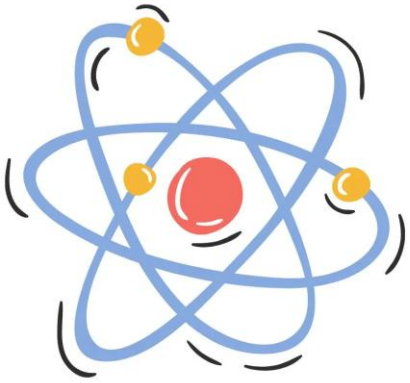

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COMPARATIVE STUDY OF FORMULATION AND EVALUATION OF ORGANIC HAIR SERUM FROM ORANGE PEEL

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Abstract: *The increasing need to have natural and environmental-friendly cosmetic products has led to the increase in interest in using herbal formulations in hair care products. The current research is on the development and comparative analysis of an organic hair serum with orange peel as one of the major bioactive agents of Citrus sinensis. Those phytochemicals present in orange peel include flavonoid, vitamin C, and essential oils which have antioxidant, anti-microbial and anti-inflammatory effects that are useful in scalp and hair health. The orange peel extract in this study was prepared with the help of the appropriate extraction methods and was introduced in various serum formulations (F1, F2, and F3) combined with carrier oils and natural additives. The ready-made formulations were tested on physicochemical characteristics such as pH, viscosity, density, and spreadability, and phytochemical screening and stability tests. The findings showed that all the formulations had acceptable levels of application to cosmetics, although formulation F3 demonstrated better properties in stability, phytochemical content, and effectiveness in general. The paper shows that orange peel, based hair serum can be used to enhance the texture of hair, decrease cases of dandruff and enhance healthy hair growth, all safe and environmental friendlies. The results indicate how natural waste resources such as orange peel can be utilized in producing cost and sustainable cosmetic products. It can be improved through more research and unification to be more commercially viable in the herbal cosmetic sector.*

Keywords: *Orange peel,* Citrus sinensis*, Herbal hair serum, Phytochemicals, Antioxidant activity, Organic cosmetics, Hair care formulation*

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1. INTRODUCTION

The cosmetics of hair care have undergone an enormous transformation over the years, and the herbs of the body have evolved into modern synthetic elements, and are gradually re-reverting to the natural remedies. In the early early days, plants were popular in maintaining the oils of their plants, herbs and extracts. As industrialization kicked off however, artificially made hair care products became popular as far as they had instant effects, they could be used longer and were simple to manufacture. Despite such gains, the serums based on chemicals re-plicate harmful chemicals such as sulfates, parabens and silicones that can irritate the head, harm hair, dry-up the skin and ultimately lead to illnesses (Chaudhari et al., 2025). These negatives have raised the consciousness of the consumers and a revival of desire towards safer and more sustainable alternatives has followed.

The emergence of the herbal hair serums has become the remedy since it merges the attributes of the natural ingredients and the contemporary formulation approaches. They are free of harsh chemicals, and are enriched with “plant-based extracts, essential oils and nutrients which support the scalp and hair. Herbal ingredients have a number of advantages including reduction on the rate of reaction, enhancement of scalp healthiness, and environmental friendliness (Erlina et al., 2024). A change in consumer preference towards organic and herbal products of cosmetics which is visible in the past few years is also initiated by the increasing awareness of environmental sustainability and health. The trend has encouraged the production of superior herbal preparations in cosmetic market.

One of the natural ingredients which was extensively researched as a useful bioactive ingredient is orange peel derived out of Citrus sinensis. Orange peel is very rich in flavonoids, vitamins C and other important oils that possess all the antioxidant, antimicrobial, and anti-inflammatory properties. The scalp health, dandruff, hair growth and hair shine are essential and are maintained by the compounds. In addition, orange peel is naturally fragranced and conditioned and, therefore, an ideal ingredient in hair care products.

