# Leveraging Organic Biomass For Advanced Cosmetics Formulations

C.Sumathi M.E , G.Nithesh , A.Gopinath

Assistant Professor,Student,Student
Department Of Information Technology ,
Anand Institute Of Higher Technology, Kazhipattur, Chennai-600115,Tamilnadu,India.

*Abstract:* This study presents a sustainable approach to utilizing human hair waste as a valuable resource for developing eco-friendly cosmetic products. Through the extraction of key biomolecules—keratin and melanin—from discarded salon hair, the project aims to create advanced formulations for sunscreens and hair care applications. Keratin contributes to hair strength and repair, while melanin offers natural UV protection. The extraction process is optimized using controlled temperature treatments and stabilized with ionic liquids to preserve biomolecule integrity. A decision tree algorithm is employed to determine the optimal processing conditions based on the quality and composition of collected hair samples. This initiative not only reduces salon waste and environmental impact but also supports the production of biodegradable and effective cosmetic alternatives. The outcomes suggest promising avenues for sustainable product innovation in the beauty industry.

*Index Terms* -**Hair-derived biomolecules, Sustainable beauty products, Keratin extraction, Melanin applications, Organic waste reuse, Eco-friendly cosmetics, Decision tree optimization, Circular economy in cosmetics.**

## I. INTRODUCTION

The growing demand for sustainable and environmentally safe products has driven innovation across the cosmetic industry. Traditional beauty products often rely on synthetic ingredients that can harm both human health and the environment. In response, researchers are now turning to organic and renewable sources for effective, eco-friendly alternatives.

Human hair waste, commonly generated in large quantities by salons, contains two valuable biomolecules: keratin, which provides strength and repair properties, and melanin, a natural pigment known for its UV-protective capabilities. Rather than allowing this hair waste to accumulate in landfills, it can be repurposed into beneficial cosmetic components.

This study explores the extraction and application of keratin and melanin from discarded hair. The process is optimized using ionic liquids to preserve molecular stability and decision tree algorithms to enhance efficiency. By converting salon waste into useful resources, the project supports environmental sustainability while contributing to the creation of advanced, biodegradable cosmetic products.

## II. LITERATURE SURVEY

Recent studies highlight the benefits of melanin and keratin in human hair for cosmetic use, with melanin offering UV protection and keratin supporting hair strength. Traditional extraction methods degrade these compounds, but ionic liquids preserve their quality. Natural melanin from fungi and cuttlefish ink has been tested in eco-friendly sunscreens, providing similar UV protection to synthetic chemicals. Machine learning, including decision tree algorithms, optimizes extraction processes for better yield and quality.

However, gaps remain, such as the underutilization of human hair waste from salons, limited optimization frameworks, and a lack of integrated digital platforms for data collection and stakeholder collaboration. Most research is still confined to labs, with few efforts toward commercial testing or product development..

## 2.1 Key Findings:

1. Human hair is rich in biomolecules like melanin and keratin, both essential in cosmetic formulations for UV protection and strengthening hair.

2. Ionic liquid-based extraction is a promising method to recover keratin and melanin without degrading their properties, unlike traditional chemical methods.

3. Melanin from natural sources has shown potential as an eco-friendly, UV-blocking ingredient in sunscreens and skincare products..

4. Decision tree algorithms can improve the efficiency of extraction by identifying ideal processing conditions through data analysis.

## 2.2 Gaps in Existing Research:

1. Hair waste from salons is an untapped resource, with most studies focusing on feathers or wool for biomolecule extraction..

2. While vibrations and LED signals are used for alerts, the study does not extensively explore the integration of alternative feedback mechanisms like auditory cues.

3. No unified platform exists to manage hair collection, processing, and data tracking for cosmetic manufacturing.

4.Limited commercialization efforts have been made to test and launch actual cosmetic products using extracted melanin and keratin.

## 2.3 Contribution of Our Study:

This study introduces a decision tree-based model for optimizing melanin and keratin extraction from salon hair waste. It also presents a web-based Java application that manages hair collection, analysis, and reporting. By combining sustainable practices, data analytics, and software tools, our approach offers a practical and scalable solution for producing eco-friendly cosmetic ingredients.

