

Strawberry Leaves Extract for Cosmetic Industry

Ana Paula Silva¹, Bruno Rodrigues², Léandra Bonny³,
Yaidelin Manrique⁴

¹Department of Chemical Engineering, Faculty of Engineering, University of Porto, Rua Dr. Roberto Frias, 4200-465 Porto, Portugal (up201702856@up.pt) ORCID [0000-0001-7612-7129](https://orcid.org/0000-0001-7612-7129);

²Department of Chemical Engineering, Faculty of Engineering, University of Porto, Rua Dr. Roberto Frias, 4200-465 Porto, Portugal (up201900485@up.pt) ORCID [0000-0003-1346-398X](https://orcid.org/0000-0003-1346-398X);



³Department of Chemical Engineering, Faculty of Engineering, University of Porto, Rua Dr. Roberto Frias, 4200-465 Porto, Portugal; ENSIC, University of Lorraine, 1 rue Grandville, 54000 Nancy, France (leandra.bonny3@etu.univ-lorraine.fr) ORCID [0000-0003-2540-2711](https://orcid.org/0000-0003-2540-2711); ⁴LSRE-LCM-Laboratory of Separation and Reaction Engineering – Laboratory of Catalysis and Materials, Faculty of Engineering, University of Porto, Rua Dr. Roberto Frias, 4200-465 Porto, Portugal; ALiCE-Associate Laboratory in Chemical Engineering, Faculty of Engineering, University of Porto, Rua Dr. Roberto Frias, 4200-465 Porto, Portugal (yaidelin.manrique@fe.up.pt) ORCID [0000-0002-7053-373X](https://orcid.org/0000-0002-7053-373X)

Abstract

In 2020, Portugal had an average strawberry production of 10 thousand tons, and 15 % was considered strawberry plant residues. This work proposed a new product that uses the compounds extracted from the strawberry residues - stem and leaves, excluding the fruit - as an active ingredient for cosmetic application. Strawberry leaves were extracted with 50 % ethanol. This extract mainly consists of lactic acid, ascorbic acid, and agrimoniin; these compounds are used in the chemical industry due to their antioxidant properties. A gel-cream formulation with 17.5 % strawberry leaves extracts was proposed. It proposed an industrial-scale production and a preliminary economic analysis to evaluate the project's profitability. The Net Present Value (NPV) was estimated as 3.40 M€ (4th year), and the pay-back time is on eight quarters.

Author Keywords. Strawberry Plant. Skin Cream. Hydrogel. Chemical Product Design.

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1. Introduction

The cosmetic industry is a global sector with an annual growth rate of approximately 5.9 %, and in the European field, this market reaches a value of 70 billion (Secchi et al. 2016; Sabanoglu 2022). Moreover, the skin care segment represents 26 % of the industry revenue. It tends to have a more significant impact over the years due to the influence of social media, i.e., it is possible to reach a wide range of potential customers from all over the world with social media posts (Binwani and Ho 2019). These numbers are attracting the attention of companies to develop new products every year (Kumar 2005). Also, the demand for more sustainable products has gained more attention due to concerns about chemical and toxic ingredients, environmental impacts, animal testing, and fair labor situation, making the companies rebrand themselves and their products (Kolling, Ribeiro, and de Medeiros 2022; Calvo et al. 2020).

This study aims to provide an overview of the viability of manufacturing a new chemical product in the cosmetic field. After investigating the region of harvested strawberry plants in Portugal, research is done about the compounds and their properties within the strawberry

plant residues, specifically, stem and leaves. The next topic performs a few product insights, including needs and ideas leading to selecting the final product. Once the starting point was settled, laboratory experiments were carried out before the scale-up to industrial production and economic analysis.

2. Raw Material: Strawberry Plant

2.1. Production

In Portugal, the average production of strawberry plants was around 10 thousand tons over the last five years, with 15 % corresponding to leaves, stems, and root residues (Smart 2021; Palha 2020). In 2017 and 2018, total strawberry production was 9.3 and 10.6 thousand tons, respectively (INE 2019). Moreover, the main regions where strawberries are produced during all seasons are Ribatejo, Odemira, and Algarve. To satisfy national demand, Portugal imports strawberries for around 17 thousand tons per year, mainly from Spain (Barroso 2018).

