Rosa Indica-Based Nail Lacquer Formulation Using Green Cosmetic Principles

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Abstract

Nail polish is a billion-dollar staple that frequently inflicts eco-hazards through synthetic dyes and volatile chemicals. Here, we introduce a green protocol that utilizes anthocyanins from Rosa indica petal extracts, employing a mostly water-based solid-liquid extraction protocol to maintain the integrity of the pigments without the use of toxic organic solvents. The film is comprised of nitrocellulose, which is dissolved in a delicate acetone-ethanol vehicle and plasticized with camphor and an adhesion and durability-enhancing agent consisting of a sulfonamide-formaldehyde cross-linking agent. Polymerisation and cross-linking processes with controlled dynamics of solvent evaporation provide the lacquer system with a robust adhesion to the nail, and a bright and glossy red colour, along with a fast-drying process. The study illustrates that using the plant-based components in bioactive dyes is possible in replacing high-hazard dyes and complies with the principles of green chemistry in cosmetic science. It is new in the field in the sense that it has incorporated natural pigments that are sustainable, achieving commercial grade in the sense of incorporating them in the nail matrices, offering a less harmful, environmentally better alternative. The next step of work should be the optimization of natural plasticizers, biobased solvents, and multifunctional additives as a further step toward more sustainable cosmetic formulations.

Keywords

Nail polish/Lacquer, Green synthesis, Stability, Polymer coalescence mechanism, Characterization

Introduction

Nail polish, also known as nail enamel, is one of the most popular cosmetic products worldwide that serves to prevent injuries as well as provide an aesthetic effect. It makes nails more beautiful, protective, and it is applied in treat-therapeutic and dermatological applications [1]. There is a long history to the art of nail decorating and it goes back to the earliest civilizations of China, Egypt and Babylon where natural pigments and plant extracts were used as a form of social, cultural and beauty-related symbolism [2]. Nail polish has evolved over the past 100 years, with its level of sophistication growing to incorporate new polymerization technologies, as well as an understanding of how to relate to the environmental concerns of the population. Contemporary nail polish is a highly synthesized combination of film-forming compositions, solvents, pigments, plasticizers and functional additives [3]. The most universally used film forming polymer would

be nitrocellulose which forms a shiny, hard film when evaporating solvent. A blend of solvents like ethyl acetate and butyl acetate will regulate the viscosity and the smoothness during application, whereas pigments will regulate the color, opacity, and brightness of the product. Additives such as plasticizers (camphor or acetyl tributyl citrate) provide flex, and the cracking is reduced, additives like resins and UV absorbers and stabilizers, can be added to improve gloss, adhesion, and durability [4]. Earlier, it was more oriented with the mid-20th century and adhesion and durability were the key aspects, when nitrocellulose appeared to be the most common resin [5]. Concerns regarding safety of ingredients in the 1970s80s relating to toxicity of the ingredients like toluene, formaldehyde and dibutyl phthalate triggered the shift to safer alternatives [6]. Towards the 1990s, resins started to contain large proportions of acrylate and methacrylate, which facilitated even stronger adhesion, improved mechanical properties and included special finishes [7]. More recently, green chemistry, sustainability, and functionality have become the drivers of innovation, including the use of bio-based resins, natural pigments and low-toxic solvents [8, 9].

Anthocyanins of the Rosa indica are one of the natural pigments that have attracted much-needed attention by reason of their high coloration capacity, antioxidant capability, and their health-promoting properties [10]. Increasing red, pink, purple color, with resistant flowers like rose petals, these flavonoid pigments create natural colorants eco-friendly in nail polish. Their ability to give vibrant colors without using artificial dyes has met the need of consumer to have herbal and eco-friendly cosmetics [11]. Besides pigments, Rosa indica extracts contain significant amounts of phenolics and antioxidants, which adds their anti-aging, anti-inflammatory, and UV-protecting properties to the enhanced potential of these ingredients in cosmetic products [12]. They can be used not just in the form of natural dyes in nail polish but also in the lipsticks, skin creams and hair products. The use of such bio derived colorants resonates with the current green cosmetic product customization principle and limit the use of toxic synthetic pigment and satisfy the regulatory and consumer pressure on less toxic and safer cosmetic products.

