Tutora
Dra. Alicia Maestro Garriga

UNIVERSITAT DE BARCELONA

Grau en Enginyeria Química

Treball Final de Grau

Development of a range of hair growth promoting products and preliminary design of their manufacturing process.

Desarrollo de una gama de productos estimuladores del crecimiento del cabello y su diseño preliminar del proceso de fabricación.

Valeria Aimmé Pinto Durazno

June 2021

Me enseñaron que el camino del progreso no era rápido ni fácil.

Marie Curie

Le dedico mi esfuerzo de años a mi madre Tania, ella ha sido mi impulso en mis estudios y carrera. Así como un día su trabajo final de grado fue dedicado hacia su amada hija, hoy yo la honro dedicándole el mío. Le agradezco su infinito apoyo en mi camino, y su eterno amor.

CONTENTS

SUMMARY

Current market trends show the preference to use cosmetic products of natural origin. It is known by consumers that the use of the medicinal properties of plants brings in some cases positive results in the treatment of diseases or for specific purposes. Specifically, this project has focused on hair loss or its poor growth. Therefore, it has been decided to develop a range of hair growth stimulating products formulated mainly by natural ingredients that have been traditionally used for this purpose and that have been shown to be effective in scientific evidence.

To carry out a product range development process, firstly a market survey was carried out to determine the format of products to be developed; then, with the information obtained, it was decided to develop a shampoo and a hair serum. Prior to the formulation process of the two products, the functional parameters that these products had to meet and what quality factors demonstrated the effectiveness of these parameters were determined. The shampoo to be developed is a product that washes the scalp and contains ingredients that stimulate hair growth and can be removed after a few minutes with water, while the serum is a product that hydrates the scalp and stimulates hair growth, without leaving an oily sensation and without the need to be rinsed.

A proposal was also made for the design of the containers, which have a capacity of 0.7 L for shampoo and 0.1L for serum in HDP (High-Density Polyethylene) plastic bottles. This process was the conceptualization of the product range.

When the products were conceptualized, a literature search was carried out on ingredients that could stimulate hair growth and that were of natural origin. For the shampoo, the Allium Cepa Bulb Extract and caffeine were decided to be used as active ingredients, and for the serum development Rosmarinus officinalis oil and sulphated castor oil were chosen in this project. The additives and excipients required for each product were also specified. Also, the concentrations of each basic ingredient in magisterial formulations, patents, or articles on cosmetic formulas were determined. The two products have been formulated to target both a dry and oily scalp population

since on one way the shampoo was formulated with ingredients that gently cleanse the hair to avoid irritation, and on the other way, the serum was an oil emulsion in water (O/W) that quickly penetrates the scalp avoiding an oily sensation.

Finally, an industrial manufacturing proposal for the two products has been developed to annually produce 210 tons of shampoo and 8 tons of hair serum. The production has been carried out in batches of 500 kg, during 3 campaigns for the manufacture of shampoo and 1 campaign for the serum. The equipment will be integrated into a plant that makes other types of similar cosmetic and personal hygiene products, so the rest of the year can be spent on other manufacturing processes. The manufacturing process has been reflected in a diagram that specifies the order of addition of the ingredients, their volume or weight and the main equipment to be used. Regarding the manufacture of shampoo, a premixing of the detergent phase is proposed, composed of the surfactants and separately, another aqueous phase that contains the active principles and additives, later they would be mixed between them. On the other hand, for the manufacture of the serum a premixing of the oily phase is proposed that will contain the oils as active principles and separately a premixing of the aqueous phase with the additives and excipients, likewise, later they would be mixed between them. It was decided to use the same equipment for the manufacture of the two products, using the supplier brands INOXPA ®, SILVERSON® and EQUITEK.

Keywords: Shampoo, serum, shampoo manufacturing, serum manufacturing, hair growth, hair stimulation.

RESUMEN

Las tendencias actuales de mercado muestran la preferencia de utilizar productos cosméticos de origen natural. Es sabido por los consumidores que el uso de las propiedades medicinales de las plantas aporta en algunos casos resultados positivos en el tratamiento de enfermedades o para propósitos específicos. En concreto, este proyecto se ha centrado en la caída del cabello, o su poco crecimiento. Por lo que se ha decidido desarrollar una gama de productos estimuladores del crecimiento del cabello formulados principalmente por ingredientes naturales que hayan sido utilizados tradicionalmente para este propósito y que hayan demostrado efectividad en evidencia científica.

Para llevar a cabo este proceso de desarrollo de la gama de productos, primero se realizó una encuesta de mercado para poder determinar el formato de productos a desarrollar, a continuación, con la información obtenida se decidió desarrollar un champú y un sérum capilar. Previo al proceso de formulación de los dos productos, se determinaron los parámetros funcionales que estos productos debían cumplir y qué factores de calidad demostrarían la eficacia de estos parámetros. Por una parte, el champú es un producto que lava el cuero cabelludo y contiene ingredientes que estimulen el crecimiento del cabello pudiéndose retirar a los pocos minutos con agua, mientras que el sérum es un producto que hidrata el cuero cabelludo y estimula el crecimiento del cabello, sin dejar una sensación oleosa y sin necesidad de enjuagar.

También se realizó una propuesta del diseño de los envases, los cuales son de capacidad de 0.7 L para el champú y 0.1L para el sérum en botellas de plástico de HDP (High-Density Polyethylene). Este proceso fue la conceptualización de la gama de productos.

Cuando los productos fueron conceptualizados, se realizó una búsqueda bibliográfica sobre aquellos ingredientes que podrían estimular el crecimiento del cabello y que fueran de origen natural. Para el champú se decidieron utilizar como principios activos la Allium Cepa Bulb Extract y cafeína, y para el sérum el aceite de Rosmarinus officinalis y el aceite de ricino sulfatado. También se especificaron los aditivos y los excipientes necesarios para cada

producto. Así mismo, se determinaron las concentraciones de cada ingrediente basándose en formulaciones magistrales, patentes, o artículos sobre fórmulas cosméticas. Los dos productos se han formulado para dirigirse a población tanto de cuero cabelludo graso como seco ya que por un lado el champú se formuló con ingredientes que limpien suavemente el cabello para evitar la irritación, y, por otra parte, el sérum fue una emulsión de aceite en agua (O/W) que penetra rápidamente en el cuero cabelludo evitando una sensación oleosa.

Finalmente, se ha desarrollado una propuesta de fabricación industrial de los dos productos para producir anualmente 210 t de champú y 8 t de sérum capilar. La producción se ha realizado en lotes de 500 kg, durante 3 campañas para la fabricación del champú y 1 campaña para el sérum. Los equipos se integrarán en una planta que fabriquen otros tipos de productos cosméticos y de higiene personal similares, de manera que el resto del año puede dedicarse a otros procesos de fabricación. El proceso de fabricación se ha reflejado en un diagrama en el que se especifica el orden de adición de los ingredientes, su volumen o peso y los principales equipos a utilizar. Respecto a la fabricación de champú se propone un premezclado de la fase detergente, compuesta por los tensioactivos y por separado, otra fase acuosa que contenga los principios activos y aditivos, posteriormente se mezclarían entre ellas. Por otra parte, para la fabricación del sérum se propone un premezclado de la fase oleosa que contendrá los aceites como principios activos y por separado un premezclado de la fase acuosa con los aditivos y excipientes, así mismo posteriormente se mezclarían entre ellas. Se decidió utilizar los mismos equipos para la fabricación de los dos productos, utilizando las marcas de proveedores INOXPA ®, SILVERSON® y EQUITEK.

Palabras clave: Champú, sérum, fabricación de champú, fabricación de sérum, crecimiento del cabello, estimulación del cabello.

1. INTRODUCTION

Hair loss is a process that occurs gradually and can appear in different ways depending on the cause and external factors. In a natural way, about fifty and one hundred hairs would be lost per day. But when the amount of hair lost exceeds considerably this amount, the person is suffering alopecia, which means unnatural hair loss, and it occurs when the new hair does not replace the one that has fallen out. (Kahn & Guerrero, 2011)

The causes can be several, as well as the form of manifestation. In general, hair loss can be related to the following factors:

- Genetic factor: It is the most common cause and is related to aging.
- Biological and hormonal factors: There are situations that can cause temporary or permanent hair loss such as pregnancy, menopause, stress, poor eating habits, illnesses or medications side effects.
- Hairstyles and treatments: The aggressive chemicals products used frequently or excessively in hair damage the hair follicle, making it weaker and consequently cause hair loss. In the same way, some hairstyles carried out repetitively can cause hair loss by traction.

1.1. THE SCALP

The human scalp is differentiated into five layers that surround the skull, from the outside to the inside it is found: the skin, the dense connective tissue, the aponeurosis, the loose connective tissue and the pericranium.

Inside the skin layer is where hair growth occurs in the hair bulbs. Hair is made up of a keratin structure that differs between the stem and the root. According to Curasco et al. (2020), the anatomical structure of hair is composed by:

• The erector pili muscle: It is a thin muscle that joins the base of the hair follicle with the epidermis and maintains the erection of the hair.

• Sebaceous gland: lubricates the hair follicle with sebum.

- Hair follicle: It is the structure in which hair is generated. Inside is the sebaceous gland and around is the hair bulb. Likewise, it houses a large network of blood vessels that provide nutrients to stem cells.
- Hair bulb: It is made up of several precursor cell layers of hair, therefore, it is where the hair root is generated.
- The dermal papilla: It is a structure that connects the dermis with the epidermis and where there is a great exchange of nutrients between the layers.

The hair growth cycle

A normal hair growth cycle is composed of three stages and affects the hair follicles (Restrepo, R. 2019):

- Growth phase (anagen phase): In this stage, the hair follicles are more active, it is when the hair is generated. It can last from two to seven years.

It is considered that approximately 80-100% of hair follicles are in the anagen phase.

- Transition phase (catagen phase): This is a shorter phase, which can last less than four weeks. In this stage, the mitosis of the cells progressively stops and therefore the hair stops growing. The hair follicle begins a state of involution, in which the hair is susceptible to falling, since the hair root is separated from the papilla. Moving the hair to the outside of the scalp.
- Telogen phase: It is a stage that can last a little more than three months. It is the final phase of involution where hair loss occurs. Approximately they can represent 10% of the hair. After this stage the follicles can enter a dormant state that can last from 2 to 5 weeks. Finally, after this stage, the hair growth cycle begins again.

1.2. NATURAL INGREDIENTS AS TREATMENT

Prevention is a great help in types of hair loss that are not related to hereditary factors. For this you can resort to balanced diets as well as food supplements to regulate the diet, use a quality shampoo according to the hair type, use products designed to strengthen the hair as well as go to specialists in case of hair loss. (Svenson Official Website).

The plants properties have been used for about 10,000 years, where there is evidence that it was used in ancient China, likewise, in the western world evidence has been found since 1,700 BC about information of the plants healing properties and their use (Jiménez Díaz, 2007).

Natural ingredients such as onion, rosemary, aloe vera, green tea, garlic have been used to treat hair-related problems since ancient times; oils such as almond, rosemary, olive, castor, argan, sesame, jojoba, avocado, among many others. The cosmetic and pharmaceutical industries have resorted to these ingredients for their formulations as they have proven to be highly effective for stimulating hair growth and related problems (González F. & Bravo Díaz L, 2017).

In the same way, there is currently a great demand for natural cosmetic products with selective plant extracts. That is why the chemical and pharmaceutical industries are increasingly linking their knowledge to bring products to the market that are effective, non-toxic and with natural ingredients.

2. OBJECTIVES

As mentioned above, the current market trend is to use effective natural products to treat certain skin conditions including hair loss. Specifically, this work will focus on natural ingredients that have been used in a traditional way with the purpose of preventing hair loss, as well as stimulating their growth, and bringing them to industrialized production of a formulated product containing them.

The main objective of this project is to develop a range of hair growth stimulating products, mainly based on natural ingredients, likewise, a preliminary design of the production process of these products will be made.

In order to carry out the project, the following sub-objectives have been proposed:

- Market analysis through surveys of a sample of the population to analyze the commercial characteristics of the range of products to be developed.
- Conceptualization of the products to be developed.
- Definition of the quality factors and indices for the formulated products.
- Selection of active ingredients, excipients and additives from the product range based on market analysis that allow obtaining the specified characteristics.
- Formulation of the product range.
- Preliminary design of the production process and selection of the main necessary equipment to obtain the desired products.