2.2. Composition

Strawberry leaves are mainly composed of polyphenols recognized for their antioxidant capacities and benefits on human health, from anti-aging properties to cancer treatment (Muthukumaran et al. 2017).

The most interesting compounds considered in this study due to the quantity present in strawberry plants were ellagic acid, ascorbic acid, and agrimoniin. The ellagic acid derivatives have the potential to protect the skin from oxidative stress and pollution and boost the production of collagen fibers. The ellagic acid quantity related to the leaves is 112.7 mg per 100 grams of fresh material (Michalska et al. 2017). In addition, ascorbic acid is known for antioxidant and anti-inflammatory properties and UV protection. The presence of vitamin C is 138.08 mg per 100 grams of fresh leaves weight (Žlabur et al. 2020). Finally, agrimoniin is the main compound found in the leaves, with almost 35 % wt., having antioxidant and anti-inflammatory activities acting against UVB-induced inflammation (Kårlund et al. 2014). Agrimoniin quantities are 498.4 mg per 100 grams of fresh material (Michalska et al. 2017). The extract composition could vary with the source of the raw material due to environmental facts such as weather, soil nutrients, water availability, etc. (Moraghan and Mascagni 1991).

3. Material & Methods

Fresh strawberry leaves (*Fragaria × ananassa*) samples were obtained from Jardiland, a retail store in Porto, Portugal (2020). The raw material was dried for 30 hours in a convection dryer at 45°C, then crushed into powder. Dried samples were extracted with 50 % aqueous ethanol (1:10 w/v) at room temperature using magnetic stirring at 600 rpm for one hour (Couto et al. 2020). Before extraction, the ethanol was removed with a rotary evaporator, and the aqueous extract was frozen and lyophilized.

4. Chemical Product Design

4.1. Needs

According to the methodology proposed by Cussler and Moggridge (2011), the product needs could be classified as *essential*, *desirable*, and *useful*. *Essential* is a mandatory characteristic; *desirable* to relate the product aspects to compete in the market, and *useful* are additional interesting ideas. Thus, for the cosmetic industry, the essential needs are a non-toxic product, safe for skin application, and easily applied. Desirable needs are, for example, white or light-colored product and considerable shelf life. While a *useful* feature, the product is inexpensive, has a good or neutral smell, and positively impacts local businesses.

After assessing the needs, the next step is brainstorming some product ideas. [Table 1](#) summarizes the author's main ideas, highlighting that there could be more ideas for each field.

Industrial Field	Ideas
Cosmetic	Vitamin C serum, facial cleanser, anti-aging, and anti-wrinkle skin cream, hydrogel
Pharmaceutic	Vitamin C tablets, skin cancer prevention body lotion, antioxidants supplements
Food	Strawberry flavor gelatin, food preserving antioxidant spray
Business to business	Vitamin C blend and antioxidant blend

Table 1: Product ideas and their respective market field

4.2. Ideas and Selection

Regarding the ideas mentioned above, only five were chosen and scored from 1 to 10 according to five specific categories, and each category has a weight factor, as shown in [Table 2](#). The first one was engineering which is related to process complexity. Quantity means the amount required of raw material to produce the product, and ease of use is associated with the manageability of the product. Finally, competitiveness represents the competition within the market among companies. The weighting factor for each category was assumed based on the criteria important to the product development progress, and the results are shown in [Table 2](#).

Criteria	Engineering	Quantity	Ease of use	Price	Competitivy	Total
Weighting Factor	0.25	0.25	0.1	0.25	0.15	1
Hydrogel	10	8	10	8	6	8.4
Skin cream anti-wrinkle and anti-aging	9	8	9	6	5	7.4
Vitamin C serum	8	8	9	6	5	7.2
Vitamin C tablets	8	2	8	6	9	6.2
Laundry detergent	8	7	9	3	3	5.9

Table 2: Specific categories and their weighting factor for product determinization

The ideas with a high score, hydrogel and skin cream anti-wrinkle and anti-aging, were selected. The combination of both ideas led to the development of hydrogel-based skin creams to deliver a refreshing and smooth product.

5. Manufacture

5.1. Results

[Table 3](#) shows each sample's moisture and extraction yields for the two fresh strawberry leaf samples. The moisture and extraction yield (dry basis) for strawberry leaves are 72.5 % and 15.4 %, respectively.