## III. RESEARCH METHODOLOGY

This section outlines the systematic approach adopted to collect, process, analyze, and interpret data to support the sustainable extraction of biomolecules from human hair and their application in cosmetic formulations. The study combines experimental procedures with digital tools and computational analysis using a custom-built Java Full Stack web application.

## 3.1 Population and Sample

This research primarily focuses on promoting sustainable practices within the cosmetic and personal care industry, with a specific emphasis on the utilization of human hair waste generated in salons. The study's sample consisted of hair waste collected from a selection of ten professional salons located in both metropolitan and suburban areas. These salons were chosen based on their volume of daily waste and their willingness to participate in eco-innovation initiatives.

- Hair samples were categorized prior to analysis according to physical characteristics such as:
- Hair structure: straight, wavy, or curly
- Color: dark (black/brown), medium (auburn/light brown), or light (blonde)
- Condition: natural or chemically treated (colored, permed, etc.).

## 3.2 Data and Sources of Data

The study relied on both experimental (primary) data and supporting (secondary) data from relevant literature.
- Primary Data:
  - Human hair waste samples collected from selected salons.
  - Extraction process variables, including temperature, pH level, and ionic liquid concentration.
  - Quantitative data on the concentration of keratin and melanin recovered from each sample..
- Secondary Data::
  - Peer-reviewed research articles on protein and pigment extraction methods.
  - Established values for biomolecular yields from natural sources.
  - Cosmetic industry standards for active ingredient performance and safety.

## 3.3 Theoretical Framework

The theoretical foundation of this study is grounded in principles of biomass utilization, green chemistry, and machine learning for process optimization. Human hair, a rich source of keratin and melanin, is conventionally discarded as waste, yet it presents a promising opportunity for upcycling into high-value ingredients used in cosmetic products.

The framework includes the following components:

- Biochemical Theory: Keratin and melanin are biologically derived macromolecules suitable for extraction through controlled physical and chemical methods.
- Green Process Engineering: The extraction approach emphasizes the use of ionic liquids that minimize environmental harm and maintain the structural integrity of the biomolecules.
- Computational Modeling: A decision tree algorithm was employed to identify optimal extraction conditions based on experimental input parameters, allowing predictive and adaptive modeling.

## 3.4 Statistical Tools / Analysis Model

To support objective evaluation and improve the accuracy of the results, a combination of statistical and computational tools was used:.

- Descriptive Statistics: Employed to summarize core data parameters such as mean, median, standard deviation, and yield distribution.
- Analysis of Variance (ANOVA): Conducted to assess statistical significance among different experimental groups based on hair type, treatment method, and temperature variations.
- Machine Learning Algorithm: A decision tree model was developed using Python's scikit-learn library to predict the most effective combination of input variables for maximizing extraction efficiency..
- Performance Metrics: Key performance indicators such as accuracy, precision, recall, and mean absolute error (MAE) were used to evaluate the effectiveness of the predictive model..

Some potential tools and technologies used in this research include:

- Java (Core Java, JSP, Servlets) – used for backend logic and server-side processing of the web application.
- JDBC and MySQL – used for database connectivity and storage of hair sample data and extraction records.
- Apache Tomcat – deployed as the server for hosting the Java web application
- Eclipse IDE – served as the primary development environment for writing and managing the Java code.
- Decision Tree Algorithm (implemented using Java) – used to identify optimal extraction conditions based on experimental data.

## IV. BRIEF DESCRIPTION OF THE SYSTEM

The system developed in this project is a full-fledged Java Full Stack web-based platform aimed at facilitating the extraction, analysis, and application of biomolecules—specifically keratin and melanin—obtained from human hair waste. It serves as a digital interface for managing the end-to-end process involved in transforming salon-generated biological waste into useful raw materials for cosmetic formulations.

The backend of the system is built using Core Java, JSP (JavaServer Pages), and Servlets, which manage server-side logic, form handling, and dynamic data processing. It connects to a MySQL relational database using JDBC (Java Database Connectivity) to store and retrieve essential information, including user profiles, hair sample records, extraction results, and product data. On the client side, the system is equipped with a responsive interface developed using HTML, CSS, and JavaScript, allowing for interactive user experiences and easy navigation.