3. PRODUCT CONCEPTUALIZATION

According to L. Zhang et al. (2017) when conceiving a new product, it is necessary to follow a series of marked steps and in a specific order to achieve success. These steps begin with a schedule of the basic tasks to be carried out to achieve the final objective, which have been exposed in the objectives section. After that, it is necessary to conceptualize the product to be developed. It starts with knowing the needs of the market, the size of the market and the competition, which will be of vital importance in determining the needs of the products to be developed.

The market study in this project has been carried out by asking a population group about their preferences in hair care products. From this study, current trends are analysed and the needs to be developed in the product range are known.

The next step is the product design, which is the most important according to L. Zhang et al. (2017). Chemicals can be classified according to molecular products, formulated products, or functional products. In the case of hair care products, these are formulated products, which are obtained by mixing selected components together to get the desired product attributes (Gani & Ng, 2015).

For the development of the product range, it is necessary to define product attributes, in which the functionalities of the products will be defined, based on these the ingredients are selected (depending on whether they are new ingredients that need development through molecular design, or whether they are typical ingredients that are already in databases or there are already methodological rules to obtain them. Once the products parameters have been defined and the formulation obtained, it will be possible to proceed with the design of the container adapted to the needs of each product to be developed and finally it will be necessary to verify the physicochemical properties of these products (L. Zhang et al., 2017).

3.1. MARKET TRENDS

To determine physical and quality parameters for the range of products, it has been decided to conduct a survey. In this survey, people answered questions related to their hair care routine and personal preferences. The sample consisted of 180 people with different ages and from different populations in Catalonia. In Appendix A it is possible to observe the responses, and as well more detailed analysis of the same.

In the survey, the study group was separated into those who use specific products for some need of their hair and those who do not. This was done to analyze the differences between the study population, as well as to be able to deepen on the opinions of people who are looking for products that satisfy a specific need for their hair.

Most people in the survey who do use specific products stated that they priorize products that stimulate hair growth and also prefer that the ingredients are of natural origin.

The most popular hair type among the entire study population was fine hair, and there was no population difference in terms of having a dry or oily scalp.

Priorities were also analyzed concerning characteristics in the daily use of shampoo, in which a fresh scent, a medium viscosity, a pearly appearance, and a white color are mostly preferred. There has not been a difference regarding the presence of sulphates and silicones in the use of shampoo. However, lathering the shampoo, in general, is a priority for respondents.

People in the sample who consume specific products, and those who did so with the aim of stimulating hair growth and strengthening it, clarified that the most common drawbacks of these products are that they dry out their scalp, do not contain mostly natural ingredients or generate other scalp problems. In addition, most of them highlighted that the product did not accomplish the objective that was specified.

Likewise, regarding the range of products that were used in this sample population, Table 1 shows the types of formats most used by the different groups of the study population.

It is also possible to say that just under half of the study population has used homemade products with the aim of stimulating hair growth, and most of them would be willing to use a product formulated mainly with ingredients of natural origin with the objective to stimulate hair growth and strengthen it.

Table 1. Comparison of the most commonly used hair care product format types.

People who use specific hair care products		**People who use specific products to stimulate hair growth and strengthen it**		**People who use generic hair care products**	
Product	**Population**	**Product**	**Population**	**Product**	**Population**
Shampoo	120	Shampoo	73	Shampoo	54
Conditioner hair mask	89	Conditioner hair mask	34	Gel	35
Serum	31	Vitamins	34	Conditioner hair mask	32
Oil	23	Hair lotion	24	Serum	13

Own elaboration

A brief analysis was also made of the most used brands of shampoo, the population highlighted: vegan or natural origin brands, Pantene, L'Oreal and H&S.

Regarding vegan or natural origin brands, the tendency to acquire these products is very high due to the little information that exists about the treatment given to animals in laboratories, consequently people prefer to purchase products designated as "Cruelty Free" to guarantee that they have not been tested on animals; as well as because that minority that feels really informed decide to buy these products consciously (Taylor et al., 2018).

On the other hand, Pantene belongs to the Procter & Gamble International company, which describes on its own website that the effectiveness of its flagship product, Repair & Care Shampoo, is because it contains vitamin Pro-V5. This vitamin has been recognized by The Swiss Vitamin Institute which is an independent laboratory recognized internationally as a vitamin reference laboratory (Pantene Official Website).

Regarding L'Oreal, according to the Carrefour Spain supermarket sales platform, which is one of the largest suppliers of shampoo brands, it is found that the best-selling shampoo of this brand is the Protective Shampoo for dyed hair Color Vive. On the official website of L'Oréal it is described

as a specific product for the care of the color treatment, therefore, of a gentle wash, and with UV filter.

Regarding H&S, which also belongs to Procter & Gamble International, according to Telva magazine, the best-selling product of this brand is Citrus Fresh anti-dandruff shampoo. Its purpose is to combat the signs of flaking of the scalp, itching, dryness, and oiliness. In addition, the label of this product says that it does not contain parabens, phosphates or paraffins.

Appendix B contains the ingredients of these 3 products, which have been consulted as a reference for the following sections.

3.2. PRODUCT FUNCTIONALITY

After having analyzed the market needs, as well as the preferences of the study population, it was decided to develop a shampoo and a hair serum in the range of products. The shampoo is selected because it is the most widely used product for hair care in general, and the choice of the serum is because it must remain on the scalp for a reasonable time that will allow the absorption of the ingredients into the scalp, as well as being one of the most popular elections among the studied population.

Likewise, Appendix C it is possible to see the main differences between the different formats of hair care products.

3.2.1. Shampoo functionality

The main functionality of the shampoo (emulsion substance) is to wash the scalp of the dirt produced by excess oils originated in the sebaceous glands, as well as dirt accumulated by other factors such as peeling of the skin or polluting particles.

Usually, the most common shampoos work in the same way: when the shampoo is applied to damp hair, the anionic surfactants reduce the surface tension of the scalp and favor the separation of sebum from the hair allowing the oily matter to be emulsified with the shampoo and the water, and then to be finally washed away with water.

The cleansing function of the shampoo may be more remarkable depending on whether the shampoo is specifically for dry, oily, or mixed hair. As these personal hair care products have

been developed, it has been common to find shampoos that contain additional ingredients that also allow specific treatment for hair (Herbal Official Website).

In this study, the second main objective of the shampoo is to stimulate hair growth by oxygenating the hair follicles to allow a correct flow of blood and nutrients to them. It is desired to achieve this purpose by formulating the product mostly with natural ingredients.

The ingredients used for this purpose will be checked against their traditional use for stimulating hair growth, as well as scientific evidence supporting that these ingredients are compatible with the objective.

Likewise, the shampoo should generate enough lather according to the market analysis. The volume of the foam (generally given by anionic surfactants) must be high since this property is quite appreciable by consumers, however, it should be emphasized that the foam generated by the shampoo is not directly related to its cleaning power. Along with this characteristic, it could also be said that the bubble size of the foam is a factor to consider, since the smaller the bubble area, the greater the active surface and therefore the greater the cleaning effectiveness of the shampoo.

The consistency and stability of the foam over time is also an important factor since, the higher these are, it will give an appearance of firmness in the application and quality that result attractive among consumers, according to Lacueva & Marimon (2019). However, the fact that the foam bubble is small does not imply that the foam consistency is high. Therefore, ingredients will be sought that allow a high consistency of foam with small bubbles.

The viscosity of the shampoo should be medium, which implies the addition of thickeners or salt to its formulation to achieve the appropriate quality. However, the addition of salt in the formulation has been a downward trend in recent years by cosmetic companies since it is irritating to the eyes, as well as not leaving a feeling of softness after application to the hair (Díaz & Villafuerte, 2012).

Due to the proximity of the product with the eyes and mucous membranes, it should not contain particularly irritating or toxic agents. Likewise, it must be fully compatible with all skin types, specifically sensitive skin.

It is of special mention regarding the formulation of the shampoo that given the strict legislation that applies to cosmetic products, biodegradable ingredients will be chosen, both in aerobic and anaerobic conditions and that are not toxic to aquatic organisms (Lacueva & Marimon, 2019).

The intended use of the product will be the type of hair specially fine and of mixed scalp. The color of the shampoo will be white and the appearance pearlescent, according to the survey carried out. Regarding the smell, it will have fresh fragrances.

Finally, the shampoo must be easy to wash with water, to facilitate its use among consumers.

3.2.2. Hair serum functionality

The serum (emulsion) is a cosmetic treatment with the main objective of nourishing the skin of the scalp and has a high concentration of active ingredients, and a liquid texture, low viscosity, which facilitates rapid and deep absorption on the skin and hair.

As the serum is mainly nutritious, it should contain a smaller number of excipients such as thickeners or emulsifiers, and likewise, the particles should be as small as possible to allow absorption to the deeper layers of the skin on the scalp (Nivea Official Website).

To carry out its purpose, the serum will contain active ingredients that stimulate oxygenation of the scalp, that nourish the roots of the hair with vitamins, and that provide strength and density to the hair.

A serum that acts on the scalp should be formulated so that it can be applied after bathing, when the hair is still damp, in this way the pores of the scalp are open, and the product is more effectively absorbed.

The serum will be applied with a dispenser on the consumer´s hands, so the viscosity should be low to facilitate the application on the scalp.

Regarding the smell, it will be ensured that the aroma of the serum comes from the active ingredients themselves, always guaranteeing that it is fresh. The color will not be a factor to be modified by additives either.

The selected ingredients should not leave oily residue or particles on the scalp after absorption.

Following the same trend of shampoo, it will be chosen to elect biodegradable ingredients, likewise, both in aerobic and anaerobic conditions and that is not toxic to aquatic organisms (Lacueva & Marimon, 2019).

As the shampoo, the serum will be also intended for people with fine hair and mixed scalp.

3.3. **PRODUCT PACKAGING**

Finally, according to L. Zhang et al. (2017) the final step in the development of a product is the design of the container. Therefore, an analysis of the packaging for the shampoo and serum will be made that will be developed in the range of products.

The packaging of a product is mainly intended to protect and transport the content from the point of manufacture to the point of distribution and use. However, packaging has acquired greater meaning in society, since it no longer only serves for this, but also to attract customers attention, promote the product and differentiate itself from other brands through the logo, color, or forms of the container.

Firstly, the material plays a fundamental factor in the design, since if it is of good quality it will allow rigidity and comfort when the client holds it. Likewise, it must be compatible with the formulation in order to maintain the integrity and formulation of the product.

In this project, a plastic material has been chosen, being easy to produce and providing sufficient rigidity and not being fragile as a glass material could be.

According to an article on the official website of the European Union (article of the year 2019), by 2030 the objective of plastic packaging is to be fully recyclable. Likewise, for the company, the use of recycled plastics provides an economic benefit due to the circular economy approach, being also beneficial for the environment and society.

In Appendix D it is possible to find a list of the most used plastics, which are currently recyclable and their characteristics (National Geographic Offical Website). According to the information obtained, HDP and PET are the plastics commonly used in shampoo packaging.

To contain the product, HDP (High-Density Polyethylene) has been chosen, since it represents greater rigidity, is cheap, and is the most used in personal care products since it is resistant to chemical products, therefore it will guarantee the preservation of the product formulation. (PlastiSax Official Website).

According to Berrada et al. (2015) there is a relationship between the type of cap in personal care products with the amount of product being used. Being the bottle products with pump dispensers the ones that consume the least product, therefore consumers can regulate the amount they want to use. For this reason, this type of pump dispenser has been chosen in the product range (see Figure 1).

Moreover, as the application of the serum will be focused on the scalp, a cannula will be added to it that allows the product to be concentrated in specific areas. In this way, the product will not spread throughout the hair and a better treatment and dosage will be allowed. Likewise, the serum will have a pump dispenser like the shampoo, and an additional removable cap that allows to protect the product from accidental spills or entry of external agents.

Also, as color also plays a role in consumer choice, thus, according to the Barcelona School of Design, the color white represents power and elegance and it is used when is wanted to represent the product as stylish. For this reason, this will be the color used to contain the product, moreover, it will have a gold dispenser (cannula too) and the letter of the label turquoise tone.

Finally, regarding the volume of the containers, the shampoo has been chosen to contain 700 mL and the serum 100 mL.