Modern nail polishes have branched out into many types depending on application and technology. Conventional solvent nail polish is a traditional nitrocellulose-based enamel with fast-drying solvents. Gel nail polish uses methacrylate resins, which are hardened by exposure to ultraviolet and light-emitting diode (UV/LED) light to provide films that are abrasion and chip-resistant. Water based polish uses water based media that offers greener, and less toxic and environmentally friendly alternatives. Breathable nail polish consist of porous formulas that allow oxygen and water vapor exchange and were marketed as better to the nails. Peel-off nail polish are easy to remove without acetone and easy to remove by aligning with consumer convenience. Powder dip processes that are a combination of resin and powder are used to provide a long-lasting finish. These advances open up nail polish to closed applications that have specialized functionalities like an increased time of application, improved interaction with the nails and environmental friendliness [13, 14].

Green chemistry has transformed the cosmetic business where more attention is directed toward safer and renewable ingredients, as well as, environmentally non-toxic procedures. In nail polish formulation this engulfs: The use of aqueous or bio-derived solution instead of petroleum based solvents. Instead of using synthetic dyes, one should use natural pigments (e.g., anthocyanins, carotenoids, chlorophyll derivatives). Developing environmentally-sensitive polymers film formation. Minimizing the use of volatile organic compounds (VOCs) to provide better consumer and environmental safety [15]. Moreover, the addition of Rosa indica anthocyanins complies with consumer demands concerning natural cosmetics and yet the sustainability conceits of the cosmetic industry. These pigments can not only enhance the visual appearance but also add some bioactivity in form of antioxidant protection besides bringing nail polish in line with the current trend that leans towards therapeutic and multi-functional cosmetics.

Although a significant number of studies have been carried out on the use of natural pigments, their application in cosmetic formulas, especially in nail paint products, has been relatively undeveloped. Relatively little evidence is available, with previous publications focusing their attention on anthocyanins in the textile dyeing, food coloring industries, and pharmaceutical purposes, and completely no evidence is available concerning their application in decorative make-ups. Traditional nail polishes are highly dependent on synthetic dyes made up of petroleum products that not only attract environmental concerns, but they may also cause certain health hazards with the presence of toxic impurities and inability to biodegrade. Against these gaps, the current research presents a new idea whereby anthocyanin extracts of Rosa indica petals will be incorporated in an easy nail lacquer formulation that can be carried out even at home laboratory. Such a green extraction process with the use of water as the only solvent eliminates toxic organic solvents, retains thermo-labile pigments, and encourages the use of renewable feedstock. Moreover, the lacquer formulation was optimized under mild processes (<35 °C) to promote energy savings and pigment stability in keeping with the main ideas of green chemistry.

Experimental

Here we used the green synthesis approach. Anthocyanin pigment was extracted by solid liquid extraction method using dried rose petals and water as solvent [11, 12]. Fresh red rose petals were picked up at Botanical Garden of the University of the Punjab, Lahore, Pakistan. The petals were properly washed using tap water in order to remove dust and surface contaminants, and shade dried at room temperature so as not to destroy thermo labile compounds. The petals were dried and ground in small pieces and turned to powder. Before use, the powder would be sieved to obtain a homogeneous particle size. The pigment extraction procedure entailed the selection of aqueous method, which is safe, easy, and highly effective in the pigment retrieval. In comparison with other organic solvents, aqueous medium is important on the basis that it evades the risk of anthocyanin degradation and is non-toxic besides promoting environmental friendly nature of dyeing with natural dyes. In the extraction process, 4 g of ground rose petals were boiled in 100 mL distilled water where a material to solvent ratio of 1:25 (w/v) was maintained. The mixture was heated for 30 minutes and was cooled to room temperature. The filterable solids were removed by using Whatman filter paper. The filtrate obtained was kept as the natural dye solution for use in future experiments.