	Moisture (%)	Yield (%)
Average	73 ± 4	15 ± 3

Table 3: Moisture and yield for the two samples of strawberry leaves

5.2. Formulation

Strawberry leaves extract was considered for the formulation of the final product, i.e., there is no isolation of the compounds of the extract. Thus, the main ingredients in the formulation for the gel-cream product are agrimoniin, ascorbic acid, and ellagic acid, conferring to product excellent antioxidants properties ([Buřičová et al. 2011](#); [Michalska et al. 2017](#); [Cvetković et al. 2017](#); [Sato et al. 2019](#); [Dias et al. 2020](#)). The strawberry leaf extract concentration in the formulation was based on the quantity of ellagic acid, which was 0.5 % of the total bottle size ([Chen et al. 2011](#)). According to [Michalska et al. \(2017\)](#), in each 100 g of the dry strawberry

plant is possible to extract 121 mg of ellagic acid. Thus, to reach the percentage intended is necessary to add 5.26 g of the extract to the product, i.e., 17.5 % of the bottle's total. Moreover, for a cosmetic formulation to be successful, it needs ingredients such as neutralizer, moisturizer, antioxidant, preservative, and water. Once this study is interested in developing a gel-cream, a gelling gun is also necessary (Couto 2017).

The gel-cream formulation was developed in a collaborative partnership with Bianca Capitani Werutsky, a product developer from DNA COSMETICS, located in Rio Grande do Sul, Brazil. The authors and B. C. Werutsky discussed specific compounds to achieve high quality, long shelf-life, and fewer environmental impacts; the formulation proposed is described in Table 4.

Ingredients	%	Ingredients	%
Distilled Water	69.5	Hydroxyethylcellulose	0.6
Strawberry Leaves Extract	17.5	Phenoxyethanol	0.2
Zinc Oxide	10.0	Citric Acid	0.1
Glycerin	2.0	EDTA (Ethylenediaminetetraacetic acid)	0.1

Table 4: Gel-cream composition.

The percentages of each ingredient are related to the product size. The compounds' functionality in the formula is: hydroxyethylcellulose has gelling gum properties, citric acid adjusts the pH to equal to the skin face, EDTA acts as ions catcher, and phenoxyethanol increases the product shelf life. The strawberry leaf extract has a brown and dark green color; for this reason, it is required to add a pigment or dye for the commercial proposal. Thereby, zinc oxide was selected for the formulation as a dye. Due to the lack of information about the minimum mass of zinc oxide to be added for the formulation to turn white, this value was estimated at 10 % (Holmes et al. 2016).

5.3. Scale-up

The industrial process is divided into two parts: pre-treatment of the raw material and production; Figure 1 shows the simplified process flow diagram. This process was designed to process 150 tons of strawberry plants per year, being produced 5931 bottles per day (leading to 1.21 M of bottles per year).