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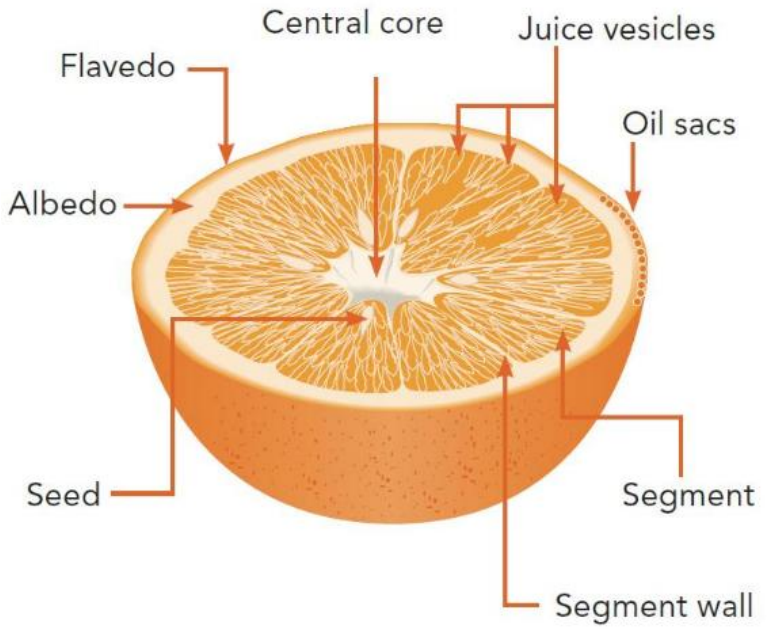

Figure 1: Botanical structure and peel morphology of Citrus sinensis

Despite the growing trend of herbal cosmetics, no standardized recipes have been established to make use of organic hair serums though there have not been enough focus over the utilization of the orange peel extracts specifically (Penkar et al., 2023). These discrepancies in the methodologies of extracting ingredients, testing and mix procedure creates untrustworthy quality and functionality of the products. Therefore, systematic studies that work towards the development and comparative analysis of different organic hair serum preparations are needed.

This paper aims to prepare an organic hair serum composition consisting of oil and orange peel extract, to test its physicochemical properties such as pH, viscosity and stability of the business, and finally compare the different formulations to analyze the most appropriate formulation. The production of safe, effective and standardized herbal hair care products will be based on the study.

2.LITERATURE REVIEW

2.1 Herbal Cosmetics and Their Significance

The importance of the herbal cosmetics has been very huge in the recent past due to its safety, effectiveness and environmental friendliness (Khadasare et al., 2024). Unlike synthetic products, herbal cosmetics are manufactured using synthetic products that are supposedly made of plant-based components that are less likely to cause side effects such as irritation or allergenic reactions,

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to any human being. All these are high content natural bioactive products that nourish, protect and repair the skin and hair. This has increased caution towards the toxicity of the chemicals based cosmetics, which has prompted customers to graviate towards herbal cosmetics. Furthermore, herbs cosmetic conforms to maintenance of sustainability as it is eco-friendly and biodegradable. They possess long-term benefits, and limited side effects that render them extremely valuable in the cosmetic science today.

2.2 History of previous studies on Hair serum formula.

Several studies to be conducted on hair serums development using synthetic and natural ingredients have been done. Traditional hair serums are normally stuffed with silicones that will temporarily turn hair and scalp shiny and smooth, this fact can lead to future deposits (Anusha et al., 2023). On the other hand, recent research has been focusing on blends of herbs that utilise such ingredients as the aloe vera, coconut oil, argan oil and essential oils. Ever since these papers demonstrated that one can manage the damages that are done to hair and herbs that are utilized as hair serums might be helpful in cooling down the hair, reducing the frizziness as well as making the hair grow faster (Khan et al., 2023). They also have been compared to unveil the fact that natural formulations are far much superior to scalp and also secure to apply to it in the long run. The aim of such formulations however largely relies on the ingredients involved and the preparation method and thus the optimisation of the formulations is necessary.

