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A Review: Formulation and Evaluation of Ammonia Free Leave-On Hair Dye

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ABSTRACT

Hair dyes are extensively used for hair colour changes and restoration; however, classical hair dye formulations with ammonia can lead to smell, skin irritation, hair drying and damaging the hair shaft. Hair dyes without ammonia have received some attention as less harmful products especially in combination with alkaline compounds like monoethanolamine (MEA). This review aims to address the issues of formulation and assessment of ammonia-free leave-on hair dyes with conditioning agents. The review touches upon hair colouring process fundamentals, dye precursors frequently used in hair dye formulations, alkalizing compounds, and conditioning agents' importance in achieving better hair appearance and manageability. Special attention will be paid to the leave-on hair dye formulations that are designed for long-term contact with hair without compromising the cosmetic effect. Formulation constituents, methods of colour creation, safety aspects and criteria of assessment are also considered in the review. Development of ammonia-free leave-on hair dyes with conditioning properties might become a prospective way of hair colouring with minimal damage to hair.

Keywords: Ammonia-free hair dye; Leave-on hair dye; Monoethanolamine (MEA); P-Phenylenediamine (PPD); Conditioning agent; Hair colouring; Hair cosmetics

INTRODUCTION

Hair dyeing is a procedure where a person can change, improve or regain the natural color of his/her hair. Hair dyes come in three varieties such as temporary, semi-permanent, and permanent dyes and oxidation dyes are mostly used for permanent hair coloring because of the reactions that occur inside the hair shaft. Traditional permanent hair dyes usually contain alkaline agents such as ammonia, which causes increased hair fibre swelling and allows dye precursor molecules enter into the hair shaft. Ammonia may have an unpleasant smell and cause scalp irritation, dryness, and damage of hair.

The increasing desire to use mild and cosmetically attractive hair dyeing formulations has resulted in the introduction of ammonia-free products. Monoethanolamine (MEA) is widely used as an alkaline agent in ammonia-free hair dye formulations. Conditioning is another aspect that should be taken into account during formulation of hair coloring products because the repeated hair dyeing process may impair the cosmetic properties of hair. Conditioning agents like keratin and emollients can be used in order to improve the cosmetic properties of colored hair.

A leave-on hair dye product is one of possible variants when dye formulation remains in contact with the hair for an extended time without being rinsed away immediately. It seems that creation of ammonia-free leave-on hair dye containing a conditioning agent may help to dye hair efficiently while trying to improve hair feel. This article reviews the principles, ingredients, mechanism of coloration, safety, and evaluation criteria of ammonia-free leave-on hair dyes.

MATERIALS AND METHODS[6,9]

Types of Hair Dyes

Hair dyes are typically categorized into four types of hair dyes, namely temporary hair dyes, semi-permanent hair dyes, demi-permanent hair dyes and permanent hair dyes, depending on how long the color lasts in the hair. Temporary hair dyes usually leave the color on the surface of the hair, while semi-permanent and demi-permanent hair dyes penetrate deep into the hair strands.

Materials/Ingredients

Ingredients that constitute ammonia-free hair colorants include an alkalinizer, dye intermediate, coupler, vehicle, emollients, conditioning agent, humectants, and viscosity builders. P-Phenylenediamine (PPD) is used as the oxidative dye intermediate in this formulation under discussion, whereas monoethanolamine (MEA) acts as the alkalinizer. The consistency and viscosity of the formulation is achieved through the use of cetostearyl alcohol and stearic acid, whereas liquid paraffin contributes to the emollient nature of the formulation. The humectant component of the formulation is propylene glycol, which helps in penetration as well. Keratin is incorporated as a conditioning agent to improve the softness and manageability of hair, and purified water serves as the aqueous vehicle.

Method of Formulation

The process involves preparing both the aqueous phase and the oil phase separately and then combining them to create the base cream. The conditioning agent together with other additives are added while stirring continuously. The alkalizing agent and dye components are then added with controlled amounts of each substance and mixed thoroughly to obtain an homogenous preparation. The end product is then packed in a suitable container that is air-tight.

ADVANTAGES

- Minimized ammonia-induced irritation: Ammonia-free products may be helpful in reducing irritation caused by ammonia-based hair dyes.
- Enhanced cosmetic acceptability: Conditioning agents may help in improving softness and smoothness of the hair after coloring.
- Leave-on product: A leave-on product ensures that there is sufficient time between the coloring product and hair interaction and simplifies the application procedure.
- Conditioning properties: Substances such as keratin and emollients may help in maintaining the desired hair characteristics during the process of coloring.
- Substitute alkalization method: Monoethanolamine (MEA) may act as an alternative to ammonia and provide the required alkalinity.