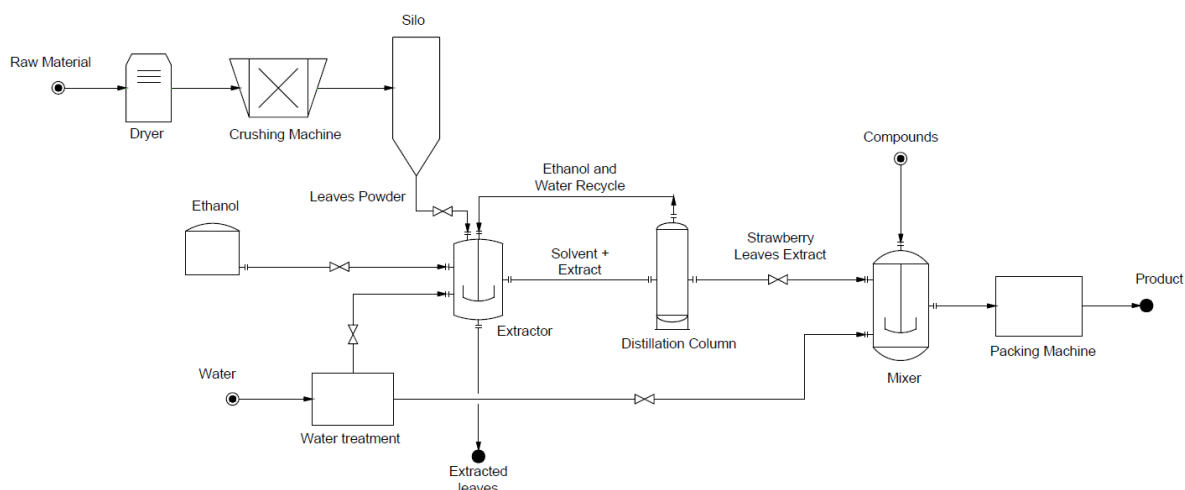


Figure 1: Simplified process flow diagram

The first step is pre-treatment, where the leaves are added to a dryer machine with approximately 600 kg per batch capacity. The dry material is transferred by trolley to the crusher machine with a crushing capacity of 1000 kg·h⁻¹. The powder is now stocked in a 3 tons steel silo by a suction motor.

The extraction takes place in the 5 tons extractor, where powder interacts with a solution containing ethanol and water, considering the same proportion as the laboratory scale. These two liquid feed streams are added by pumps and controlled by control valves. The operation extraction system features a double-linked filter separating solid from liquid. The solid part, extracted leaves, are removed to be sent posteriorly and treated at a local residual treatment facility.

After the extraction, the solvent with the extract is sent to a distillation column with a capacity of 200 L.h⁻¹. This phase is required to obtain a concentrated extract, recycle both compounds, water and ethanol, and reuse them in further extraction. It is assumed that 90% is reused.

In parallel, water from the company is treated in a 250 L.h⁻¹ purified water machine by reverse osmosis and then stocked in a tank for extraction and mixing operations.

The 100 L mixing machine is fed with three streams: two side liquid feed streams (with pumps and controls valves), one for the extract and another for purified water; an upstream inlet is a top entry where workers add the remaining solid and liquid compounds manually. All three streams may follow the ingredients feed order at room temperature:

- Firstly, 70 % of the purified water necessary in the formulation is added with zinc oxide. The mixing time is 20 minutes leading to white color and water-like consistency.
- Secondly, hydroxyethylcellulose and citric acid are added to the mixer for thirty minutes, mixing until it reaches white color and gel consistency. Note that in this step is mandatory to measure the pH of the solution with a pH meter. Finally, the extract, glycerin, EDTA, phenoxyethanol, and 30 % of purified water are fed, and the mixing time required is twenty minutes to lead to the final product aspect.
- The final step is the bottling line with 25 bottles per min capacity and proceeding to storage in boxes.

5.4. Location

Many factors are considered to selecting the company location. The most important one is for the industry to be nearest to strawberry farms and commercial centers to minimize the cost of transporting raw materials and products.

In line with [Gabinete de Planeamento e Políticas \(2007\)](#), it is noticed that most Portuguese strawberry farms are in the south and west of the country. For these reasons, the chosen region to build the company was in the southwest or south of Portugal.

Therefore, it was decided to set up the company in the Lisbon industry area since it is close not only to the strawberry farms but also to the more prominent commercial centers of the country.

To obtain an estimate of rent was searching real-states websites, namely *Idealista* and *Casa Sapo*, for prices in the Lisbon industrial area. It is possible to conclude that the average m² rent price is about 6 €·m⁻². Assuming that it will need about 1 110 m² to comport the company, the rent for the place will be approximately 6 660 €.

5.4.1. Layout

After selecting the area for the company, the following stage is the layout plan. It requires the consideration of some factors, such as the location of auxiliary rooms, storage, installations, and offices. The plant layout must be laid out to give the most economical flow of materials and personnel around the site ([Sinnott and Towler 2009](#)).

Beyond the main process units and storage (raw material, water, final product, and other compounds), we have the auxiliary rooms that include: maintenance workshops for

maintenance work on equipment; a laboratory for quality control; administration offices and administration; parking lot; refectory; locker room and control room.

6. Economic Analyses

Economic analysis is an important factor when developing a chemical product, whether the product is commodities or non-commodities. Furthermore, the analysis allows the company to recognize the project's viability and supports the investors in understanding the organization's perspectives. In this study, a cash flow economic study was performed to estimate the necessary investment and its return in a specified period. These analyses were realized based on [Cussler and Moggridge \(2011\)](#).