2.3 Phytochemical Properties of Orange Peel.

The Orange peel which is extracted out of Citrus sinensis is a rich source of phytochemical with high biological properties. It contains flavorful acids of flavonoids, such as hesperidin and naringin which is a high-strength antioxidant and anti-inflammatory (Tiwari et al., 2021). Additionally, a lot of vitamin C can be found in orange peel which is important in the synthesis of collagen and scalp health. Peel contains the essential oils with antimicrobial properties which can be used to cure dandruff and scalp infections. Other compounds such as carotenoids are added to phenolics which contribute additional therapeutic potential to it (Kavitha et al., 2025). These phytochemicals contribute towards strengthening the hair, enhancing the oxidative stress, and generally improves the overall health of the hair as well, so orange peel is a good compound that should be added to the preparations of herbal hair care.

2.4. What does antioxidants play in Hair Care

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The antioxidants are essential towards ensuring that your hair is healthy because it assists in providing your hair with protection against oxidative attacks by the free radicals. Pollution, UV radiations and stress induce the generation of free radicals which weaken hair cases, precipitate the fall of hair, graying and the scalp diseases (Tiwari et al., 2025). Antioxidants are used to neutralize the harmful molecules thereby preventing damage to it and facilitating the hair growth. Natural antioxidants (especially flavonoids) found in plants and vitamin C are particularly handy to enhance scalp health to give ones a better hair condition (Dongre et al., 2024). The presence in hair care products helps them to reinforce hair follicles, maintain moisture level and reduce swelling. Thus, the most important elements of the modern day herbal hair formulations are the ingredients containing antioxidants.

2.5 Research Gap

Although, massive research has been conducted on herbal based beauty products (including hair care), very minimal research has been conducted on the formulation, as well as the comparative analysis of the organic hair serums with the use of orange peel extract. The existing literature is inclined towards the single ingredients rather than producing standard formulations. In addition, comprehensive evaluation including culture (in terms of physicochemical features, stability and comparison of performance between different formulations) does not exist. This is the loophole that requires a scientific study in order to develop an effective, stable and a uniform organic hair serum. The next study will address this gap since it will attempt to come up with different varieties of hair serum based on orange peel and conduct a comparison study with the objective of coming up with an effective formulation.

3. MATERIALS AND METHODS

3.1 Materials Required

The organic hair serum ingredients were, firstly, the orange peel produced by Citrus sinensis which was the major bioactive ingredient. Carrier oils such as coconut oil and argan oil which have nourishing and moisturizing properties were applied (Vinay, 2019). This was topped off with other ingredients to humectify, treat and calm the skin like aloe vera gel and other essential oils to add fragrance and healing factors. All the materials were analytical or cosmetic in order to ensure the quality and safety of the formulation.

3.2.The orange peel collection and preparation

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Orange peels were freshly harvested, washed using distilled water to wipe out impurities and were subjected to a drying process, as well (Shende et al., 2024). Drying of the peels under shade in few days was done to maintain the phytochemical properties of the peels and not to degrade under direct sunlight. The peels were then completely dried and then ground using a mechanical grinder in the fine powder form. The away powdered material was then put in airtight containers till it is utilized further to prevent its absorption and contamination by water.

3.3 Extraction Methods

Different methods were used in extracting the orange peel powder with an intention to extract bioactive compounds. Soxhlet extraction was carried out with the help of a proper ethanol in order to make the phytochemical extraction effective (Wuttisin et al., 2017). The other method was known as cold maceration which involved dissolving the powdered peel in a solution at room temperature over an extended period of time which would enable active constituents to diffuse over the whole peel. Furthermore, it also obtained the necessary oil of the orange peel which is very rich in aromatic and antimicrobial agents via steam distillation (Rodrigues et al., 2024). All these measures were essential since they brought optimal recovery of useful components that they could use in formulation.