DISADVANTAGES

- Formulation complexity: Ammonia-free formulations would need careful choice and balance of alkalizing and coloring agents.
- Increased development time: There could be a possibility that some formulations need some additional time to reach the desired color depth.
- The resulting color shade may differ: It could be influenced by several factors including the natural color of the hair, the condition of the hair, pH, and the time of the process.
- The cost of the formulation: The cost of the formulation would increase due to the usage of specific components.
- Optimal pH: Sufficient pH level is required for successful color development.

APPLICATIONS

The main purpose of leave-on hair colorants without ammonia is coloring, improving and restoring the color of hair. Leave-on hair colorants can be applied on natural hair or grey hair to achieve a certain color while bringing more benefits to the hair using conditioning agents.

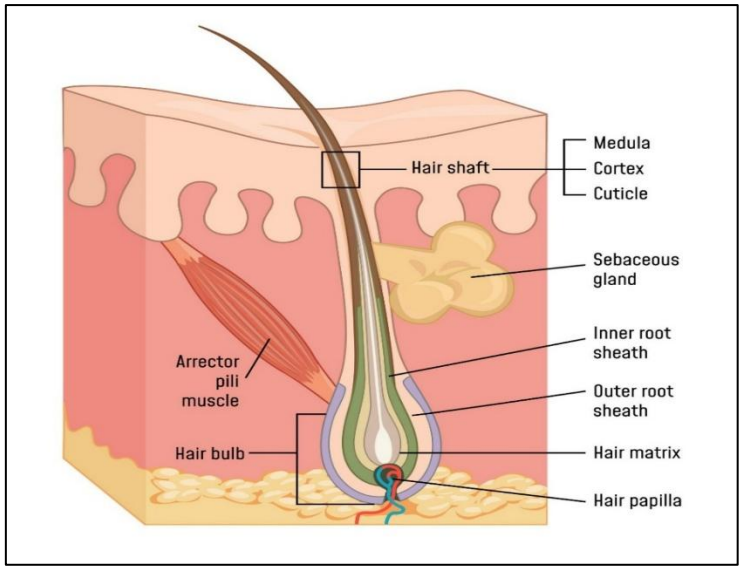
- Coverage of grey hair - This hair colorant will be useful in restoring the color of early grey or naturally grey hair.

- Improving the hair color - For increasing or modifying the color of the hair.
- Root touch up - It can be used in coloring newly grown hair.
- Hair care - Due to the presence of conditioning agents, it will bring softness, smoothness, and manageability in addition to coloring.
- Personal grooming - It will be used as an alternative for regular hair-coloring products with ammonia.
- Leave-on hair coloring - Formulations which should be left on the hair for some time.

HAIR ANATOMY AND STRUCTURE[1,9]

Hair is made up of keratin and forms out of the hair follicle, which exists in the skin. The external part of the hair is called the hair shaft whereas the root part is found in the follicle. The hair shaft is made up of three concentric layers, which are cuticle, cortex, and medulla.

- Cuticle: This is the outermost layer, which comprises keratinized overlapping cells. The cuticle layer acts as a protective barrier for the inner layers and affects the penetration of hair dye components.
- Cortex: This is the main layer of hair, which contains keratin and melanin pigments, giving hair its natural color and strength. Oxidizing hair dyes act on this layer mostly.
- Medulla: This is the innermost layer that comprises loosely arranged cells and air spaces. Medulla can sometimes be absent in finer hair.
- Hair follicle: It is a tubular structure enclosing the hair root.



Hair is a keratinized appendage of the skin that develops from a specialized structure known as the hair follicle. It is composed mainly of the fibrous protein keratin, along with lipids, water, pigments, and other structural components. From the perspective of hair colouring, understanding the structure of the hair shaft is important because dye molecules must interact with and penetrate the different layers of the hair to produce a lasting colour.

The hair can be broadly divided into the hair shaft and hair root. The hair shaft is the visible portion extending above the skin surface, whereas the root is located within the hair follicle. The hair shaft consists of three major layers: cuticle, cortex, and medulla.

1. Cuticle

The cuticle is the outermost protective layer of the hair shaft. It consists of several layers of flattened, overlapping keratinized cells arranged like roof shingles. The cuticle protects the inner cortex from physical and chemical damage and acts as an important barrier to the penetration of cosmetic ingredients. Alkaline conditions used in permanent hair colouring can cause the cuticle to swell or lift slightly, facilitating the movement of dye precursors into the inner regions of the hair.