Figure 1. Shampoo packaging design's example.
(Image taken from Pinterest)

3.4. **PRODUCT CONCEPTUALIZATION SUMMARY**

The range of products to be developed will be focused on stimulating hair growth, with a formulation of natural ingredients.

The shampoo will be developed with the main functionality of washing the scalp with the specifications mentioned before and in accordance with the preferences obtained when conducting the survey of the study population sample.

On the other hand, when developing a hair serum, the main functionality will be to nourish the skin of the scalp through an easily absorbed formulation.

Table 2 lists the functional characteristics of each product, as well as characteristic parameters of each one, including its packaging.

Table 2. Summary of the functional characteristics of the product range.

Parameter	Shampoo	Capillary Serum
Function	-Wash hair and the scalp -Stimulate hair growth	-Nourishing the scalp's skin -Stimulate hair growth
Hair type	-Fine hair -Dry and oily scalp	-Fine hair -Dry and oily scalp
Characteristics	-Long lasting foam - Medium viscosity -Biodegradable ingredients -White color -Nacre appearance -Fresh scent	- Low viscosity -Biodegradable ingredients -Non-greasy/non-oily finish -No color additives -No additives
Packaging design	- HDP (High Density Polyethylene) and recyclable bottle -Bottle with pump tap -Bottle in white color, gold color for pump lid.	

	-Extra cap for serum's packaging bottle -Cannula for serum's packaging bottle	
Printed design etiquette	-Turquoise color for print letters -Printed: product's name, brand's name, instructions for use, composition, type of hair recommended, manufacturing and expiration date	
Volume (mL)	700	100

Own elaboration

4. ESTABLISHMENT OF QUALITY FACTORS

Once the functionalities and design of the products to be developed have been set, it is necessary to determine the quality factors that will contribute to establishing the processes required to obtain them (L. Zhang et al. 2017).

The quality of the products will be determined by how and to what extent they fulfill the main objective, as well as those additional factors that are different and decisive in the market competition. For this reason, two sections have been divided in this chapter. The first will analyze the quality factors related to the functionality of the products, and the second part will analyze the quality factors related to sensory parameters. The respective tests have been proposed that will measure the quality index of the factor studied.

4.1. FUNCTIONAL QUALITY FACTORS

In this section, the aspects related to the main functionalities of the range of products to be developed will be discussed.

Firstly, the main functionality of shampoo, which is to wash hair will be discussed, and since the higher lather is preferred by consumers, the aspects that provide a greater and more stable lather will be described.

Then, in respect the serum, it must comply with the nutrition of hair follicles, therefore it is necessary for it to penetrate the skin layer. Related to this aspect, the physicochemical parameters that allow the penetration of the product on the scalp will be determined.

Finally, the safety factors of the range of products that imply that they are compatible with the skin will be analyzed, especially the serum, since it will remain on the scalp for a long time, and that it will be preserved over time.

FOAMING AND CLEANSER SHAMPOO EVALUATION

Surfactants are the main components in the cleansing function of the scalp, and its foaming properties. The choice of this implies not only the effectiveness of the product as a cleaning agent, but also as a market need with respect to the volume of foam produced by the shampoo. Usually, the volume of surfactants in a shampoo is 10-25% of the total ingredients (Klein & Palefsky, 2007).

According to the author Klein (2004), the best method to evaluate the foaming capacity of the shampoo is to carry out a blender foam volume and drainage test.

Blender foam and drainage test

This evaluation was determined by Henkel Corporation. To carry it out, it is necessary to dilute the shampoo mixture to 10% by volume, and from this extract 4 g and add it in a blender. Next, 146 g of water are added at a temperature of 29 ° C. The mixture is stirred for 10 seconds at medium speed. The foam is then poured into a 1000 mL graduated cylinder. The initial volume is determined and after 3,5 minutes the position of the foam-water interface is measured. This test determines the foam generating capacity and the foam separating capacity from the water. In the same way, this test can also be carried out by adding castor oil, which additionally determines the cleansing power of the shampoo on dirty hair.

The foam of the shampoo can be stabilized if the liquid phase is thickened, therefore, it is important to use rheological modifiers that help in this purpose.

The effectiveness of the cleansing power of shampoo is reflected by lowering the surface tension of water, according to Al Badi & Khan, a quality shampoo would reduce the surface tension of pure water from 0,07228 N/m to about 0,0004 N/m. In this project, it would be recommended to use tensiometer monitors that make this evaluation possible.

Rheological characterization

The quality of the shampoo will also be determined by how it behaves in the different aspects of the use of shampoo: when it passes through the dispenser, when it is in the hands of the consumer and its subsequent application on hair. This aspect will be marked mainly by surfactants and the way in which they mix and form three-dimensional structures.

There is a key parameter called the key packaging parameter Pc, the less than 0,5 is considered that the detergent power of the shampoo is better, since spherical or cylindrical structures would be formed. This parameter represents a simplification when choosing the most suitable surfactant.

Commonly shampoos follow a non-Newtonian flow model, having high viscosity at low shear rates, which is especially important since it is a quality parameter of the product. With this, through flow curves it is possible to characterize the viscosity of the shampoo and make new formulations based on the data obtained.

It is usual in the cosmetic industry that these desirable non-Newtonian fluid characteristics are conferred by adding salt to the shampoo mixture, which increases its viscosity in sulphate-based formulations. (Cornwell, 2018).

ABSORPTION OF THE SERUM ON THE SCALP

According to Costa et al. (2021) the efficacy of this product is based on penetrating the skin layer and conducting the product through the hair follicle. Waiting for this process only with the active ingredients would not lead to success, so it is necessary to use skin permeation promoters. In recent years, topical drug applications have led to a new transport pathway using nanoparticles. These have the advantages of having greater solubility on the skin, allowing high concentrations of the product letting it to focus on specific parts of the body, high stability and a controlled release of the product.

However, this route implies a higher cost in the production and according to the purpose of the study, the classic formulations of scalp serum continue to have great advantages in terms of stimulating hair growth. Among them, it is pointed out that they are simpler formulations to adjust with respect to concentrations, they can be produced in industrial quantities much faster and with less costs than, for example, nanoparticles.

The skin is more permeable to hydrophobic molecules than to hydrophilic ones, this is a factor to consider in the formulation of the product and likewise, studies show that a good enhancer of skin penetration are those with a hydroxyl group.

It should be considered that the carrier used should not irritate the skin, it should hydrate it and allow the absorption of the active ingredients to the hair follicles.

The permeability of the product can be quantified and characterized with tests on skin tissues from a donor or cell cultive, which will be analyzed in fluorescence microscopy using dye testers. This test makes it possible to quantify the amount of product that passes through the skin, that adheres to the follicle and that which can penetrate the inner layers. From these tests it is possible to modify the product formulation to optimize absorption on the skin.

Finally, it should be appreciated in the formulation that dermal permeation is influenced by thermodynamic activity and physicochemical compatibility between the active principle and the promoter (enhancing agent), likewise skin absorption is characterized by Fick's first law of

diffusion where is quantified the amount of solute that could cross the membrane of the skin layer (Rodriguez, 1998).

PRODUCTS SAFETY TESTING

Quality control versus safety that compromises the products is extremely necessary and important, not only from the consumer's point of view as a guarantee of the product they use, but also for the brand of the product. For a company, the confirmation that its products are successfully subjected to microbiological tests is an added value (Tecnosoluciones, 2020).

Currently, there is no official method for microbiological control and therefore compliance with ISO standards implies a standardization of control to comply with EC regulation No. 1223/2009 of the European Parliament. Specifically, the ISO 17516: 2014 standard is the one that defines the microbiological limits.

Among the factors that stand out for these tests are product composition, pH, alcohol content in the formulation, osmotic pressure, surface tension, oxygen present, packaging and manufacturing conditions.

Considering the existing regulation in Table 3, the microorganisms of special mention by the regulations and their quantities are exposed in the case of products not related to children, because of the application in the ocular or mucosal areas (Condalab Workshop).

Preservatives are responsible for preventing the proliferation of microorganisms in products, but over the years it has been seen that a small part of the population is sensitized to these so it is not possible to use them. This has made cosmetics with parabens for example to be frowned upon in popular culture, even though these are less sensitizing than other preservatives more commonly used in cosmetic products (Pastor et al., 2017).

On the other hand, according to Grimalt (2017) not only the presence of microorganisms is key to the safety of the products, but also that they are suitable for direct contact with skin. To evaluate how it behaves in it, there are different methodologies that will be cited below.

Pre-launch test

In a group of volunteers, the product is applied to a part of the scalp and that area is protected from external contamination or oxygen. For 48 hours it can remain in the applied area, and during

this time the product must be reapplied. Finally, the area is analyzed to check if the product has irritated the skin or signs of sensitivity have appeared.

Percutaneous absorption

This aims to quantify the amount of product that is absorbed on the skin, as an example, in the previous subchapter the technique was mentioned by means of fluorescent microscopy.

Post marketing evaluation

For a consumer it is necessary to have the guarantee that the product will not cause serious problems in its application on the skin, and in case this happens it is necessary to provide on the label the address or telephone number of the manufacturing company to which can be addressed in case of adverse causes on the skin, or any other incident related to the product.

Table 3. Specifications in cosmetic products according to the ISO rule section 17516: 2014

Type of microorganism	Limit
Total aerobic microorganisms mesophiles (bacteria, molds and yeasts)	≤ 1 x 10^3 CFU(1) per gram
Escherichia coli	Absence in 1 g or 1 ml
Pseudomonas aeruginosa	Absence in 1 g or 1 ml
Staphylococcus aureus	Absence in 1 g or 1 ml
Candida albicans	Absence in 1 g or 1 ml

(1) CFU: A colony-forming unit is a unit used in microbiology to estimate the number of viable bacteria or fungal cells in a sample.

Own elaboration

4.2. **SENSORIAL QUALITY FACTORS**

In this section, the commonly analyzed factors will be described with reference to sensory analysis. This allows to analyze and interpret the opinions of consumers regarding a product so that the quality parameters can be standardized. According to C.K.H. Lee (2014), the attributes usually analyzed in the cosmetic industry, and used in personal care products are differentiated

according to the sense, thus, for example, related to texture, the following parameters can be analyzed: oiliness, smoothness, softness, stickiness, and viscosity. For the other human senses fragrance, color and appearance will be analyzed.

The sensory analysis tests will be carried out through a subjective hedonic analysis, in which the surveyed (consumer) will present their perception regarding the indicated parameter (Huber, 2017) using a scale from one to four depending on whether they agree less or more as follows:

1-Totally disagree

2-Partially agree

3-Agree

4-Totally agree

TEXTURE ANALYSIS

The tactile-sensory properties of a cosmetic, is an important topic in the concept of the products range development.

Firstly, the shampoo texture will be highly viscous, so that as it is not fluid in texture, it influences the perception of the consumer as more concentrated and easier to apply according to the survey carried out. In the same way, it should feel creamy and smooth to the client. When the foam is generated, it must be consistent and abundant.

On the other hand, the serum texture should be of medium viscosity, it should spread easily in contact with hands and should not leave an oily residue or be sticky. Likewise, the mixture must be homogeneous, and therefore the sensation when using it must be smooth, without particles or solid remains.

Viscosity parameter will be considered as the consistency of the emulsion in the texture analysis.

In Table 4 it is possible to find a format of the test to be carried out by the surveyed in the sensory analysis with respect to the texture in the range of products. The shampoo and serum texture analysis will be considered positive the closer to three and four the score (according to the previously determined scale) in the parameters reflected in Table 4.

Table 4. Texture analysis test

Shampoo			**Serum**		
Parameter	Scale (1-4)	Comments	Parameter	Scale (1-4)	Comments
Medium consistency			Medium consistency		
High creaminess			High spreadability		
Stable lather			Low oiliness		
Abundant lather			Low stickiness		
High smoothness			High smoothness		

Own elaboration

SCENT ANALYSIS

In this analysis, the shampoo will have special mention since the serum will not have additives that modify the odorant properties of the mixture.

This decision has been made considering that the serum will be absorbed by the skin layer, and will remain impregnated in the scalp, so by own decision it is decided not to modify the natural essence of the mixture.

Moreover, according to the survey conducted, the shampoo will have a fresh fragrance. In the natural cosmetics industry, it has recently been decided to add essential oils that cover the aroma of the excipients and active principles, but since these can cause allergic reactions or present irritation in sensitive scalps, those fragrances that are more suitable should be considered for any skin type. In the same way, it will not be a priority that the scent of the shampoo last over time after washing.