The peels of fresh oranges were washed and dried shade way 5-7days and approximately ground. Solvents consisted of solvent to extract the powdered peel and as such, ethanol was used on the peel. The dried peel powder (approximately 50 g) was macerated with 250 mL of 95% of ethanol, taken off after 48 hours in an intermittent shaking. A mixture was filtered using muslin cloth then filter paper (Whatman). The filtrate was concentrated at 40 to 45degC in a water bath to obtain a semi-solid extract. A container was then taken with an airtight cover into which the extract obtained was stored pending additional formulation.

3.4.Recipe of Hair Serum

Hair serum was developed in three variants of F1, F2 and F3 by maintaining the levels of the oils and the carrier as well as the orange peel extract. All formulas contained equal portions of extracts of carrier oils, glycerin, aloe vera and essential oils (Mukherjee et al., 2025). This was achieved through the individual mixing of the oil phase and the aqueous phase and then mixing gradually with continuous stirring of the mixture leading to a homogenous mixture. Clear airtight containers where they were kept were employed (Wasnik et al., 2024). This was accomplished by setting up

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a composition table that would be utilized in order to compare the ingredients content and ratio of the elements in both of the formulations.

3.5 Evaluation Parameters

The hair serums made were tried based on various parameters. Physicochemical tests were performed (PH, viscosity, density and spreadability) to determine the quality and suitability of products in application (Al-Sagheer et al., 2023). The screening was done on phytochemical to determine flavonoids, phenols and alkaloids. Experiments in solid state were performed at different temperatures to find out the stability against time of the formulations. Also microbial testing was conducted to determine the safety of the product along with the shelf life. This was determined by the formulation that received the greatest number of critiques; and this one was considered the most reliable and efficient (Vinay, 2019).