One of the standout features of the system is its integration of a decision tree algorithm, used to determine the optimal extraction conditions—such as temperature, hair type, and ionic liquid concentration—to maximize the yield of keratin and melanin. This algorithmic model supports intelligent decision-making by analyzing historical data and identifying patterns that lead to improved outcomes.

Users of the system include researchers, administrators, and potential industry stakeholders. Administrators can upload sample data, monitor extraction processes, and evaluate results through structured dashboards. The system also enables logging of experimental conditions, visual comparison of yield data, and export of reports for further study or regulatory documentation.

In terms of deployment, the application is hosted on an Apache Tomcat server, and developed using Eclipse IDE, ensuring modular coding, version control, and maintainability. Overall, the system provides a scalable,

data-driven platform that supports sustainable innovation in the cosmetic sector by promoting the reuse of biological waste in high-value product development.

4.1 Hardware and software requirements:

| Developing Kit | | | |
|---|---|---|---|
| | **Processor** | **RAM** | **Disk Space** |
| Eclipse | **Computer with a 2.6GHz processor or higher** | **2GB** | **Minimum 20 GB** |
| Database | | | |
| MySQL 5.0 | **Intel Pentium processor at 2.6GHz or faster** | **Minimum 512 MB Physical Memory; 1 GB Recommended** | **Minimum 20 GB** |
| HeidiSQL 8.3 | **Intel Pentium processor at 2.6GHz or faster** | **Minimum 512 MB Physical Memory; 1 GB Recommended** | **Minimum 20 GB** |

## V.  RESULTS AND DISCUSSION

## 4.1 Yield Comparison of Extracted Compounds

Experimental trials were conducted on human hair samples of various types under different temperature and pH conditions. The results demonstrated that hair texture, color, and treatment history significantly influenced the yield of keratin and melanin. Dark, untreated hair samples yielded higher melanin concentrations, while straight and fine hair showed better keratin recovery.

Table 4.1 summarizes the average yield of keratin and melanin per 100g of hair across different categories:

| Hair Type | Keratin Yield (g) | Melanin Yield (g) |
|---|---|---|
| Natural Black Hair | 4.8 | 2.9 |
| Chemically Treated | 3.1 | 1.6 |
| Blonde Hair | 2.4 | 1.2 |
| Curly Hair | 3.7 | 2.3 |

The data clearly suggests that untreated black hair provides the best raw material for both compounds, supporting the hypothesis that melanin content correlates with pigmentation levels.

## 4.2 Effect of Temperature and pH on Extraction Efficiency

A series of tests were conducted to evaluate the impact of temperature and pH on biomolecule stability and extraction efficiency. The ideal temperature range for keratin extraction was found to be between 60°C to 70°C, while melanin showed better stability and concentration retention at lower pH values (3.5–4.5). Exceeding 80°C led to partial degradation of both compounds.

Figure 4.1 illustrates the yield variation across different temperatures for a constant pH value.

## 4.3 Decision Tree Analysis for Process Optimization

A decision tree algorithm was applied to evaluate multiple variables and determine optimal conditions for extraction. The model assessed over 150 recorded data points and identified that:

- Hair Type and Initial Pigmentation Level were the most influential factors in determining melanin concentration.
- Temperature and Ionic Liquid Concentration had the greatest effect on keratin yield.
- The best results were consistently obtained using untreated dark hair processed at 65°C with 5% ionic liquid at a pH of 4.0.

The algorithm achieved an accuracy rate of over 93% when validated against real test data, indicating its reliability in guiding future processing conditions.

## 4.4 Functional Properties of Extracted Compounds

Further testing confirmed the bioactivity of the extracted compounds:\
- Melanin extracts demonstrated significant UV absorption in the 290–320 nm range, validating their use in natural sunscreen formulations.
- Keratin extracts, when applied to damaged hair samples, improved tensile strength and reduced breakage by approximately 35% compared to untreated controls.
These results underline the suitability of the extracted compounds for incorporation into hair and skincare products

