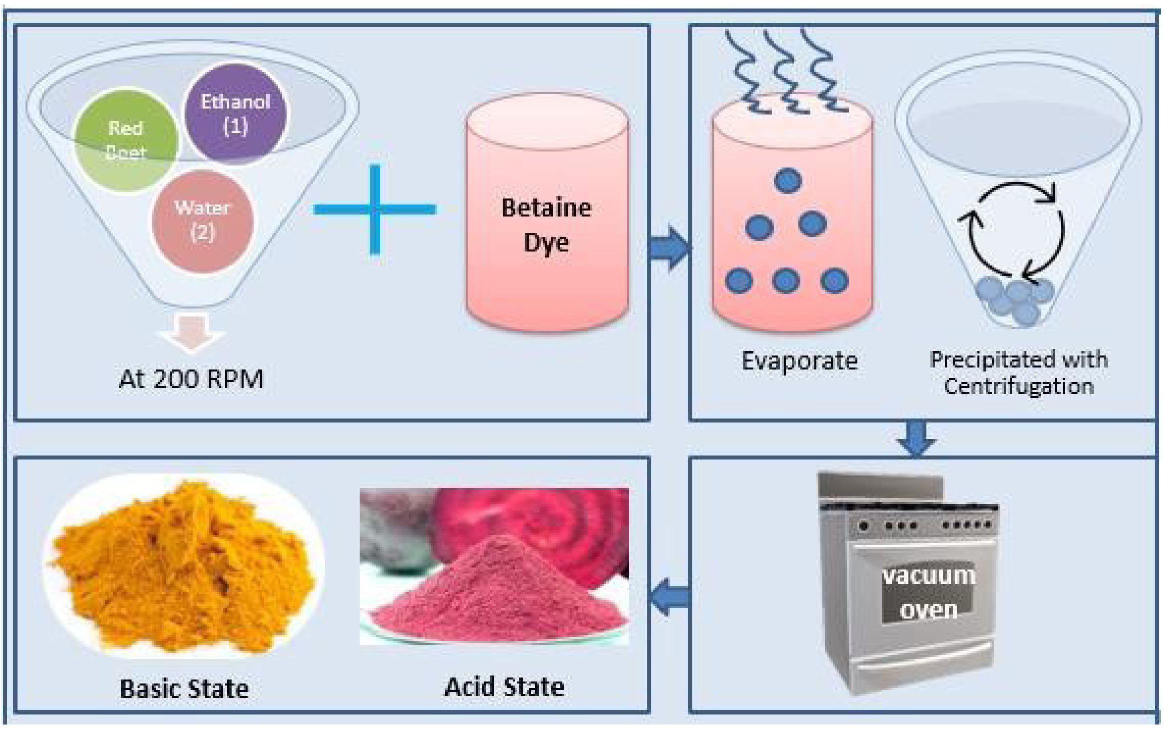

Figure 9: Extraction of red beet.

Red beets were purchased from local markets and kept at 4°C until needed. To enhance the surface area of the beets utilized in the study, they were first rinsed and then grated. The 10 g grated beet pieces were added to a 1000 mL ethanol/water (4:1) combination and mixed for 2 hours at room temperature with a mechanical mixer at 200 rpm. The active dye was transferred to the liquid fraction of the colored liquid after it was filtered. An evaporator at 1500 rpm and a vacuum at 50°C were used to extract the color from the solvent. Ultracentrifugation at 13,500 rpm for 10 minutes was used to precipitate the colloidally dispersed material, which was subsequently dried in a vacuum drying oven. The new dyes' chemical structure was determined using a Perkin-Elmer Spectrum 100 ATR-FTIR spectrophotometer. The spectra were measured with wave numbers ranging from 650 to 4000 cm^{1}, UV-2450 model and UV-VIS spectrophotometer was used to determine the dye's color character [34,35].

ADVANTAGES OF NATURAL DYES

Take advantage of renewable resources, there are no health risks, and they can even be used to treat illnesses. The chemical reactions are rather minor, and there are no disposal issues. They are simple and in tune with nature and great deal of imagination are required to utilize these colors wisely. They assist to offer employment for rural people and preserve traditional handicraft and the application technique for these dyes is less expensive. They have a delicate tint, are soothing to the eyes, and are beneficial for the skin with a higher tinctorial value. Dyes are environmentally friendly and biodegradable which has conserve energy because the raw materials aren't derived from petroleum goods and waste material is utilized to make compost [36,37].