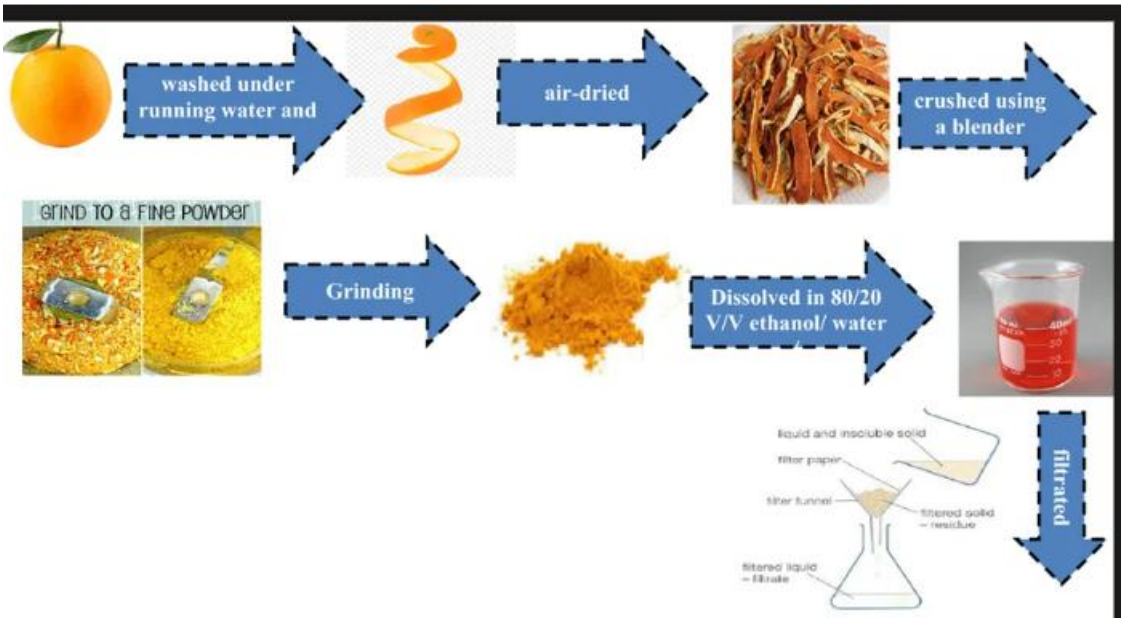

Figure 2. Extraction of Orange Peel by Ethanolic Solvent Extraction Method

4.PHYTOCHEMICAL ANALYSIS

4.1 Active Compounds in Orange Peel

Citrus sinensis is the source of orange peel which is a rich source of bioactive compounds that make it a valuable source of peel in terms of therapeutic and cosmetic use. Of these, the most noticeable phytochemicals are flavonoids which are found in high levels (Janakiraman et al., 2023). These compounds, like hesperidin and naringin, possess good antioxidant as well as

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antimicrobial effect which is necessary to keep the scalp healthy and infection free. These flavonoids assist in counteracting free radicals, and safeguarding hair follicle against oxidative damage, consequently leading to healthier hair growth (Michael-Igolima et al., 2023).

Another important ingredient is vitamin C which can be found in abundance in orange peel. It is vital in collagen production which is vital in keeping hair strong and in its structure. Furthermore, vitamin C helps in increasing iron absorption, which indirectly helps in increasing hair growth, and preventing hair loss (Peng et al., 2024). It is also used as an antioxidant thus making the scalp immune to environmental damages.

Some of the compounds found in essential oils extracted out of the orange peel especially by steam distillation include limonene which is antimicrobial and gets anti-inflammatory effects. Such oils, besides handing out a sweet scent, help to decrease dandruff, calm down irritated scalp, and fix hair texture (Abelan et al., 2022). The combination of the positive hair care effect of these compositions leads to the use of orange peel as a synergistic phytochemical ingredient in the formulation of hair care products.

4.2 Contribution to Hair Health.

Phytochemicals available in orange peel are useful in improving the health of the hair in a variety of ways. The antioxidant effect of flavonoid compounds and vitamin C are effective in the fight against oxidative stress due to the environmental pollution, UV radiations and chemical exposures. The compounds help reduce the amount of hair fall by neutralizing free radicals to help avoid hair damage in the hair follicles, and whilst encouraging the growth of hair that is stronger (Imaduddin et al., 2025).

Other than being an antioxidant, orange peel has immense anti-inflammatory effect. One of the leading dandruff victims is caused by scalp inflammation, resulting in itching and hair thinning. The anti-inflammatory elements of orange peel facilitate in improvising the scalp, relieve irritation and keep the hair growing in healthy environment (Ben Hsouna et al., 2023). Moreover, the antimicrobial agents of the essential oils help in managing fungus and bacterial infectious ailments, which commonly cause dandruff and scalp ailments.

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A combination of these bioactive compounds will result in the hair being much better than ever: greatly enhanced texture, greater natural shine, and being much more manageable. Frequent use of methods of application of orange peel extract can result in a healthy, shiny and stronger hair.

4.3 Comparative Phytochemical Results

The three formulations (F1, F2 and F3) were subjected to a comparison in terms of phytochemical analysis to determine the occurrence and magnitude of the most important bioactive compounds (Wang et al., 2020). Results showed that there were differences in the phytochemical composition depending on formulation.

Table 4.1: Comparative Phytochemical Screening of Formulations

Phytochemical	F1	F2	F3
Flavonoids	+	++	+++
Phenols	+	++	++
Alkaloids	-	+	+
Vitamin C	+	++	+++
Essential Oils	+	++	+++

(+ = Low, ++ = Moderate, +++ = High, - = Absent)

Judging by the table, it can be seen that formulation F3 exhibited the best concentration of flavonoids, vitamin C and essential oils, which means that it has the best phytochemical profile. F2 showed moderate concentrations of most of the compounds, and F1 had a relatively lower concentration (Chaudhari et al., 2025). These findings indicate that higher concentrations of orange peel extract increase the phytochemical composition of the formulation that can be positively used to impact its properties.