On the other hand, an additional fragrance will not be added to the serum, since the active ingredients, being mainly of natural origin, will provide their own aroma.

In Table 5 it is possible to find a format of the test to be carried out by the surveyed in the sensory analysis with respect to the fragrance of the shampoo.

According to Klein & Palefsky (2007) in the typical composition of a shampoo the fragrance makes up between 0.1-2% of the total ingredients. Likewise, it must be considered that it must be premixed with a solubilizer that allows its correct addition to the mixture. On the other hand, the antioxidant agents used will protect the color and aroma of the fragrance used in the shampoo.

Table 5. Shampoo scent analysis test

Shampoo		
Parameter	Scale (1-4)	Comments
Fresh scent		
Cause allergic reactions		
Scent appropriate intensity		

Own elaboration

VISUAL ANALYSIS

In this analysis, special mention will also be made of shampoo. Since the color in the shampoo is an important factor in the marketing of the product, it is necessary that it remain unaltered for as long as possible and maintain its initial appearance. This is achieved through the antioxidants that will be added to the shampoo formulation. Nevertheless, according to Klein & Palefsky (2007) it is interesting to use UV absorbers that guarantee color stability.

As mentioned before, the shampoo will be white and pearly in appearance, and the serum will have the color resulting from mixing the ingredients. Any change in this coloration during the use of the product could indicate that the formulation has been damaged, therefore an evaluation that determines the limits to which the products may be exposed is essential.

A proposal of the National Sanitary Surveillance Agency (2004) is to submit the products to illumination given by sunlight or spotlights that resemble sunlight (for example, ultraviolet light sources) and determine by means of a pattern the color expected by the products, if there are any changes in the formulation, as well as determining to which radiation values the products may be exposed.

In this way, taking into account that the products will be used in a domestic environment, their stability is guaranteed.

5. SELECTION OF INGREDIENTS

Following with the development of a product proposed by Zang et al. (2017), after having analyzed the market trends and the quality factors that will be chosen in the range of products, it is now possible to begin selecting those ingredients that meet the stated purposes.

The selection of ingredients in cosmetic industry follows an experiment-based trial-and-error methods. In other words, there are not commonly heuristics or formulas that describe the behavior of the ingredients on the human body. However, the available databases together with computational models allow facilitating the selection of those ingredients that meet specific purposes.

This project will use a search on articles, journals and studies that provide a source of information for the determination of ingredients and their amounts.

In general, the products have three types of ingredients:

• Active principles: These are the ingredients that are intended to fulfill the purpose set by the product on the consumer's skin.

• Excipients: They are the vehicle for the active principles to be applied on the skin and conditions the way of applying the product.

• Additives: These are additional ingredients that can be added to the formula to provide properties such as preservation, aroma, color, thickness, among others.

In the choice of ingredients, it will be given priority that most of them are of natural origin, likewise the factors considered in the previous sections will be considered.

The ingredients for each product will be discussed separately, however as the main objective is to stimulate hair growth and strengthen it, similar ingredients will be shared in the active ingredients.

5.1. SHAMPOO

5.1.1. Active ingredients

With the aim to satisfy the needs of consumers, the shampoo should stimulate hair growth and strengthen it, and clean it.

NATURAL INGREDIENTS STIMULATORS OF HAIR GROWTH

For years numerous ingredients have been used in popular culture that have been considered beneficial for hair growth or to prevent hair loss.

As it is pointed out by Anna Herman, Andrzej P. Herman (2016) conventional treatments for thin hair include drug therapy and hair transplantation. Minoxidil and finasteride are the only two drugs approved by the FDA for hair growth in men, while minoxidil is the only drug available to women with AGA. Both drugs have proven effective, but many patients are wary of their unknown long-term side effects and possible side effects. This has sparked increased interest in alternative remedies such as herbal products and their active components.

It should be noted that herbs and their active ingredients to achieve the desired therapeutic effect must be able to penetrate the epidermal barrier and hair follicles. After that, the herbal formulation can influence hair growth through stimulating or inhibiting activity of various growth factors, cytokines, hormones, or enzymes. Some herbs and their active components allow to maintain active hair growth in the anagen phase, while some inhibit capillary apoptosis in the catagen phase.

However, the studies carried out have not been able to determine precisely what is the pathway by which these ingredients act on the scalp, but it has been possible to verify that they act on the hair bulb through oxygenation (A. Herman & A. Herman, 2016).

Therefore, since the shampoo will remain on the scalp for a short time, it is necessary for the active ingredients to quickly penetrate the hair bulb as long as they reach the desired objective before the hair is washed.

For the shampoo use, a search has been made for those ingredients on which there are studies that confirm that their penetration into the skin has been fast and effective.

Teichmann et al. in 2007 demonstrated that 2-minute contact between a shampoo with 1% of caffeine and the skin surface was sufficient for its penetration deeply into the hair follicles and remains there for up to 48 h, even after hair washing.

Recently, it has been demonstrated that caffeine, a naturally occurring purine-based alkaloid, has a high penetration efficacy into the skin after topical application. Moreover, the results presented suggest that penetration of the shampoo formulation into the hair follicles is a fast process, as a contact time of two minutes between the shampoo and the scalp skin was sufficient for the formulation to penetrate efficiently in the hair follicles. Moreover, caffeine inhibits the activity of the 5α-reductase and leads to a significant stimulation of human hair follicle growth in vitro, a fact which may have important clinical impact in the management of androgenetic alopecia (Fischer, Hipler & Elsner, 2007).

According to the study carried out by Teichmann et al. (2007) and the concentration of caffeine they used, it was decided to apply caffeine at 2% by weight in the shampoo mixture, also, caffeine is soluble at ambient temperature (21 g/L, Solar R., 2018). The increase of caffeine concentration with respect to the formula proposed by Teichmann et al. has been made based on an own decision to achieve a greater increase in the stimulation of hair growth.

Another ingredient commonly used in hair growth stimulation is onion. Onion contains high amounts of flavonoids, which are most well-known for their antioxidant, anti-inflammatory, and antimicrobial properties (Ding et al., 2013).

Specifically, the studies highlight the variant red onion Allium Cepa, of which its shell has a higher concentration of flavonoids compared to other vegetables. Among the main ones are quercetin, isorhamnetin and kaempferol (Fajardo et al. 2016).

Vascular endothelial growth factor (VEGF) is a growth factor that stimulates vasculogenesis and angio-genesis, stimulating hair growth by facilitating the supply of nutrients to the hair follicle, providing an increase in the base of the follicle diameter and this is provided by red onion Allium Cepa, moreover it is soluble in water (Ding et al., 2013).

For all the above, Allium Cepa Bulb Extract has been chosen as the main active ingredient to stimulate hair growth. The bulb has been chosen and not the shell as mentioned in the studies since the process is more profitable economically using all the onion extract.

It has been found in other brands of shampoo with onion extract, (such as Babaria, VidalForce, Nuggela & Sulé, Armonia) that the concentration of the extract reached 3% of the mixture thus it has been decided to increase this concentration to 5% by volume on the shampoo mixture.

SURFACTANT

The cleaning action of the shampoo is determined by the main detergent, although other complementary detergents can be added to this, generally in the cosmetic industry this action is carried out by sulphates (Klein & Palefsky, 2007). However, despite the controversies regarding the use of sulphates in shampoo, the survey carried out did not show a significant preference in the group of people studied. So, these will be used as the main detergent of the shampoo.

There is a category of sulphates that are less irritating to sensitive skin and these are ethoxylated sulphates, however, these have lower detergency power, and it is possible that during the manufacture of the ingredient, 1,4-dioxane would be obtained as a by-product, the same that is considered carcinogenic and mutagenic. Therefore, products that contain it cannot be classified as organic. Specifically, Sodium Laureth Sulphate is discussed, the same that can be found in numerous formulations of personal care products.

Among the most used anionic surfactants it is possible to find the Sodium Laureth Sulphate, the Sodium Coco Sulphate and Sodium Lauryl Sulphate, this latter considered more efficient but more abrasive with the skin, according to Idun Nature (2014).

It is worth mentioning that Sodium Coco Sulphate is categorized as a product of ecological origin since it is obtained from coconut oil (Klaassen, 2010).

For this reason, the solid Sodium Coco Sulphate (SLS) is selected as the main detergent of the shampoo, due to its high action as a cleaning agent, emulsifier, and foam booster (Klein & Palefsky, 2007). It will be used in 15% by volume on the mixture.

As a secondary surfactant, one will be chosen that provides softening properties to the hair, in this way, the dryness on the hair that the main detergent can cause is diminished.

Among the different surfactants that are considered to be mild, the Cocamidopropyl Betaine has been selected since, according to INCY Beauty (2017), apart from being an excellent surfactant, it provides the following characteristics to the shampoo:

• Antistatic: Reduces static electricity by neutralizing the electrical charge on a surface

• Improves the quality of the foam produced by increasing one or more of the following properties: volume, texture and / or stability

• Hair conditioner: Leaves hair easy to comb, flexible, soft and shiny and / or gives volume, lightness, and shine.

• Viscosity control agent: Increases or decreases the viscosity of cosmetics

According to Jacob & Amini (2008), Cocamidopropyl Betaine is an amphoteric surfactant, which contains an anionic group (hydroxyl group) and a cationic group (quaternary ammonium group), this structure gives it properties as a foam booster, thickener, and softness enhancer. It is also compatible in the formulation with Sodium Coco Sulphate and on the recommendation of the authors Klein & Palefsky (2007) this secondary surfactant will be at 5% by volume in the product.

5.1.2. Additives

Once the active ingredients of the product have been determined, it is necessary to add to the shampoo the additives that allow the formulation to remain stable and homogeneous so that the consumer can use it with guarantee.

As Klein & Palefsky (2007) mention apart from the surfactant that will perform the cleansing action of the shampoo on the scalp, it is necessary to add conditioners, agents that control viscosity, humectants, preservatives, pearlescent and coloring agents, pH adjusters and fragrance additives.

CONDITIONER

One of the disadvantages of using a shampoo in personal care, especially for people with long hair, is that it dries out the hair, making it rough and difficult to comb. In fact, this is a negative factor since hair that is not easy to comb, is easier to be pulled or broken. Therefore, for the purpose of the range of products that will be developed is a disadvantage; that is the reason why the incorporation of agents that help to increase the softness of the hair not only will allow the satisfaction of the consumer due to its easy combing, but also will help not to weaken the hair follicles increasing the effectiveness of the shampoo.

The fact of using anionic surfactants that unbalanced the polarity of hair fiber, makes necessary to counteract this effect by adding conditioning agents to the mixture, the same that will add cationic charge to the hair.

According to Klein & Palefsky (2007) there are different types of cationic conditioning agents, but in a general way they could be classified between those accumulative cationic polymeric compounds or those that are fatty in nature.

The first ones have been widely used in the cosmetic industry since they are quite compatible with anionic surfactants and provide sufficient shine and softness to the hair. However, there exist a problem which is that their prolonged use can end in an excessive accumulation on hair. This is counterproductive to the purpose of the shampoo since the polymer being deposited on the scalp would not allow the absorption of the active ingredients.

Having this information into account, it will be decided to use oil conditioning agents. To prevent oil from interfering with the foaming effectiveness of surfactants, it is necessary to create an oil-in-water (O/W) emulsion and incorporate it into the shampoo.

According to Goreja, (2004) shea butter is one of the most nutritious and hydrating products on the market. Shea butter has been used since ancient Egypt for uses on the skin or hair. Moreover, it has anti-inflammatory and antimicrobial properties. It is composed principally by triglycerides, fatty acids, wax esters and vitamins (A, D, E).

Kim et al. (2021) determined the efficacy of the treatment for hair recovery using masks with shea butter in concentrations of 1%, 3% and 5%, with 5% being the most effective in terms of restructuring the hair fiber.

In order that the shea butter does not interfere with the formation of foam or the viscosity of the shampoo, it will be used in low concentration, and it has been decided to add Cetrimonium Chloride, which will also be used simultaneously to soften the hair.

Cetrimonium Chloride is a quaternary ammonium that, being a cationic surfactant, helps to promote a soft and pleasant touch on the hair. Moreover, it is a highly used compound in shampoos that regulates the negative charge of the surfactant on the hair fiber, making it compatible with the surfactants used and water soluble.