CHALLENGES FOR NATURAL DYES

Natural dyes limitations, which contributed to their demise, are now being addressed. Availability color yield dyeing procedure complexity shade reproducibility. Natural dyes have a limited number of suitable dyes, allowing only wool, natural silk, linen, and cotton to be dyed; they are also non-standardized; they have an inadequate degree of fixation; they have insufficient fastness properties; they are polluted by heavy metals and large amounts of organic substances; they are not available in standard shade cards, precise and specific ways of application, or standard norms. Because they can't be mass-produced, they're expensive and demand around 500 acres of land per kilogram of dye. Their fastness qualities are also poor due to: a weak dye-fiber link between the natural dye and the fiber; a change in color caused by the breakdown of the dye metal complex after washing; and the ionization of natural dyes during alkaline washing [24,34].

FUTURE SCOPE OF NATURAL DYES

The lost cultivation technique for the staple vegetable coloring matters must be researched in order to achieve acceptable shade gamut and fastness properties, Natural disperse dyes must be developed for man-made fibers, in non-toxic areas like food, drugs and cosmetics natural dyes alone can be successfully used. It will be the more fascinating carrier if the proper attention is given to natural dyes has bright future further now is suppressed due to the lack of knowledge about them. Antimicrobial biodegradable, Non-toxicity, environment Friendly, and Aesthetically appearing resulting in employment generation and untilization of waste land [38].

Natural dyes for smart packaging

As an indicator for intelligent packaging: Food packaging is now used for more than just protecting food; it also serves as a means of communicating whether a product is fit for eating or not. We named this type of packaging smart and intelligent packaging, or pH-sensing film. However, most pH sensor film is made using artificial colors, which will limit its application in food packaging due to customer concerns about food safety. Artificial dyes are carcinogenic or mutagenic, which could harm aquatic life and humans. As a result, natural colors derived from plants are viable options for biodegradable packaging materials.

Provide antimicrobial properties for active packaging application: The antimicrobial activity of crude extracts of plant phenolic compounds against human pathogens has been thoroughly investigated in order to identify and develop new nutritious dietary ingredients, as well as medicinal and pharmaceutical goods. However, very little information about the antibacterial properties of pure natural colors is available. Natural dyes are generally active against a variety of germs; however, Gram-positive bacteria are more susceptible to anthocyanin action than Gram- negative bacteria [39].

As an antioxidant material for active packaging application: Antioxidants are commonly found in substances that are easily oxidized. Several studies have suggested that the natural color content of fruits and vegetables, as well as their antioxidant activity, contribute to the fruits and vegetables' protection against degenerative and chronic diseases. Some plant and fruit extracts that are high in phenolic compounds have been shown to reduce mutagenesis and carcinogenesis. The antioxidant activity of the natural dye has been proven to be superior to that of vitamins C and E. The anti-carcinogenic effect of these compounds is due to their ability to restrict free radicals through the donation of phenolic hydrogen atoms [40,41].

Protect the ink migration from the packaging into the food: Packaging made of glass and metal is termed an "absolute" barrier. Because these materials inhibit migration, any ink can be utilized on the exterior of these packing materials [42,43]. The potential for ink migration in other materials must be assessed. Migration is a concern with both paper and plastic packing. These inks aren't meant to have any kind of chemical reaction with the user or the goods. A vegetable-based dye ink is used to print M&M'S® and Skittles [44].

DISCUSSION

The food industry's use of a suitable indication can be beneficial for food safety, monitoring, and providing information about the packaged food product. Apart from phenolic compounds (flavonoids), nitrogenous compounds (chlorophyll derivatives), tocopherols, carotenoids, and ascorbic acid are among the phytochemical substances that have antioxidant activity. These dyes are safe and environmentally friendly and contain medicinal and therapeutic properties. Growing plants for dye extraction encourages forestation, resulting in a great ecological balance. Synthetic dyes are made using various carcinogenic chemicals, and the effluents that are dumped into rivers or vented into the atmosphere pollute the environment.

CONCLUSION

In recent years, natural dyes from various plant sources for printing have been developed, and smart packaging technologies have been integrated into food packaging systems to satisfy the needs of the food supply chain. This analysis emphasizes the enormous potential of natural dyes and finishes with a discussion of the limitations of using natural colors in packaging materials. The study of natural dyes packaging technologies may lead to improvements to the current system.