To make 100 mg Lacquer 50 gm Acetone as solvent was taken and 16 gm Nitrocellulose was added, and kept on hot plate for thorough mixing for about 40-50 minutes at 3 rpm speed and room temperature [13]. After 5 minutes 9 gm Toluene sulfonamide formaldehyde and 4.8 gm Camphor was added in it. Later about 10 min 7 ml Ethyl alcohol was added gradually. After 10 minutes 3 gm Citric acid and 1-2 ml Anthocyanin was added. Whole procedure carried out on hot plate at room temperature. After thorough mixing temperature was increased up to 35°C and process kept on for 15-20 minutes until all the ingredients dissolved and red coloration of shiny lacquer appeared. After the lacquer formation it was applied on a human nail and observed its properties. Some tests were performed, such as: Nonvolatile, Dryness, Color Test, Film Smoothness, Gloss Estimation Test, Film Hardness, Adhesion, and Resistance to Abrasion, Water Permeability Test, Application and Stability Test [15].

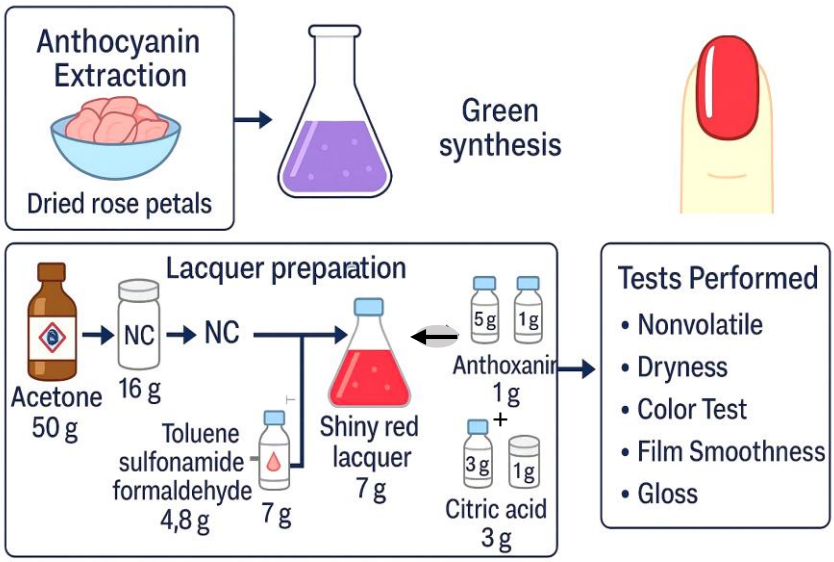


Figure 1. Schematic Diagram of Lacquer Formation by Green Synthesis Approach

Results and Discussion

The lacquer consists of a mechanism involving primarily the evaporation of solvent to promote polymer coalescence mechanism. The release of the volatile solvent mixture (acetone and ethanol) starts as the formulation is put in contact with the nail surface. This evaporation decreases the solubility of nitrocellulose and causes its polymer chains to come closer together and physically entangle and pack [16]. Camphor, which acts as a plasticizer wedges itself between the molecules of nitrocellulose and loosens the bonding between molecules, increasing flexibility and at the same time removing the tendency to brittle fragility [17]. At the same time, the tosylamide-formaldehyde resin interacts with nitrocellulose in a cross-linking reaction colliding with hydroxyl groups that results in a three-dimensional polymer strata that increases adhesion, hardness, and gloss [18, 19]. It is mentioned that citric acid participates in the stabilization of anthocyanins during the drying phase because it forms hydrogen-bonding interaction networks, and this prevents pigment degradation [20]. The last stage will lead to the obtaining of a dense shiny, red-colored film sticking solidly

to the nail keratin.
In general it involves polymerization, crosslinking and solvent evaporation as explained below:

$$n\,[C12H16N4O12] \rightarrow (C12H16N4O12)n + nH2O \ldots\ldots\ldots \text{Eq } 1$$

$$(CH2O)n + (C12H16N4O12)n \rightarrow [C12H16N4O12(CH2O)nC12H16N4O12]n + nH2O \ldots\ldots\ldots \text{Eq } 2$$

$$\text{Solvent} \rightarrow \text{Vapor} + \text{Heat} \ldots\ldots\ldots \text{Eq } 3$$