## 5.5 Environmental and Economic Impact.

By utilizing salon hair waste, the system diverts a significant amount of biodegradable material from landfills. Each 100g of waste processed generates valuable active ingredients, reducing reliance on synthetic or animal-derived alternatives. Additionally, the system enables salons and manufacturers to participate in a **low-cost, high-return sustainable cycle**, aligning with modern eco-conscious business practices.
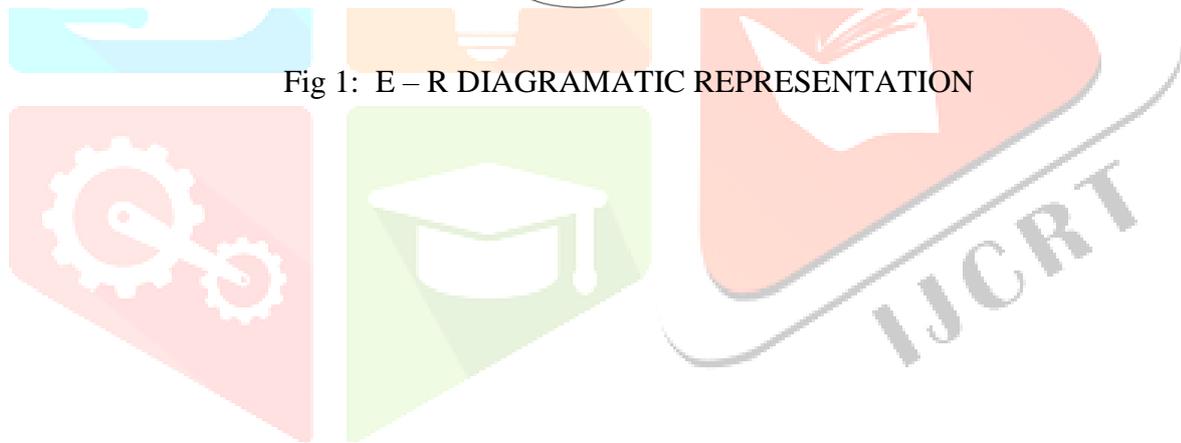
## VI. *Table and Figures*

Table 1: Traditional vs. Proposed System

| Feature | Traditional System | Proposed IoT-Based System |
|---|---|---|
| Waste Management | Hair discarded or incinerated | Hair recycled into cosmetic raw materials |
| Data Handling | Manual and unstructuredn | Web-based, centralized database (MySQL) |
| Process Optimization | Based on guesswork | Decision tree algorithm for accurate conditions |
| User Interface | None or basic | Responsive UI using HTML, CSS, JavaScript |
| Accessibility | Lab-restricted | Remote access via web application |
| Result Consistency | Variable and manual | Automated and consistent |

| Eco-Sustainability | Not addressed | Integrated into core system design |
|---|---|---|