It is very similar to another conditioning ingredient named Behentrimonium Chloride. In fact, only the number of carbon atoms they contain differs, which slightly changes the feeling of the

conditioner on the hair when it is applied, being the cetrimonium chloride very light, almost imperceptible when the hair is still wet, while with Behentrimonium Chloride, it is possible to feel the product on the hair (Lush Official Website).

The legislation in Europe allowed for Cetrimonium Chloride in rinse products for hair and facial hair is a maximum of 2.5% (INSI Beauty Official Website).

For all the information exposed above, as conditioning agents for shampoo, shea butter (Butyrospermum Parkii Butter) and Cetrimonium Chloride have been chosen in concentrations of 1 and 1.5% by volume, respectively.

HUMECTANTS

Moisturizers also help maintain hydration on hair that is lost by surfactant. In this project, it has been chosen to add a moisturizer apart from a conditioning agent since the range of products that will be developed is intended for all types of hair, and therefore it is necessary to add an extra hydration, especially for those hair that are dry and fine.

According to Klein & Palefsky (2007), the most widely used moisturizers are polyols. These compounds contain hydroxyl groups that are to adhere to carboxyl groups on hair fibers. However, it is also believed that because these compounds are water soluble after application they also wash off.

Specifically, glycerine will be used in this shampoo. Glycerine can be produced synthetically from petroleum derivates, or from animal or vegetable fats by saponification. Some of its characteristics are that is colorless, hygroscopic liquid (which absorbs moisture), and has emollient power, so it also helps to preserve the moisture of the product and does not allow it to dry out. Glycerine in fact is widely used in the cosmetic industry for its strong hydration on the skin and hair (Betancourt et al.,2016).

It has been decided to use the glycerine at 6% by volume over the shampoo product, after having consulted formulations in existing patents.

THICKENERS

As discussed throughout the project, the consumer likes more a high viscosity in shampoo. Therefore, the addition of thickeners is extremely necessary. In addition to ensure that the consumer perceives the product as more concentrated, the addition of a thickener also helps prevent the product from fading during use.

In most shampoos and cosmetic products, the use of salt as a thickener has been widely used as it is a cheaper option.

However, it is known that salt promotes dryness of hair, and therefore would counteract the effects of moisturizers and emollients that are added to the mixture. For this reason, the cosmetic industries have used new salt-free shampoo formulations given the recent controversies surrounding its use in personal care products.

Therefore, after having gathered information on the different alternatives to salt as a thickener in shampoo, it was decided to use Lauryl Lactyl Lactate.

According to Gil & Arevalo (2018), this compound is a biodegradable ester with hydrophobic, non-ionic characteristics, which makes it soft with the emollient properties and conditioning agents of shampoo, also it is water soluble.

Furthermore, due to its rheological characteristics as a thickener, this compound improves the stabilization of dispersed particles in the mixture, such as the pearlizing agents that will be discussed later. Likewise, it allows its use at pH values lower than 7.5 and does not interfere with the foaming of the main surfactants.

It is recommended to use 0.3 to 3% by volume.

The volume concentration of Lauryl Lactyl Lactate has been determined to be 2.5%.

PRESERVATIVES

As previously mentioned according to Klein & Palefsky (2007), as with any other personal care product, the formulations that are developed must be properly preserved so that, when manufactured, they are free from microbial contamination and resist contamination when stored. in inventory and when used by the consumer.

Since the surfactants used are biodegradable, preserving them is an even greater challenge as they are a food source for microorganisms.

Continuing with the use of ingredients that are as natural as possible, it has been found in the bibliography that the preservatives used in natural cosmetics are for example: Benzoic acid, Caprylyl Glycol, Sodium benzoate, Sorbic acid, Potassium sorbate, Dehydroacetic acid, Salicylic acid), Levulinic acid or Sodium levulinate.

But, since these may have limited efficacy on the product, it is necessary to add chelating complexes. The presence of calcium or magnesium from the water can cause decomposition reactions together with other ingredients of the cosmetic product and lead to a deterioration of the product, but also, a water with a lot of lime can hinder the detergent system of a shampoo decreasing its detergency. The presence of EDTA helps to remove ions from the solution and prevent them from interfering.

In addition, EDTA also has antimicrobial properties against gram-negative bacteria, hence it is included as an adjuvant (booster) of the antimicrobial preservative system. The presence of chelators such as EDTA is because it allows to increase the permeability of the cell membranes of bacteria, blocking iron (chelating effect), stop cell metabolism, and inhibit the growth of bacteria and microorganisms.

Lawan et al. (2009) determined the efficacy of the preservative Caprylyl Glycol in water-based emulsions against the microorganisms evaluated in cosmetic compounds and allowed to determine that for a concentration of 1% by volume on the emulsified mixture it was completely effective against bacterial growth. To improve the preservation of the mixture, they also studied the combined effect with Ethylhexylglycerine, however they emphasized that the industrial cost increased slightly when making this combination.

According to the Dermocosmetic Institute (Official Website), Caprylyl Glycol is a clear liquid with moisturizing and emollient properties that has antimicrobial actions against fungi, yeasts, and bacteria. The pH range over which it is recommended to use this compound is 5 to 7, and its concentration dose between 0.3 and 1% by volume. For its correct operation it is advisable to disperse it in the aqueous phase during the formulation of the shampoo.

For this reason, in this project, Caprylyl Glycol has been chosen as a preservative together with the addition of a chelating agent.

Varvaresou et al. (2009), pointed out that the use of EDTA on cosmetics is under discussion since, although they are effective agents, their biodegradability is low, and they recommend the

use of Phytic acid instead. According to Daneluti et al. (2015) Phytic acid is a potent inhibitor of iron-catalyzed hydroxyl radical formation as it chelates the free iron and then blocks its coordination site. Furthermore, these authors remarked that several studies have uncovered its antioxidant activity in some products and protective effects against oxidative damage in emulsions. As a result, it has led to an enhancement of shelf life for these products.

For this reason, phytic acid has been widely used in cosmetic emulsions as an antioxidant for skin care products.

In the same the study carried out by Daneluti et al. (2015) highlighted that in the formulation of the cosmetic product they developed, the concentration of Phytic acid was 5% by volume.

Considering the information described Caprylyl Glycol and Phytic acid will be used as preservatives in volume concentrations of 0.5 and 3% respectively.

COLOURANT

According to Preston (1987), pearlescent agents frequently utilized in cosmetic compositions may be stearic acid and insoluble metal salts thereof, such as magnesium stearate or zinc stearate, glyceryl stearates, ethylene glycol mono and distearates, polyethylene glycol distearate, glycol amidostearate, alkyl glyceryl ether sulfonates, certain fatty alkanolamides, and even insoluble resin latex dispersions.

The type of pearlescence achieved may vary from flat to highly reflective or iridescent depending on the amount, size, shape and reflective or refractive power of the pearlescent agent used as the opacifier.

Bolzinger et al. (2007) classified pearlescent agents into two categories: free substrate particles that basically consist of one optically homogeneous material of high refraction index having a platelet shape; and particles that have a layered structure on a substrate.

Ethylene glycol distearate (EGDS), which is part of the first group, has been chosen as the pearlescent ingredient. This ingredient is one of the most used in cosmetics and its main advantage is that it can be added to the formulation at room temperature. Likewise, its stability is not affected using an anionic surfactant and it does not affect the abundance of the foam (Bolzinger et al.)

A volume concentration of Ethylene glycol distearate of 2% has been chosen according to Klein & Palefsky (2007).

To add the white color as a pigment to the shampoo, Titanium Dioxide has been chosen. Its most important properties are that it is non-toxic, it has compatibility with mucous membranes and the skin, and it has good dispersibility in organic solutions. For these reasons, this pigment is widely used in cosmetics.

In the same way, it is also one of the substances that most reflect the radiation they receive and due to the properties of this compound, it also provides ultraviolet protection to the shampoo mixture, and therefore, it is one of the whitest pigments. (Quiroa, 2014).

According to Regulation (EC) no 1223/2009, Titanium Dioxide can be used in products prepared at a maximum concentration of 25% and following the recommendations of Klein & Palefsky (2007) it has been determined that the concentration of the Titanium Dioxide pigment would be of 2% by volume.

pH ADJUSTER

Continuing with the formulation proposed by Klein & Palefsky (2007), it is necessary to guarantee that the shampoo has a suitable pH for the scalp so that its application on the scalp is pleasant and not harmful.

According to Fiume et al. (2014), Citric acid is reported to function in cosmetics as a chelating agent, pH adjuster, and fragrance ingredient. Some of the inorganic salts of citric acid are reported to function as a skin-conditioning agent, buffering agent, cosmetic astringent, oral care agent, cosmetic biocide, or pesticide. Also, VCRP (Voluntary Cosmetic Registration Program) data obtained from the FDA in 20118 and data received in response to a survey of maximum reported use concentration by category conducted by the Personal Care Products Council indicates that 10% of 6795 in cosmetic formulations, which are rinse-off formulations, contained Citric acid.

In the same way, taking into account the information provided by the study in which it is indicated that the maximum concentration found in rinse-off products with Citric acid content was 10%, and following the recommendations of Klein & Palefsky (2007), it has been decided that Citric acid would be chosen as a pH modifier in a maximum concentration of 1%, taking into

account that this parameter should be modified during the formulation of the product, since Citric acid would be added to the mixture until reaching a pH that falls within the range 5.5- 7.5.

FRAGANCE

Finally, in the additives added to the shampoo formula we would find the fragrance. As has been determined in previous chapters, this fragrance is intended to be fresh to achieve success in the consumer's perception.

According to Klein & Palefsky (2007) fragrances are also a major cost contributor to shampoo and as such are typically used at low concentrations of 0.2-1.0%. The order of addition, premixing with a solubilizer, and the temperature at addition, are all factors that need to be considered when adding a fragrance to a shampoo. Also, the antioxidant Titanium Dioxide as a UV absorb is used to protect the color stability of the shampoo due to the fragrance being used.

Herman et al. (2013) carried out a study on the properties as antimicrobial agents that essential oils have and determined that an emulsion with a concentration of 2.5% by weight of Eucalyptus extract on a cosmetic emulsion had sufficient antimicrobial power to keep the emulsion stable.

The Eucalyptus leaves (Eucalyptus globulus Leaf) have in its composition essential oils whose main constituent is cineole or eucalyptol (terpenic oxide ether) also contains: terpeneol, terpenic carbides, aliphatic alcohols, tannins, flavonic pigments, etc; and it has been shown that aqueous extracts of this plant have anti-inflammatory properties (Bacallao et al., 2002).

It has been concluded from the literature that the concentration of Eucalyptus globulus Leaf extract will be 1% by volume.

5.1.3. Excipients

The excipient or vehicle is the chemically inactive part of the topical product that serves as the basis for bringing the active substance into contact with the skin. The topical medicine, to be effective, must cross the inert barrier that the skin supposes and reach the dermis, metabolically active layer, where the active principle will perform its function. The excipient stabilizes the active ingredient and improves its absorption and penetration into the skin, such that the choice of an appropriate excipient maximizes the bioavailability of the active ingredient on the scalp. In

addition, the vehicle has other beneficial effects due to its refreshing, protective, moisturizing, occlusive or astringent properties, depending on the case, which contributes to the final efficacy of the treatment (Córdoba & Borbujo, 2014).

Once the active ingredients and additives have been selected, it is possible to determine the vehicle, based on the function of the shampoo, an aqueous base is chosen, specifically distilled water. This will be free of impurities or microorganisms and will represent the rest of the percentage by volume of the shampoo mixture.

5.1.4. Shampoo formulation summary

In Table 6 it is possible to see the ingredients that will appear on the label of the shampoo container, named by the INCI nomenclature (International Nomenclature of Cosmetic Ingredients), accompanied by their concentration by volume and the function they perform.

Table 6. Specifications of the ingredients of the shampoo.