6.1. Cash flow

The first step in the analysis is to evaluate the research & development department. The necessary quantity of workers to develop the gel-cream was calculated based on [Peters, Timmerhaus, and West \(2002\)](#). Then, it was considered 8 hours daily shift, five days per week, and five processing steps (dryer, crusher, extraction, mixer, and storage). Also, the production is almost 200 kg per day⁻¹, the equipment has a medium size, and the process is a combination of manual and automated. It is considering that the process has an average condition to determine the acceptable number of workers. From the graph, it was possible to conclude that it is necessary for 11 workers and one supervisor daily in the company.

The annual salary is 34,912 € and 46,550 € for workers and supervisors, respectively, with an additional tax of 25 % benefits and 100 % overhead. The overhead is an indirect cost on the company's outgoing, which does not apply to the production ([The Investopedia 2021](#)). Therefore, the total amount of money invested in employees is 417,495 € per year. Equipment for the gel-cream production is another criterion within the economic analysis and is listed in [Table 5](#).

Equipment	Price (€)	Equipment	Price (€)
Dryer	20,248	Mixer	20,696
Crusher	8,924	pH meter	212
Water Distillation Machine	3,574	Packing Machine	48,197
Extractor	17,818	Silo	1,788
Distillation Column	107,904	Accessories*	97,893
Total		327,660	

*It was assumed 30 % of the total equipment for the accessories

Table 5: Price for the equipment for industrial gel-cream production
 (obtained from alibaba.com)

A shipping tax was estimated to be 100 % over the equipment price since it is shipped from outside the European Union; it also represents insurance and additional taxes. To calculate the investment required for start-up criteria, it was assumed that 20 % of total equipment costs totalizing 65,532 €.

Thereby the following criteria are production which is represented in [Table 6](#). Pricing is based on the amount needed for each ingredient in all 30 mL glass dropper bottles, and the price of each ingredient includes the shipping taxes from outside the European Union. Each dropper bottle costs 2 €, including the layout and shipping taxes leading to an annual investment of 2.42 M€. The sales and marketing department received an investment of 80 % of production costs, representing the costs of the annual ingredients adding up to the bottle purchased. The product unit cost was calculated on the relation between the ingredient's total cost and the number of dropper bottles, both parameters annual.

Materials	%	Annual quantity (kg)	Price (€/kg)	Annual price (€)
Hydroxyethyl cellulose	0.6	218	6.28	1,368
Citric Acid	0.1	36	2.34	85
Glycerin	2.0	726	3.58	2,599
EDTA	0.1	36	5.38	195
Phenoxyethanol	0.2	73	4.66	338
Zinc oxide	10.0	3,630	7.66	27,805
Ethanol		72,319	2.00	144,637
Total				177,029

Table 6: Data correlating ingredients quantity with the market price

For the revenue, it was assumed that the sale would reach 80 % of the annual production of units, and the rest would be sold at a discount or some promotional marketing strategy. The price per bottle, including IVA, was estimated at 7.40 €, in line with similar competitive products. Net sales revenue, shown in Table 7, was 7.14 M€ per year.

Annual Unit Sold	1,210,000	Product Production Cost	2.15 €
Total Product Investment	2,597,029 €	Product Selling Price	7.40 €
Sales and Marketing Department	2,077,623 €	Annual Profit	7,143,840 €

Table 7: Net annual sales and annual profit

Then, it was considered a product with a four-year lifetime. The cost of development, new equipment, start-up, and production was described previously to construct the table to calculate the cash flow. Each cost and income were considered in a specific period, as Table 8 presents. The development resumed in the third quarter of the fourth year due to the need for reformulation to achieve more sustainable and environmentally friendly results and develop new products.

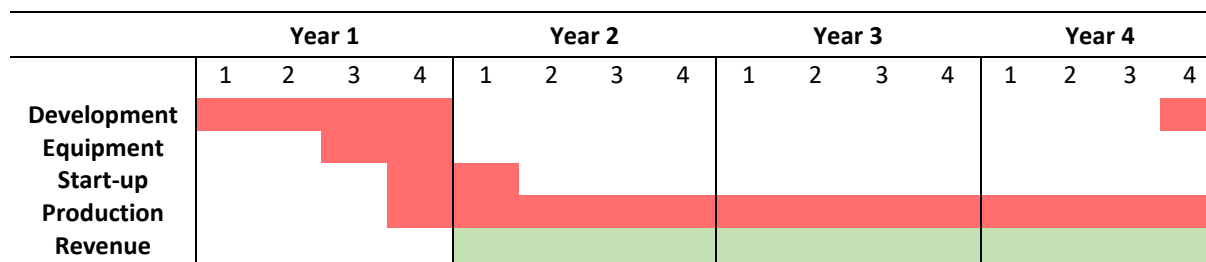


Table 8: Gantt chart showing the consideration point of costs (red) and incomes (green). Adapted from Cussler and Moggridge (2011).