The use of natural dyes of this sort contributes to the enhancement of consumer quality of life. Scaling up and industrializing anthocyanin for packaging applications could be difficult, so it should be considered early in the development process to ensure a successful commercialization. The expense of implementing the technology must be proportional to the benefit received by the specific food product, legislative and regulatory difficulties must be resolved, and customer acceptance must be widespread.

REFERENCES

1. Michel B, Bernard A, Bietsch A, Delamarche E, Geissler M, Juncker D, et al. Printing meets lithography: Soft approaches to high-resolution patterning. IBM J Res Dev. 2001;45(5):697-719.
2. Ahmed S. Technology of Printing Inks: Raw materials and formulations for different substrates in letterpress printing screen printing. 2007.
3. Kunjappu JT. Essays in ink chemistry :(for paints and coatings too). Nova Science Pub Incorporated. 2001.
4. Singh S, Gaikwad KK, Lee YS. Anthocyanin-A natural dye for smart food packaging systems. Korean J Packag Sci Technol. 2018;24(3):167-180.
5. Pingale RR. Soy-based flexographic ink for linerboard printing. 2018.

6. Kandirmaz EA, Ozcan A, Ural E. The effect of paper coatings containing biopolymer binder and different natural pigments on printability. Nord Pulp Pap Res J. 2021;36(4):643-650.

7. Cheng Y, Fu Y, Ma L, Yap PL, Losic D, Wang H, et al. Rheology of edible food inks from 2D/3D/4D printing, and its role in future 5D/6D printing. Food Hydrocoll. 2022;132:107855.

8. Singh S, Gaikwad KK, Lee M, Lee YS. Temperature sensitive smart packaging for monitoring the shelf life of fresh beef. Journal of Food Engineering. 2018;234:41-49.

9. Chidan Kumar CS, Chandraju S, Ahmad T, Mythily R, Made Gowda NM. Extraction and evaluation of a new acid-base indicator from black gram husk (Vigna Mungo). Synth React Inorganic, Met Nano-Metal Chem. 2012;42(4):498-501.

10. Gaikwad KK. Recent Developments in Intelligent Packaging Systems for Food Processing Industry: A Review Development of novel oxygen scavenging package for food packaging View project Development of Bio-based Phase change material for application in food packaging View project. Artic Int J Food Process Technol. 2021.

11. Niaounakis M. Biopolymers: Processing and Products. William Andrew. 2015:447-458.

12. Kirth-Othmer. Encyclopedia of Chemical Technology. 2022.

13. Khodabakhsh ZM, Pekarovicova A. Fleming PD. Inkjet Ink with Soy Protein.

14. Ahmed S. Technology of Printing Inks. 2007.

15. Zhang Y, Zhu Y, Zheng S, Zhang L, Shi X, He J, et al. Ink formulation, scalable applications and challenging perspectives of screen printing for emerging printed microelectronics. J Energy Chem. 2021;63:498–513.

16. Kanda N, Asano T, Itoh T, Onoda M. Preparing "chameleon balls" from natural plants: Simple handmade pH indicator and teaching material for chemical equilibrium. J Chem Educ. 1995;72(12):1131–1132.

17. Grigoras CG, Destandau E, Zubrzycki S, Elfakir C. Sweet cherries anthocyanins: An environmental friendly extraction and purification method. Sep Purif Technol. 2012;100:51-58.

18. Singh S, Gaikwad KK, Lee YS. Anthocyanin: A natural dye for smart food packaging systems. Korean Journal of Packaging Science & Technology. 2018;24(3):167-180.

19. Pace GV. Printing inks for food contact packaging and articles. In Global Legislation for Food Contact Materials. Woodhead Publishing. 2022;219-227.

20. Thompson B. Printing materials : science and technology. 2004:591.

21. Zieba-Palus J, Trzcińska BM. Establishing of chemical composition of printing ink. J Forensic Sci. 2011;56(3):819-821.

22. Khankaew S, Boonsupthip W, Pechyen C, Suppakul P. Screening of naturally-derived pH dyes from plant extract powders as colorimetric bio-indicator and possible application in intelligent packaging. In 26th IAPRI Symposium on Packaging. 2013;10-13.

23. Othman M, Yusup AA, Zakaria N, Khalid K. Bio-polymer chitosan and corn starch with extract of hibiscus rosa-sinensis (hibiscus) as P H indicator for visually-smart food packaging. In AIP Conference Proceedings. AIP Publishing LLC. 2018;1985(1): 050004.