Ingredient (INCI)	% Concentration	Function
Water	52.8	Excipient
Sodium Coco Sulfate	15	Surfactant
Glycerine	6	Humectant
Cocamidopropyl Betaine	5	Surfactant
Allium Cepa Bulb Extract	5	Active ingredient
Phytic acid	3	Preservative
Lauryl Lactyl Lactate	2.5	Thickener
Titanium Dioxide	2	Colourant
Ethylene glycol distearate	2	Colourant
Caffeine	2	Active ingredient
Cetrimonium Chloride	1.5	Conditioner

Butyrospermum Parkii Butter	1	Conditioner
Citric acid	1	pH Adjuster
Eucalyptus Globulus Leaf Extract	0.7	Fragance
Caprylyl Glycol	0.5	Preservative

5.2. **HAIR SERUM**

5.2.1. Active ingredients

The purpose of serum is to nourish, and it must have active ingredients that stimulate hair growth and allow its absorption on the scalp.

NATURAL INGREDIENTS STIMULATORS OF HAIR GROWTH

Information on medicinal plant extracts has been sought that have been proven to treat hair loss. It was found that Panahi et al. (2015) conducted a trial in which they compared the efficacy of the 2% Minoxidil treatment against a treatment based on rosemary oil. After 6 months from starting the study, it was determined that there were no significant differences in terms of hair growth, since the two groups obtained an increase in hair growth and a delay in hair loss, so it was confirmed that rosemary oil acts as a natural stimulator of hair growth, leaving aside the irritation and itchiness factor that Minoxidil caused.

Rosmarinus officinalis is a medicinally important plant that belongs to the family Lamiaceae and is commonly known as rosemary. It is widely used as a remedy for stimulating hair growth. In addition, some species showed antibacterial, antimutagenic properties, anti-inflammatory, hypoglycemic, hypolipidemic, hypotensive, antiatherosclerotic, antithrombotic, hepatoprotective, and hypocholesterolemic effects. Moreover, as an advantage, the province of Murcia (Southeast Spain) is one of the major processors and importers of rosemary (Shashi et al. 2021) what will facilitate the manufacturing process.

According to Muñoz (2002), the main components of rosemary essential oil are: camphor, 1,8-cineole, apinene and other monoterpenes such as borneol, b-pinene, limonene and p-cymene. Sesquiterpenic lactones are also found such as carnosol, rosmanol, epirosmanol, isorosmanol, 7-methoxyrosmanol, rosmadial; also, it is possible to find triterpenic acids such as ursolic acid and betulinic acid; in the same way triterpenic alcohols are found such as betulin; phenolic acids such as caffeic, and chlorogenic, rosmarinic and flavonoids components.

As stated by Muñoz (2002) rosemary was attributed to have medicinal characteristics in ancient Egypt being widely used in popular culture, being even used centuries later by the court of Isabel from Hungary as therapeutic treatment. Therefore, after having found information about

its properties, and varied bibliography referring to rosemary as a medicinal plant and a helper in the treatment of hair loss, it has been decided to use the oil of the Rosmarinus officinalis plant.

Considering its pharmacological action in medicine, the extract of the rosemary plant has been used in concentrations of up to 25% for medications by ingestion, while topically concentrations of up to 70% in hydroalcoholic extract have been used (Muñoz, 2002).

Taking into account the formulation that has been found, as proposed by Rodríguez et. al (2011) in topical creams with rosemary essential oil, it can be used at 2% by weight; for this reason, it has been decided to determine that the essential oil of the Rosmarinus officinalis plant will be 5% by volume in the serum mixture.

On the other hand, it has been determined to use another essential oil that provides stimulating properties for hair growth. According to the consulted bibliography, castor oil has shown efficacy for this purpose. As Valderrama (1994) points out in his book, castor oil is obtained by pressing the seeds of the Ricinus communis plant. The oil is colorless and transparent, it stands out for its high content of fatty hydroxy acid, which gives it its physicochemical properties that are widely used in cosmetics. Moreover, it is a viscous oil, so it can add its characteristic to the serum. Among its components as fatty acids can be found palmitic acid, stearic acid, oleic acid, linoleic acid, dihydroxystearic acid, and mostly ricinoleic acid.

Failor (2001) points out that castor oil also acts as a solvent because it has alcoholic properties derived from ricinoleic acid, and likewise, it is easily absorbed through the skin, which also provides emollient and moisturizing properties to the scalp. Among its cosmetic applications, it is stood out that castor oil is one of the major components in formulations for the growth of eyelashes.

To avoid the oily sensation that this oil can leave on the hair, there is a variant of castor oil, which is Sulphated Castor Oil. This oil is produced by adding sulfuric acid to castor oil, that allows the oil to be soluble in water and maintain its properties on the scalp. Thus, Sulphated Castor Oil is characterized by being an anionic surfactant, therefore, a solvent for essential oils in water, emulsifier, humectant, and antioxidant. However, it does not generate too much foam despite being a surfactant (Dermocosmetic Institute Official Web).

Failor (2001) recommends using sulphated castor oil at 3% by weight in formulations for soaps and shampoos, which therefore will go away from the skin quickly, however, for its use in lotions it is mentioned that it can be used up to 90% by volume. Therefore, considering that it is

desired that these active ingredients penetrate and perform their function on the scalp, it has been decided to use Sulphated Castor Oil at 7% by volume in the shampoo mixture.

No evidence of topical toxicity has been found due to prolonged use of sulphated castor oil or rosemary oil.

5.2.2. Additives

As it has been mentioned above, the addition of ingredients that might difficult the process of stimulating hair growth should be avoided as far as possible.

The use of Sulphated Castor Oil, apart from being an active ingredient, has the function of being a surfactant, so it will help the emulsion of rosemary oil in the aqueous mixture of the serum.

Therefore, in this section, only the addition of thickeners, preservatives and pH adjuster will be considered. The fragrance of the serum will be considered fresh due to the aroma of rosemary oil itself, and it is not necessary to add additional fragrances that might result allergenic to consumers. In the same way the addition of colorants will be avoided because it is sought to produce a product formulated in a natural way principally.

THICKENERS

It has been decided to use a thickener that is hydrophilic, with compatibility on the skin that does not cause irritation and that provides a more viscous texture to the hair serum.

Alvarado et al. (2010) describe the use of gums in the food and cosmetic industry as a proposal for the use of thickeners of natural origin. It is also described that gums are formed as a result of the disintegration of internal plant tissues; generally, as a result of physiological or pathological disorders, which produce a decomposition of the walls and cell content through a process called gummosis or gummy degeneration. These contain a large number of sugars (arabinose, galactose, mannose and xylose) and are closely related with pectins. Likewise, they describe those gums are colloidal in nature and soluble in water, but insoluble in alcohol and ether.

López et al. (2018) in a study on the most used gums in the food and cosmetic industry mention arabic gum and guar gum, among others. Arabic gum is a naturally derived substance that is used in the manufacture of natural cosmetics in many different ways. It is within the

thickening and gelling additives and is characterized by creating a shiny layer given by the gel layer that it forms. By contrast, guar gum is not a gelling substance, so it only acts as a thickener and stabilizer for emulsions.

Guar gum is obtained from the seed of Cyamopsis Tetragonolobus, a plant that belongs to the legume family. One of the important properties of this gum is its ability to hydrate quickly in cold water and produce highly viscous solutions. It is used mainly as a thickening agent, stabilizer, and water retainer. Acacia Senegal Gum is the INCI denomination name given to this gum. Other properties that make it useful for this purpose is that it can be found in a non-ionized form and with a wide range of pH values that can be worked on, from 3 to 11 (Alvarado et al., 2010).

Moreover, according to Ortiz et al. (2017) gums as thickeners in cosmetics provide the following advantages over other thickening ingredients:

• Ease of location and application in a specific area with respect to solutions.

• Absence of fat content, which makes them ideal for hairy areas, fatty areas, and folds. They avoid maceration.

• Pleasant cosmetic appearance and transmission of freshness.

According to the studied literature, its maximum concentration is 1.5% in high viscosity products such as shampoos or thick creams. Regarding the concentration by volume of Acacia Senegal Gum, it has been chosen to be 0.3% by volume.

PRESERVATIVES

The choice of the preservative in the serum is highly important since the ingredients used are biodegradable, and therefore, enhance the proliferation of microorganisms.

It has been decided to use the same preservatives in the two products developed is this project. According to the Dermocosmetic Institute (Official Website), the use of Caprylyl Glycol as a preservative was mentioned before, since it has been shown to be effective against bacteria, molds and yeasts. On the other hand, as a chelating agent, Daneluti et al. (2015) recommended the use of Phytic acid in cosmetic formulations up to 5%.

Consequently, it has been decided to use higher concentrations of these preservatives because the use given to the serum can cause that it would be exposed to external agents that

can contaminate it. Therefore, it has been determined that the concentration of Caprylyl Glycol will be 0.7% by volume, and Phytic acid 3.5% by volume.

PH ADJUSTER

The addition of a pH adjuster has not been considered because as the pH of the scalp is from 5 to 5.5, with the addition of Phytic acid the mix would be balanced for use on the skin of the scalp since the oils and excipients do not influence the mixture.

5.2.3. Excipients

The selection of the conductive vehicle for the active ingredients has been selected based on the compatibility of the active ingredients. In the serum format there are various options for applying the product. According to Iglesias et al. (2016) the types of formats that can be found for hair loss treatments are: hydroalcoholic solutions, consistent gels, fluid gels, emulsions, oils and hair foams.

As mentioned in previous sections, this project aims to formulate a serum that mostly is compatible with all kinds of scalps, for this reason, the hydroalcoholic solutions have been eliminated due to the high dryness that they can cause to the scalp.

In order to create a serum that does not leave an oily residue on the hair, it has been decided to formulate an oil-in-water (O/W) emulsion. According to Muñoz (2008) among the vehicles that can be used for O/W emulsions that also provide an emollient effect on the skin are propylene glycol, urea, glycerine, sorbitol, panthenol, among others.

It has been chosen to use urea as a conductive vehicle for the active ingredients because according to Cabanes et al. (2008) the use of urea on the skin has been widely studied, and the multiple benefits it provides on the skin have been proven. Among the properties found on urea, the authors declare that it is an excellent emollient, desquamative, antimicrobial, humectant, and excellent promoter of topical drug absorption on the skin. It has been used to treat flaking, itching, or dryness on the skin in concentrations of up to 30% in creams, and its effectiveness has been corroborated by improving skin hydration in a notorious way.

Muñoz (2008) points out that urea weakens the hydrogen bonds that bind the keratin of the skin, facilitating the penetration of the active ingredients. In the same way, urea must be formulated in a slightly acidic medium, so it can be compatible with the serum being formulated.

This author recommends the concentration of urea in moisturizing cosmetic preparations from 0.5 to 5% by volume.

On the other hand, Vargas et al. (2008) recommend its use in cosmetic preparations in concentrations lower than 10% since its use in higher concentrations may cause a sensation of itching in the consumer in the long term.

Considering the information presented, it has been decided to use urea in 8% by volume as a conductive vehicle for the active ingredients, being distilled water the remaining component of the serum mixture, since urea is soluble in it.

5.2.4. Serum formulation summary

In the same way as in the shampoo, the next table (Table 7) contains the ingredients named by the INCI nomenclature, followed by the concentration determined by volume and the function they will perform in the serum.

Table 7. Specifications of the ingredients of the serum.

Ingredient (INCI)	% Volume	Function
Water	75.5	Excipient
Urea	8.0	Excipient
Sulphated Castor Oil	7.0	Active ingredient
Rosmarinus officinalis oil	5.0	Active ingredient
Phytic acid	3.5	Preservative
Caprylyl Glycol	0.7	Preservative
Acacia Senegal Gum	0.3	Thickener

6. PRELIMINARY DESIGN OF THE MANUFACTURING PROCESS

Finally, once the functionalities, quality factors, and ingredients that will compose the shampoo and serum have been considered, it is possible to go on to design the production process. To do this, first, the annual production will be determined, then the process equipment will be selected and finally, the order of the ingredients added will be set.

6.1. ANNUAL PRODUCTION

To estimate the annual production, a brief analysis of demand has been made on the possible consumer population of this range of products in accordance with the data presented by the INE (National Institute of Statistics) agency on July 1, 2020, and also extrapolating the results of the survey carried out on the sample of 180 people, assuming that the developed products are aimed at the population in Spain, which is composed by 47,351,566 people, from which 26,479,829 are between the ages of 20 to 60 years, including men and women, the possible demand would be explained as follow.