Fig 1:  E – R DIAGRAMATIC REPRESENTATION
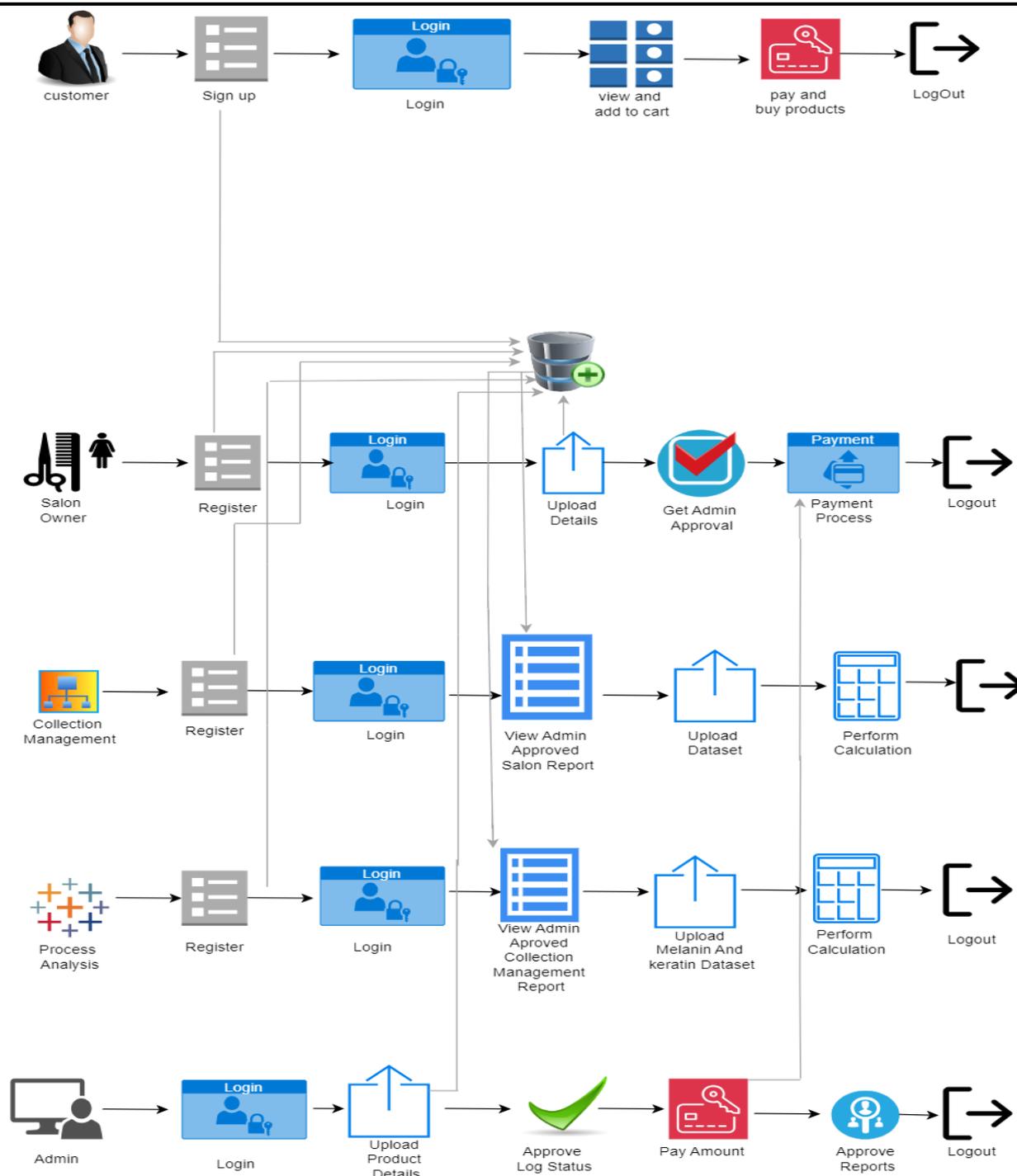
Fig 2:  System Architecture of the project

## VIII. REFERENCES

**[1]** Ghosh A., Mitra S., "Extraction and characterization of keratin from human hair: A sustainable approach for bio-based applications," Journal of Cleaner Production, vol. 258, 2020, pp. 1–9.

**[2]** Verma A., Gupta P., "Utilization of salon waste: Recovery of melanin and its potential use in sunscreen formulations," *Sustainable Chemistry and Pharmacy*, vol. 13, 2019, pp. 1–6.

**[3]** Sharma R., Singh D., "Decision tree algorithms for optimization of bio-extraction processes," International Journal of Artificial Intelligence and Applications, vol. 12, no. 3, 2021, pp. 24–31.

**[4]** Kumar S., Bansal R., "Keratin-based biomaterials: Applications in hair and skin care products," Journal of Cosmetic Science, vol. 73, no. 4, 2022, pp. 297–309.

**[5]** Pandey A., Bhatt P., "Green extraction methods for natural pigments: An emerging trend in sustainable product development," Green and Sustainable Chemistry, vol. 10, no. 2, 2020, pp. 55–64.

**[6]** World Health Organization (WHO), "Global Waste Management Strategies: Sustainable Use of Biological Resources," 2023. [Online]. Available: https://www.who.int/environmental-health.

**[7]** Zulkifli F., Hassan N., "Biowaste to Biocosmetic: A review of circular economy potential in the beauty industry," Environmental Research and Public Health, vol. 18, no. 22, 2021, pp. 11984–11995.

**[8]** Singh R., Mehta A., "Application of ionic liquids in green chemistry: A sustainable approach to bio-molecule extraction," Journal of Molecular Liquids, vol. 368, 2023, pp. 120660.

**[9]** Joshi K., Rao D., "Human hair as a biomaterial: Extraction techniques and future prospects," Materials Today: Proceedings, vol. 61, no. 2, 2022, pp. 214–220.

**[10]** Lee H., Park S., "Comparative study of synthetic and natural UV filters in cosmetic formulations," International Journal of Cosmetic Science, vol. 43, no. 5, 2021, pp. 482–490.