24. Bowes A, Collins S, Elliott S, Harris LT, Hazlett L, Methe E, et al. Important early synthetic dyes: chemistry, constitution, date, properties.

25. Maciel VB, Yoshida CM, Franco TT. Development of a prototype of a colourimetric temperature indicator for monitoring food quality. J Food Eng. 2012;111(1):21–27.

26. Maraval M, Flieder F. The stability of printing inks. Restaurator. 1993;14:141–171.

27. Maran JP, Priya B, Manikandan S. Modeling and optimization of supercritical fluid extraction of anthocyanin and phenolic compounds from Syzygium cumini fruit pulp. J Food Sci Technol 2014;51(9): 1938–1946.

28. Ishak I, Muhamad II, Marsin AM, Iqbal T. Development of purple sweet potato starch base biodegradable film. J Teknol. 2015;77(31):75–78.

29. Stoll L, Silva AM, Iahnke AO, Costa TM, Flores SH, Rios AD. Active biodegradable film with encapsulated anthocyanins: Effect on the quality attributes of extra-virgin olive oil during storage. J Food Process Preserv. 2017;41(6):e13218.

30. Gaikwad KK, Lee YS. Novel natural phenolic compound-based oxygen scavenging system for active packaging applications. J Food Meas Charact. 2016;10(3):533–538.

31. Deshmukh RK, Gaikwad KK. Natural antimicrobial and antioxidant compounds for active food packaging applications. Biomass Convers Bioref. 2022:1-22.

32. Pimpodkar N, Shikalgar S, Shinde N, Bhise S, Surve B. Rhoeo syathacea and Allamanda cathartic extract as a Natural Indicator in Acidometry-Alkalimetry. Asian J. Pharm. Ana. 2014;4(2):82-84.

33. Luchese CL, Frick JM, Patzer VL, Spada JC, Tessaro IC. Synthesis and characterization of biofilms using native and modified pinhao starch. Food Hydrocoll. 2015;45:203-210.

34. Ozcan A, Arman Kandirmaz E. Natural ink production and printability studies for smart food packaging. Color Res Appl. 2020;45(3):495-502.

35. Hellstrom D, Saghir M. Packaging and logistics interactions in retail supply chains. Packag. Technol. Sci. 2007;20(3):197-216.

36. Chawla R, Sivakumar S, Kaur H. Antimicrobial edible films in food packaging: Current scenario and recent nanotechnological advancements: A review. Carbohydr Polym Technol Appl. 2021 Dec 25;2:100024.

37. Deylami MZ, Rahman RA, Tan CP, Bakar J, Olusegun L. Effect of blanching on enzyme activity, color changes, anthocyanin stability and extractability of mangosteen pericarp: A kinetic study. J Food Eng. 2016;178:12-19.

38. Barnes JS, Nguyen HP, Shen S, Schug KA. General method for extraction of blueberry anthocyanins and identification using high performance liquid chromatography–electrospray ionization-ion trap-time of flight-mass spectrometry. J Chromatogr A. 2009;1216(23):4728-4735.

39. Deshmukh RK, Gaikwad KK. Natural antimicrobial and antioxidant compounds for active food packaging applications. Biomass Convers. Bioref. 2022:1-22.

40. Gaikwad KK, Singh S, Lee YS. A new pyrogallol coated oxygen scavenging film and their effect on oxidative stability of soybean oil under different storage conditions. Food Sci Biotechnol. 2017 Dec;26(6):1535-1543.

41. Castaneda-Ovando A, de Lourdes Pacheco-Hernandez M, Paez-Hernandez ME, Rodríguez JA, Galan-Vidal CA. Chemical studies of anthocyanins: A review. Food Chem. 2009;113(4):859-871.

42. Chandra A, Rana J, Li Y. Separation, identification, quantification, and method validation of anthocyanins in botanical supplement raw materials by HPLC and HPLC– MS. J Agric Food Chem. 2001;49(8):3515-3521.

43. Arapitsas P, Turner C. Pressurized solvent extraction and monolithic column-HPLC/DAD analysis of anthocyanins in red cabbage. Talanta. 2008;74(5):1218-1223.

44. Chen F, Sun Y, Zhao G, Liao X, Hu X, Wu J, et al. Optimization of ultrasound-assisted extraction of anthocyanins in red raspberries and identification of anthocyanins in extract using high-performance liquid chromatography–mass spectrometry. Ultrason Sonochem. 2007;14(6):767-778.