5. FORMULATION AND EVALUATION RESULTS

5.1 Organoleptic Properties

https://doi.org/10.71058/jodac.v10i05003

The smell, color and texture of the prepared hair serums were analyzed. There was acceptable physical characteristics in all three formulations that could be used as cosmetics. Formulation F1 had a light yellow appearance and a slight citrus smell with a slightly thin consistency (Erlina et al., 2024). F2 was redder-orange in color with a sweet citrus aroma and medium viscosity. F3 was deeper orange in color, had good natural smell and was more viscous in texture.

All the preparations were non-greasy and had a smooth texture, easy to apply and to be absorbed by the hair. F3 was the most acceptable in terms of color and natural odor among the three as it has a richer color and strong natural smell which are a hallmark in herbal cosmetic products.

5.2 Physicochemical Results

To assess the quality of the formulations, their stability, and applicability, physicochemical properties of the formulations were measured.

Table 5.1: Physicochemical Evaluation of Hair Serum Formulations

Parameter	F1	F2	F3
pH	5.5	5.8	6.0
Viscosity	Low	Moderate	High
Density	0.90 g/ml	0.92 g/ml	0.94 g/ml
Spreadability	Good	Very Good	Excellent

The pH of all formulations was moderate to be applied on the scalp implying that all the formulations are safe and non-irritating. The orange peel extract viscosity was enhanced at increased levels of the extract and the F3 had high levels of viscosity (Penkar et al., 2023). The rates of the densities were comparable in all the formulations, implying the stability of the preparation. Spreadability tests revealed that F3 possessed the best spreading characteristics therefore becoming easy to apply.

5.3 Stability Analysis

The stability tests were conducted as the formulations were stored at different temperatures including the room and high temperature. The observations were noted after a couple of weeks in order to identify whether any changes in color, smell, pH or even consistency occurred.

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Figure 2 indicates that the smell and texture of formulation F1 varied a bit over time, indicating that this product is less stable (Khadasare et al., 2024). F2 was relatively steady and had a few changes in its characteristics. F3 showed the greatest stability and no significant modifications were detected in its physical or chemical properties. The presence of bioactive compounds and essential oils in F3 that might have been increased due to its elevated stability could also have contributed to its increased stability.

5.4 Comparative Analysis

The three were compared and it was discovered that F3 was better than F1 and F2 based on phytochemical content, physicochemical properties and stability (Anusha et al., 2023). The higher concentration of Orange peel extract in F3 resulted in the higher antioxidant and antimicrobial activity that augmented its usefulness in hair products.

F2 had a medium level of performance and may be considered a medium formulation with good characteristics. F1 was effective to some degree, but it still contains a lesser phytochemical content and stability; therefore, it was not that suitable compared to the other preparations (Khan et al., 2023). Overall, F3 proved to be the most promising formulation since it demonstrated improved results in all aspects of the assessment.

6.DISCUSSION

The results of development of the organic hair serums and its dissection are educative on the possible application of orange peel as one of the key components of hair processing products. Phytochemical composition also showed that the required bioactive compounds of flavonoids, vitamin c and the essential oils that have been discovered to have anti-oxidant as well as anti microbial effects were present (Tiwari et al., 2021). The outcomes show that the orange peel extract may be used in the preparation of the scalp to make it healthier and increase the quality of hair.

Comparison of the formulae revealed that the higher the concentration of the orange peel extract, the more the whole process of the serum works. Formulation F3 with the highest concentration of extract was deemed with better physicochemical properties, better content and stability phytochemical (Kavitha et al., 2025). This implies that the efficacy of the formulation in terms of concentration of active ingredients and its formulation are directly correlated.

The results of the current study compared to the previous studies on herbal hair serums are consistent with the earlier results that demonstrated the benefits of natural ingredients as used in

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hair care. The herbal preparations have been shown to be safe herbal preparations and more compatible with the scalp than the synthetic preparations (Tiwari et al., 2025). The benefits addition to use of orange peel extract is on the basis of rich-phytochemical profile and multi functional property.