In this system, Rosa Indica anthocyanin is a natural pigment and bio biofunctional one. Anthocyanins can protect against oxidative stress and absorb UV light (300-400 nm), which endows them with photoprotective chances [21, 22]. The pH measured was 6.7 which was under normal range. They have been reported to boost their radical scavenging activity that results in higher durability against discoloration and oxidative degradation, which is favorable to nail health [23]. Anthocyanins would also not experience the toxicity, which occurs in synthetic azo dyes, and it is biodegradable and safer to be in constant contact with the cosmetic product. The lacquer would also be easier to deal with because it has a suitable viscosity of ~30 cps, which ensures that the lacquer can be applied without worrying of sags and uneven coverage. A drying time of 10-15 min was noticed, in accordance with commercial eco-friendly lacquers [25]. Mechanical performance indicated chip resistance along with the stability of water following 24 h application. The flexibleness of camphor is cited to account the observed film toughness that has been causally ascribed to crosslinking between nitrocellulose (N) and resin.

All these characteristics were explained in the literature and confirmed in this experiment. All the ingredients played their role well. When applied to the nail surface, nitrocellulose, a polymer that forms films, creates a tough, long-lasting coating.
In such a system, anthocyanins in Rosa indica are used as natural colourants and functional agents. Anthocyanins are UV light absorbants Nail polish formulations often have their pH adjusted with the use of a mild organic acid, in the form of citric acid. It can also be utilized to make the polish more acidic and lower its pH, which will boost the solubility of other chemicals and help stabilize the formulation. Citric acid can also preserve the other contents of the nail polish because it is an antioxidant. In doing so, the polish performance over time can be sustained and shelf life extended. It makes the nail surface soft and smooth which benefits the conditioning of the nails. This would raise the level of adherence and persistence of the polish and render the nails more open to it. Natural foods like rosella, rose, cherries and strawberries contain naturally the flavonoid pigment referred to as Anthocyanin. It has become popular as a beauty feature in recent years especially nail paint. It has been shown to effective antioxidants and these properties could help protect the nail against oxidative and free radical damage. This would help in the overall well-being and appearance of the nails. It has also been found to contain UV-absorbing properties, thereby helping to protect the UV rays damaging effects on the nails. In this manner, there is a possibility to reduce the risk of sun damage like yellowing, discoloration, and others. It might also help strengthen the nails as it increases their structure and decreases the cracking or breaking of the nails. This could make the nail polish have more endurance and take longer. It has been proven that it has moisturizing properties, something that may help moisturize and nourish the nails. This can be used to prevent drying of the nails or causing brittleness of the nails.



Figure 2. Nail's appearance where a: nail before application of nail polish, b: applied nail polish, c: after removal of nail polish.

Future Directions

Nail polish formulation and research is constantly evolving with many potential future development and exploration opportunities.

1. Alternative ingredients in nail polish, such as more plant-based and environmentally friendly can be altered with the natural ingredients and sustainability being more of a concern. Additional research can be undertaken regarding the use of natural colours rather than synthetic ones, e.g., turmeric or beetroot. In addition, it could be studied whether solvents which are not toxic, and biodegradable can be used.

2. Adding functionalized resins would enhance adhesion and tensile strength of nail polish, as it was evidenced by Chandra et al. (2019). It is possible to use other functionalized resins with some of the features, e.g., UV protection or bacterial capabilities, but these qualities were not covered in this study.

3. The development of intelligent materials and technology can lead to "smart" nail polish that can change color or identify the presence of health issues, including changes in the level of blood sugar or dehydration. Future research may focus on the development of such types of nail polish that are wearable with sensors and the like.

Conclusion:

Put simply, nail polish is one of the popular cosmetics that existed thousands of years ago. Having initially attracted potential and interest by being improved in its properties and now being studied on how to use alternative ingredients and natural pigments, it has seen significant alterations over the course of time in terms of its compositions and coloration. Nitrocellulose as a film-forming resin, sulfonamide formaldehyde as a resin, acetone as a solvent, ethyl alcohol as a diluent, camphor as a plasticizer, Anthocyanin as a color, and citric acid as a stabilizer, make a first new nail polish composition, which is the subject matter of the present paper. The result of the process is that nitrocellulose is polymerized during the process, which softens the polymer, allowing it to adhere to the nail surface. Using purely natural and non-harmful ingredients, this new nail polish composition may offer a unique hue and durable caress.

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