According to the survey carried out, 70% of people in the sample uses products for a specific purpose, 42% of the total sample uses products to stimulate hair growth and strengthen it. In the same way, 8% uses serum products and 28% uses shampoo for this purpose. From the total survey carried out 72% would be willing to use products formulated mostly with natural ingredients, and finally taking into account that since they are new products on the market, considering for example that 5% of them could actually purchase the range of products developed, the demand for serum is 72,068 and shampoo is 268,251 units over the population of Spain (see Appendix A).

This estimated demand has been rounded to an annual production of 80,000 units of serum and 300,000 units of shampoo, considering that the estimated population purchases each of the products once a year.

Cabrera & Gallardo (2009) determined the density of several commercialized shampoos for the treatment of dandruff, from which it could be concluded that on average these shampoos had 1,020 g/mL of density. On the other hand, it has been found that the density of urea, castor oil,

and rosemary oil is 1,320 g/mL, 0.950 g/mL, 0.825 g/mL respectively, and together with the concentration in volume that has been determined it is possible to approximate the density of the serum to 1.013 g/mL, at room temperature. Therefore, rounding these values, in this project it will be assumed that the densities of the shampoo and the serum are 1.0 g/mL. Considering that the capacity of the containers specified above is 100 mL for serum and 700 mL for shampoo, the annual mass production of serum and shampoo can be estimated at 8,000 and 210,000 kg/year respectively (see Table 8)

It is decided to use a discontinuous batch production since it is economically more favorable and allows a certain versatility when changing the product to be elaborated. Likewise, the cleaning of the equipment will be easier (Cunill et al., 2010).

It has been chosen to use batches of 500 kg to produce the serum and the shampoo, likewise, the equipment for the elaboration of the range of products will be the same, so they can be reused, with the aim of reducing costs of the plant. To estimate the manufacture time of the products, the estimated campaign time and the number of campaigns to be carried out will be proposed. When the equipment is not producing this range of products it will be free for possible use in other processes.

Table 8. Specifications of the production.

	Serum	**Shampoo**
Annual product units (ud)	80,000	300,000
Product unit volume (L)	0.1	0.7
Annual volume production (m^3)	8	210
Annual mass production (kg/year)	8,000	210,000
Batch capacity (kg)	500	500
Annual batch number	16	420

6.2. **MANUFACTURING PROCESS**

First, the production process of the shampoo will be described, then the serum elaboration. In the same way, it will be determined for the serum production the equipment that can be reused from the shampoo manufacturing process, or if additional ones are necessary for the defined production.

6.2.1. Shampoo manufacturing process

According to Montalvo & Rondan (2013) in the global shampoo manufacturing process, in general, 8 stages can be found. In order, these are the reception of raw materials and storage, preparation of production and equipment, deionization of water from the production line, preparation of the detergent base and stabilizer base, addition of additives to the mixture, quality control, packaging, and finally labelling. In this project, only the stages for the manufacture of the shampoo mixture and its packaging will be described, assuming that the ingredients to be used are already prepared for its use in the process.

Montes et al. (2019) agree with other authors that for manufacturing shampoos with natural ingredients these should be separated into 2 categories: the detergent base and the stabilizing base of the shampoo. The detergent base is one in which the fundamental principles of shampoo are united, these are, surfactants, and they are mixed with a small amount of water. The stabilizing base is the vehicle where the active ingredients that will stimulate hair growth and some additives are added.

For the shampoo manufacturing process, the proposal of these authors has been chosen as a guide for the order of mixing the ingredients.

Next, the order of addition of the ingredients and their volume (or weight) for a production of 500 kg will be shown, approximating that the density of the shampoo mixture is the one from water.

DETERGENT BASE PRE-MIXING

The first unit operation that will be found in the process is a pre-mixing stage in a stirred tank where the detergent base of the shampoo will be prepared. This tank will be the largest because it is where all the ingredients will be added, therefore it constitutes the overall mixing volume.

In this tank, Sodium Coco Sulphate (75 kg), Cocamidopropyl Betaine (25 L), Lauryl Lactyl Lactate (12.5 L) will be added together with about 10% of the total distilled water required for the mixture (25 L).

A small amount of water needs to be added to facilitate dissolution of the Sodium Coco Sulphate and mixing of the formula. Likewise, this small amount of water will prevent excessive foam formation that interferes with production.

This base of about 138L, will be homogenized for 15 minutes at a low stirring speed of 20 rpm and at room temperature. Also, the low stirring speed allows not too much foam to be formed, not being necessary to work in a vacuum.

STABILIZING BASE INGREDIENTS PRE-MIXING

In parallel, in another stirred tank the active ingredients and some additives will be pre-mixed. A volume of distilled water of 15% of the total required (40 L), the Allium Cepa Bulb Extract (25 L), Caffeine (10 kg), Butyrospermum Parkii Butter (5 kg), and finally the Titanium Dioxide colorant (10kg) and Ethylene glycol distearate (10 kg) will be added to this tank.

Butyrospermum Parkii Butter is a solid fat at room temperature, so it is necessary to bring this mixture to a higher temperature to melt it. Its melting temperature is 45ºC (Acofarma, n.d.), so it has been decided to bring this mixture to a temperature of 50ºC.

This mixture of an approximate total volume of 100 L will be mixed for 20 min also with low stirring (20 rpm) at 50 ° C.

The flow rate of liquid water required at 80ºC has been estimated that would circulate through the heating jacket at 15 L/min during the 20 minutes to heat the mixture to 50ºC (see Appendix E).

This mixture will be the one that will be added to the detergent base of the shampoo, so this equipment could be positioned at a higher height so that its impulse is facilitated by gravity.

MIXING

Then, with the help of a pumping equipment, the stabilizing base will be slowly added to the detergent base of the shampoo. This mixing period while adding the stabilizer base should continue at low agitation (20 rpm), so this process can last 30 minutes, at an addition rate of the stabilizer mixture of about 3 L/min.

Next, when the formulation is mixed, the remaining ingredients will be added in the following order: Glycerine (30 L), Cetrimonium Chloride (7.5L), Caprylyl Glycol (2.5L), Eucalyptus Globulus Leaf Extract (3.5L) and Phytic acid (15 L).

Finally, the remaining distilled water (200 L) will be added, and the pH of the medium will be controlled. To be able to adjust it in a range of 5 to 5.5, Citric acid will be added starting with a volume of 5 L, but this value will be adjusted to reach the desired pH.

This process of adding the missing ingredients could last 30 min, then the addition of water and Citric acid could last 15 min.

It will be mixed for 20 minutes at the same speed of 20 rpm and at room temperature.

Packaging

Once the shampoo mixture is manufactured, it is possible to continue with the packaging process. A pump will impulse the shampoo mixture from the mixing tank to the packaging area; considering that with a production of 500 kg of shampoo, 714 units of bottles can be packaged. This operation is expected to take approximately 1 hour, assuming that a bottle filling time is 5 seconds. It has been considered that the packaging process is done by an automatic packer, capper, and labeller equipment.

An additional two and a half hours have also been considered in the global process for the interventions of the operators or equipment preparation. It can finally be estimated that the shampoo production process is 6 hours.

6.2.2. Serum manufacturing process

Contreras et al. (2021) comment that in the manufacture of oil-in-water (O/W) emulsions it is advisable to premix the oil phase in hot (with the hydrophobic ingredients), and separately to premix the aqueous phase with the hydrophilic ingredients.

After that, the two phases can be mixed, and the thickener added to the final mixture. The addition of the thickener at the end of the process facilitates the mixing of the ingredients, as well as a lower energy consumption.

The formulated serum is a non-stable emulsion so that after the mixture has stood, the two phases will separate. However, the mixture will be considered stable enough to be processed and packaged by shaking. The serum contains 12% oils, therefore the effectiveness of the temporary stability of the serum mixture is that the stirring must be carried out quickly, thus ensuring that the oil drops in the water are as small as possible.

Next, based on Contreras et al. (2021), the order of addition of the ingredients is exposed. In the same way, their approximate volume is indicated, assuming that their density and the density of the mixture is the same as the water.

OILY PHASE PRE-MIXING

In a stirred tank, the active ingredients will be mixed. Due to their oily nature, it is convenient to mix them first with each other before adding them to the serum mixture (Danila et al., 2021). The mixing of Rosmarinus officinalis oil and Sulphated Castor Oil could be done at room temperature but stirring is easier if it is carried out to a higher temperature, so the temperature of the tank will rise to 50 ºC.

The rosemary oil (25 L) will be added first, and later the castor oil (35 L). The two ingredients will be homogenized for 5 minutes at a low stirring speed of 20 rpm and then this mixture will be taken to the general mixing area of the serum. At this stage, there will be no foaming problems due to the low speed and the low foaming capacity of Sulphated Castor Oil.

The flow rate of liquid water required at 80ºC has been estimated that would circulate through the heating jacket at 36 L/min during the 5 minutes to heat the mixture to 50ºC (see Appendix E).

AQUEOUS PHASE PRE-MIXING

This premix phase will take place in the overall mixing tank. It will start by pouring all the distilled water (378 L) into the tank and then the urea (40 kg) will be added. This mixture will be carried out at a stirring speed of 20 rpm for 5 minutes at room temperature.

MIXING

The 60 L oil phase will be slowly added to the volume of about 418 L of aqueous phase. To carry out this addition, a stirrer will be used that will rotate at 200 rpm, and the flow rate of the oil phase will be 6 L/min. so this mixing operation could take 6 minutes.

It is necessary that the stirring speed be higher as this will produce shear forces that will allow the formation of the sufficiently stable O/W emulsion for the packaging process. Even so, if in the mixture left to stand it is possible to distinguish the two phases in the product, the recommendations for using it will warn that the product must be shaken before using.

Then, while the emulsion stabilizes and without stopping the stirring, the following ingredients will be added: Phytic acid (17.5 L), Caprylyl Glycol (3.5 L), and finally the thickener Acacia Senegal Gum (1.5 L). Stirring will continue at 100 rpm for a further 15 minutes at room temperature.

Packaging

The serum emulsion will already be manufactured, and it will be possible to proceed to the packaging process. For this volume of 500 kg of serum, 5,000 bottles of 0.1 L capacity can be packaged. An automatic machine will be used that allows the packaging, capping, and labelling of the product. The time required has been estimated at 7 hours, considering that a bottle filling time is 5 seconds.

Finally, considering an additional time of two and a half hours for plant operations or interventions by operators in the serum manufacturing process, the total manufacturing time is 10 hours.

6.3. **PROCESS FLOWSHEET**

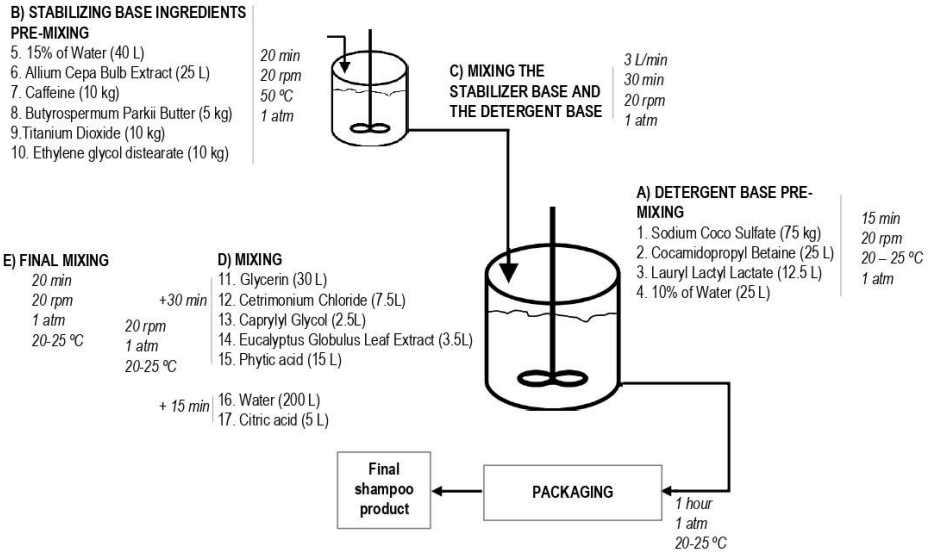


Figure 2. Shampoo process flowsheet

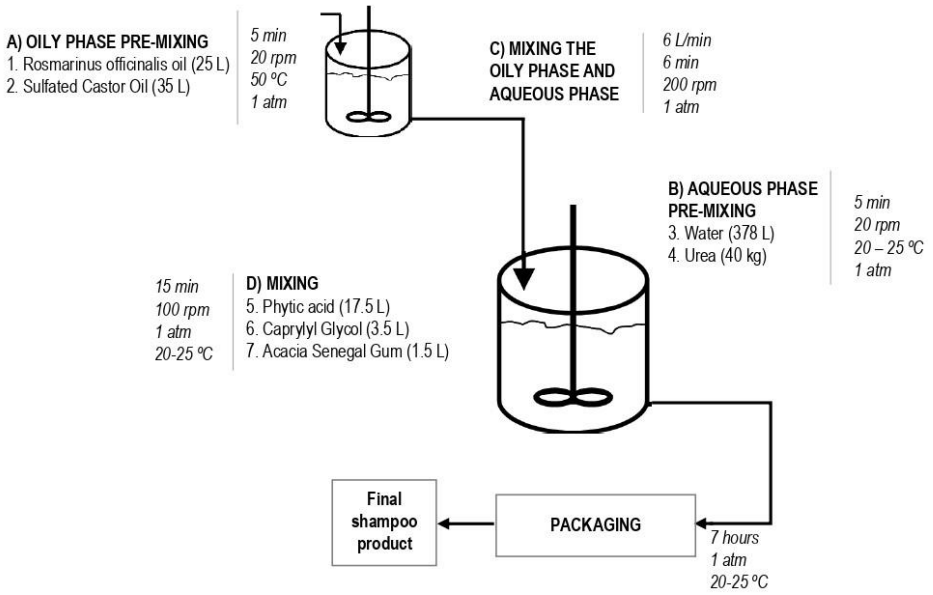


Figure 3. Serum process flowsheet

6.4. **CAMPAIGN MANUFACTURE**

In this section, a proposal for the annual campaigns for the manufacture of shampoo and serum will be made.