What led to the selection of F3 as the best formulation is that it is most suitable as it has the best pH, it is most spreadable, the viscosity is higher and the stability is enhanced. These aspects make it more convenient and accessible to practice. In addition, it has great antioxidant qualities leading to improved environmental protection.

However, the study has certain limitations. The evaluation was performed in a controlled laboratory setting and no analysis of the long term impact of the hair growth and the healthy conditions of the scalp was assessed with the help of clinical trials (Dongre et al., 2024). As well, the amount of raw materials and extraction may vary, causing the results to be deviated.

Nevertheless, despite the weaknesses, the paper can demonstrate that an orange peel-based organic hair serum can become a potentially powerful and safe substitute of the synthetic products. It may be possible to conduct research in the future to incorporate more complex formulation techniques, mass production and clinical trial in an effort to further expand its applicability in the cosmetic industry.

7. APPLICATIONS AND BENEFITS

7.1 Cosmetic Applications

The formulated organic hair serum containing orange peel extract of Citrus sinensis is observed to possess diversity in usage in the cosmetic science. Some of its important uses include in hair as growth serum where invigoration of hair follicles and healthy hair growth are achieved through the action of the flavonoids and vitamin C in them (Vinay, 2019). The antioxidant agents inhibit the scalp against oxidative stress that ultimately diminishes the hair loss and increases the hair density after some duration. Another attribute that makes the formulation an effective anti-dandruff formulation is its antimicrobial property of orange peel extract (Wuttisin et al., 2017). It helps to control the fungal growth on the scalp, the scale flakes, irritation and itch. It also enhances the feel of hair, its coating and handles hence suitability in day to day hair policy.

7.2.Advantages vs synthetic Products.

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There are certain advantages of the organic over other conventional synthetic hair serums usage. It is environmentally conserving as it is manufactured using natural and biodegradable materials which do not harm the environment (Shende et al., 2024). It is toxic-free and safe and can be applied in the long term as it does not contain any harmful substances such as parabens and sulfates. Preparation of drugs with the help of herbs is traditionally weak on the scalp and provides minimum opportunities of the drug producing any side effects such as irritations or allergic reactions (Rodrigues et al., 2024). Moreover, their payoffs are long-term since they do not give a momentary cosmetic appearance but benefit the hair.

7.3 Commercial Potential

The increased demand of products like hair serum based with orange peel have led to high market potentials in the use of such products. Consumers have an increasing need to get natural substitutes, which are safe, effective and sustainable (Mukherjee et al., 2025). The prospects of orange peel extract as a large-scale ingredient is provided with its unique characteristics, its high cost-effectiveness, and easy availability. With the correct standardization and quality check this formula has enormous commercialization opportunities in the cosmetic production.

8.CHALLENGES AND FUTURE PERSPECTIVES

Incorporation of organic hair serum has a few issues though it has its advantages. Such common problems that may result to unstable states are the natural structure of ingredients that may be easily deteriorated in the long term. Standardization is another problem as because of the variations in raw materials and extraction methods the production can be different and thus it can affect the products in a negative way. More investigations are needed into the improvement of stability to employ more sophisticated techniques such as nano-formulations and encapsulation. Moreover, new methods of extraction could be applied to enhance the performance and efficiency of bioactive compounds, ensuring the high quality and performance products.

9.CONCLUSION

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The current study presents the findings of the application of orange peel extract in the production and testing of an organic hair serum which is proving to be effective. The findings show that the serum is rich in phytochemical properties, which aid in improving the quality of hair, reducing dandruff, and increasing the shine. It was found that the optimized version of the formulations was more efficient and stable. The overall verdict of orange peels-based hair serum is that it is a safe, natural and efficient alternative to synthetics. It is proposed that it need to be formulated further and made commercial as an herbal cosmetic product which is sustainable.

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