The cash flow cost is calculated by the summation of the revenue and cost of each quarter, and the net cash flow is a summation of the cash flow (Cussler and Moggridge 2011). Moreover, money undergoes value variations within an estimated time in the economic market, so an adjustment was made to the values obtained, calling this concept "time value of money." These adjustments were made using Equation (1), assuming a monetization rate of 15 %.

$$\left[\begin{matrix} \text{adjusted} \\ \text{cash} \\ \text{flow} \end{matrix} \right] = \frac{\text{present value}}{\left(1 + \frac{\text{monetization rate}}{4 \text{ quartes}} \right)^{n-1}} \quad (1)$$

where n is the number of quarters involved.

Figure 2 shows the adjusted net cash flow in each quarter. Net cash flow is the product's total value, which is the sum of all the incomes and outgoings until the period studied. Return on investment is the cumulated profit from the time studied divided by the initial investment. The pay-back time is when the initial investment is recovered by net profits (Cussler and Moggridge 2011).

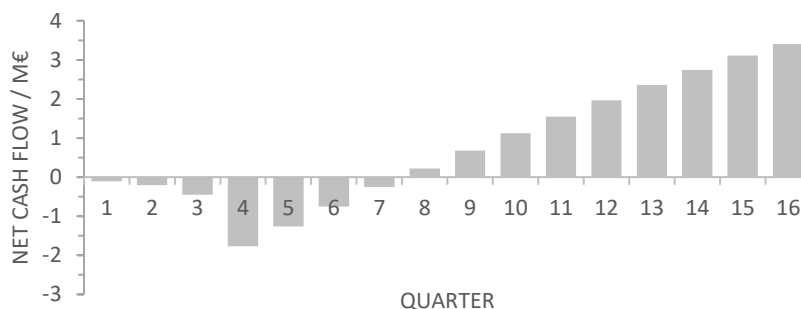


Figure 2: Adjusted net cash flow per quarter

By analyzing the economic indicators and the graph, it is possible to conclude that the company will require an initial investment of 1.77 M€. Estimate that the return on investment is 48 %, and the net present value after 16 quarters is 3.40 M€. Further, the pay-back time is on eight quarters.

7. Conclusion and Future Perspectives

The strawberry leaves have shown many interesting compounds for cosmetic applications. This study sought to develop a product that meets the market needs and reuses the strawberry plant residues. Therefore, after deep research about the active compounds and their properties, brainstorming ideas, and selecting one, it was concluded that the most interesting idea was to perform a skin cream with gel consistency for anti-aging and anti-wrinkle characteristics.

Afterward, the manufacturing complexity was provided by an industrial analysis allowing determining the process from the receipt of the raw material, treatment, and production of the skin cream. Also, this analysis has considered benefits in the social and economic field, such as jobs and financial investment in Portugal.

Finally, an economic perspective was developed to inform the necessary quantity of initial investment to analyze the project feasibility; however, some considerations were assumed, which led to an approximate final value. Despite the small variances, the value was acceptable and showed that the project is feasible for development with social and economic profits.

Despite the project being considered achievable, a more specific study with better parameters needs to be done. Thus, to achieve higher quality and result standards in this study is recommended to invest in a few segments such as laboratory and pilot plant, industrial and economic. The laboratory perspective is related to analyzing the concentration of each compound present in the Portuguese strawberry leaves extract and testing of formulation in humans. Also, a pilot plant refers to testing all the parameters and equipment to move to an industrial scenario. On an industrial scale seeking higher daily production and quality, a study about the viability of replacing the batch process for continuous processes focusing on optimization should be considered. A business plan is required in the economic analysis once it is a complete assessment. After improving these parameters, the study will provide a more comprehensive overview of cosmetic development.

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