2. Cortex

The cortex forms the major portion of the hair shaft and provides most of its mechanical strength, elasticity, and shape. It consists of elongated keratin fibres arranged within cortical cells. The cortex contains melanin pigments, which are primarily responsible for the natural colour of hair. During oxidative hair colouring, dye precursors penetrate the cortex and undergo oxidation and coupling reactions to form larger coloured molecules, resulting in a more permanent colour.

3. Medulla

The medulla is the innermost layer of the hair shaft. It consists of loosely arranged cells and may contain air spaces. The medulla is not always continuous and may be absent in fine hair. It has relatively less importance in the hair-colouring process compared with the cuticle and cortex.

4. Hair Follicle and Root

The hair follicle is a tubular structure within the skin from which the hair develops. The hair root is located inside the follicle and is connected to structures involved in hair growth and nourishment. The follicle contains the hair bulb and matrix, where actively dividing cells contribute to the formation of the hair fibre.

Importance in Hair Dyeing

The structural organization of hair plays an important role in the effectiveness of hair dyes. The cuticle acts as the primary barrier, while the cortex is the principal site involved in permanent oxidative colour development. Alkalizing agents such as monoethanolamine can promote changes in the hair fibre that facilitate penetration of dye precursors. Conditioning agents incorporated into hair-dye formulations can help improve the surface properties, softness, and manageability of the hair following chemical treatment.

ADVANCED STUDIES

Recent research in hair-dye technology focuses on developing milder, safer, and multifunctional formulations with improved colour performance and hair-conditioning properties. Ammonia-free systems using alternative alkalizing agents such as monoethanolamine (MEA) are being investigated to improve consumer acceptability while maintaining effective colour development.

Advanced formulations are also exploring conditioning polymers, proteins such as keratin, natural extracts, and protective agents to reduce the undesirable effects of repeated colouring and improve hair softness and manageability. Research is further directed toward improving colour retention, formulation stability, controlled dye release, and compatibility with different hair types.

Emerging approaches include the use of nanotechnology, encapsulated dye systems, bio-based colouring materials, and multifunctional hair-care formulations. These developments may help produce hair dyes that combine effective and durable colouring with improved cosmetic and conditioning benefits.

FUTURE PERSPECTIVE

Future research on ammonia-free leave-on hair dyes may focus on developing safer, more effective, and multifunctional formulations with improved colour intensity and durability. Greater attention can be given to natural and bio-based colouring materials, novel conditioning agents, and advanced delivery systems to improve dye penetration and hair protection.

Further studies are also needed to optimize formulation stability, pH, colour retention, conditioning performance, and compatibility with different hair types. The development of formulations that provide both effective colouration and enhanced hair-care benefits may contribute to more convenient and cosmetically acceptable hair-dye products in the future.

DISCUSSION

The development of ammonia-free hair dyes represents an important approach toward improving the cosmetic acceptability of hair-colouring products. Conventional hair dyes use alkaline conditions to facilitate the penetration of dye precursors into the hair shaft. The use of alternative alkalizing agents such as monoethanolamine (MEA) provides an ammonia-free approach while supporting the requirements of oxidative colour development.

The incorporation of conditioning agents such as keratin, together with emollients and humectants, can provide additional cosmetic benefits by improving hair softness, smoothness, and manageability. This is particularly relevant because repeated chemical colouring may affect the physical properties of hair. A leave-on formulation also provides an alternative mode of application, allowing the formulation to remain in contact with the hair for the intended period.

However, successful development requires careful optimization of pH, viscosity, homogeneity, colour development, stability, and conditioning performance. The balance between effective colouration and desirable hair-care properties is therefore an important consideration. Overall, ammonia-free leave-on hair dyes with conditioning agents show potential as multifunctional hair-colouring formulations combining colour enhancement with improved cosmetic properties.

CONCLUSION

Ammonia-free leave-on hair dyes provide a promising approach to modern hair colouring by combining effective colour development with improved cosmetic properties. The use of alternative alkalizing agents such as monoethanolamine (MEA), along with conditioning ingredients such as keratin, emollients, and humectants, can support the development of multifunctional hair-dye formulations. Proper optimization of formulation components and evaluation parameters is essential to achieve satisfactory colour, stability, conditioning effect, and user acceptability. Overall, continued research in this area may contribute to the development of more convenient and cosmetically acceptable hair-colouring products.

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