Considering that the production time of a batch of shampoo is 6 hours, it is proposed to produce two batches per day, from Monday to Saturday. There will be three campaigns dedicated to the manufacture of shampoo throughout the year, in which each campaign will last about twelve weeks. In each campaign, 140 batches will be produced.

Regarding the serum, taking into account that each batch takes 10 hours to be manufactured, a single campaign per year is proposed. In which a batch will be made per day, from Monday to Saturday also, for three weeks in a row.

6.5. **SELECTION OF EQUIPMENT UNITS**

The selection of equipment will be made based on the efficiency that they represent versus cost. Taking into account that a production of 500 kg has been considered for the two products, the equipment that can be used for the two manufacturing processes will be sought. For the proposed manufacture, two mixing tanks (agitated vessels), a heating system, an automatic packaging, capping, and labelling machine are necessary.

According to Martínez Aguilella (2020) in the choice of the mixing tank, the characteristics of the tank, the agitation system, the baffles, and in the case of this project, a heat transmission system must be considered. Regarding the tank, apart from the size of the tank, the type of bottom of the tank is important, which can be hemispherical, flat, or conical. Those that are curved facilitate the cleaning or discharge of the tank. When choosing the agitation system, the power that the motor can reach, and the type of agitator must be taken into account.

For low agitations of between 20 to 150 rpm, paddle agitators are usually used, which drive the fluid in a radial and tangential direction, which, when colliding with the tank walls, drive its movement in an axial direction. Martinez Aguilella (2002) also points out that in these tanks with low agitation the use of baffles is not so essential. On the other hand, for higher stirring, it is more advisable to use agitators in the form of marine propellers, they stand out for its fluidity in axial direction, or flat turbine impellers that impulse the flow in radial direction where the use of baffles plays an important role to avoid the formation of vortices that can lead to the entry of gas into the

liquid. Marine propeller shaped agitators are more recommended for low viscous fluids, while on the other hand, flat turbine agitators can be used in a wide range of viscosities. Finally, there are also anchor-type agitators that are recommended for mixing high-viscosity ingredients and non-Newtonian fluids.

The baffles are elements attached to the tank that prevent the formation of vortices, so the mixing of the liquids is more effective when they are used. These can have different inclination angles with respect to the axis angle of the tank. Likewise, these are usually 1/10 of the diameter of the tank. (Martinez, n.d.).

Finally, it is necessary to consider a heat transfer system like a heating jacket or coil. The main difference between these two systems is that the coil is immersed in the fluid to be heated, so it can interfere with the mixing process. On the contrary, the jacket is a double bottom that surrounds the tank without being in contact with the fluid to be heated (Martinez Aguilella, 2002).

In this project it has been chosen to work with two mixing tanks with agitation system. According to the proposed shampoo and serum manufacturing procedure, a tank with a capacity of 100 L will be necessary where the smaller volume pre-mixes will be prepared, and another with a capacity of 500 L where the final mixing will be made. Moreover, the one with the smallest capacity will need a jacket heating system that reaches a temperature of 50 degrees. Regarding the agitation system, it will be used one anchor type for the smaller volume tank and another with a turbine with baffles will be used for the larger volume tank.

The chosen equipment is mentioned below. Appendix E contains the technical specifications of the suppliers.

500 L CMC BATCH MIXER EQUIPMENT, INOXPA ®

The highest volume mixing equipment of the INOXPA ® brand CMC model has been chosen. This equipment is made of AISI 316L stainless steel, has a working capacity of 500 L to 1000 L, and allows working at atmospheric pressure at room temperature since it does not have heat transfer equipment. It also has accessories that allow the control of the process through level gauges, sampling, pressure valves, among others. It is a closed system that allows the incorporation of a stirrer proposed by the client, as well as the possibility of incorporating deflectors.

IMMERSION BATCH MIXER FX, SILVERSON®

Since the type of agitator for the larger volume tank of the INOXPA brand allows the incorporation of an agitator according to the customer's choice, it has been decided to choose the SILVERSON mixer. This agitator is composed of blades surrounded by a head that allows high shear on the mixture. It is aimed at emulsions, to homogenize or solubilize mixtures. According to the manufacturer's information, the type of flow created would resemble a turbine agitator, reducing the processing time of the mixture by up to 90%. Its working range is from 5 to 3,000 L. It is built in AISI 316L stainless steel and has a power of up to 3,000 rpm.

Since the type of agitator for the larger volume tank of the INOXPA brand allows the incorporation of an agitator of the customer's choice, it has been decided to choose the SILVERSON mixer. This agitator is composed of blades surrounded by a head that allows high shear on the mixture. It is aimed at emulsions, to homogenize or solubilize mixtures. According to the manufacturer's information, the type of flow created would resemble a turbine agitator, reducing the processing time of the mixture by up to 90%. Its working range is from 5 to 3,000 L. It is built in AISI 316L stainless steel and has a power of up to 3,000 rpm.

100 L MIX-1 BATCH MIXER, INOXPA ®

For the smaller volume tank of 100 L, the model manufactured by the INOXPA brand has been chosen. This equipment is made up of AISI 316L stainless steel, and in addition to the tank, it has a lid, stirrer, and a jacketed heating system. Heat transfer can take place with steam, hot water, or thermal fluid. It allows working at atmospheric pressure. Likewise, it has level control devices, sight glasses, and thermometers. Finally, the agitation system is an anchor type with the possibility of installing deflectors.

EQUITEK EQUIPMENTS

The EQUITEK brand has been chosen for the packaging, capping, and labelling machine. They are three independent machines that belong to the same range and are therefore compatible with each other and allow the process to be efficient. For the packaging machine, the DVS volumetric packaging equipment has been chosen, which is designed for viscous formulations belonging to the cosmetic field and is especially compatible with shampoo packaging. For the

capping machine, a model that screws the cap onto the bottle has been chosen, it is from the ERS SERIES. This model requires the intervention of an operator who places the cap on the bottle and the equipment will plug them. Finally, for the product labelling, the ESZ SERIES model has been selected. This equipment allows to place self-adhesive labels on the container, which can be cylindrical, oval, or flat, so it allows the equipment to be used for other processes.

7. CONCLUSIONS

In this project, it has been possible to develop a formulation based principally on natural ingredients that are known in the traditional market as hair growth stimulators. The present work was done by means of a bibliographic search on the possible ingredients known as hair growth stimulators and on which scientific evidence was found, and from which it was possible to develop the range of products of this project and its preliminary manufacturing process.

In this project it has been decided to develop a formulation and its industrial manufacturing process for a hair serum and shampoo based on a market survey. Through this survey, it was also possible to determine parameters such as appearance, foam, viscosity, and aroma of the shampoo to be developed.

As a previous step to the formulation, the functionalities that these products should achieved were presented, and a design proposal was made for the containers and their volumetric capacities, from which the shampoo container has a capacity of 0.7 L, and the serum has 0.1 L. The shampoo was formulated to wash the scalp and stimulate hair growth and can be removed after a few minutes with water, while the serum was formulated to hydrate the scalp and stimulate hair growth, without leaving an oily sensation and without the need to rinse it. In the same way, the quality factors that would need to be met so that these products can achieve the proposed functional objectives were defined.

Allium Cepa Bulb Extract and Caffeine were selected as active principles for stimulating hair growth, and Rosmarinus officinalis oil and Sulphated Castor oil for the serum. Likewise, additives and excipients, mostly of natural origin, that allow these products to be suitable for both oily and dry scalp, were also selected.

On the other hand, the preliminary shampoo manufacturing process was designed, specifying the order of addition of the ingredients, the stirring time of the mixtures, and the equipment necessary to carry out the industrial process.

Regarding the manufacture of shampoo, a premixing of the detergent phase is proposed, composed of the surfactants and separately, another aqueous phase that contains the active principles and additives, later they would be mixed between them. On the other hand, for the manufacture of the serum, a premixing of the oily phase is proposed, it will contain the oils as active principles and separately a premixing of the aqueous phase with the additives and excipients, in the same way, later they would be mixed between them. It was decided to use the same equipment for the manufacture of the two products, using the supplier brands INOXPA ®, SILVERSON®, and EQUITEK.

Finally, the annual production of cosmetic products was determined in 210 t of shampoo and 8 t of serum, manufactured in batches of 500 kg capacity, and the manufacturing process was proposed through 3 campaigns to produce shampoo and 1 campaign for the production of the serum, thus obtaining 300,000 units of shampoo and 80,000 of serum product.

REFERENCES AND NOTES

Alvarado Vázquez Marco Antonio, Rocha Estrada Alejandra, Moreno Limón Sergio. Plantas productoras de ceras, gomas y resinas. De la lechuguilla a las biopelículas vegetales, **2010**. Universidad autónoma de Nuevo León.

Anna Herman, Andrzej P. Herman, Mechanism of action of herbs and their active constituents used in hair loss treatment, **2016**. Fitoterapia, Volume 114, Pages 18-25, https://doi.org/10.1016/j.fitote.2016.08.008.

Berrada-Gomez M.-P., M. Galonnier, S. Guillou, A. Rielland, D. de Javel, P.- J. Ferret, Influence of packaging on cosmetic product quantity of use, **2015.** Toxicology Letters, Volume 238, Issue 2, supplement, Page S95,

Betancourt-Aguilar, C., Mello-Prado, R., Castellanos-Gonzáles, L., & Silva-Campos, C. N. Características de la glicerina generada en la producción de biodiesel, aplicaciones generales y su uso en el suelo, **2016**. Cultivos tropicales, 37(3), 7-14.

Bolzinger M.A., C. Cogne, L. Lafferrere, F. Salvatori, P. Ardaud, M. Zanetti, F. Puel, Effects of surfactants on crystallization of ethylene glycol distearate in oil-in-water emulsion, Colloids and Surfaces, **2007.** A: Physicochemical and Engineering Aspects, Volume 299, Issues 1–3, Pages 93-100, https://doi.org/10.1016/j.colsurfa.2006.11.026.

Cabanes, C. T., Ferré, A. M., & Neira, M. S. El valor de la urea en el cuidado y tratamiento de la piel, **2008**. Dermatología Peruana, 18(1), 41-44.

Cabrera Villacorta, B. L., & Gallardo Vásquez, G. J. Determinación de la calidad de champús anticaspa comercializadas en el distrito de Trujillo, **2009**. Universidad Nacional de Trujillo.

Castrillón J, Bedoya García M, Burbano Reyn F, González Valbuena S, Muñoz Urrego L, Pinilla Díaz D. Estudio sobre la perdida de cabello y las prácticas de cuidado entre los estudiantes de la Universidad de Manizales, Manizales (Colombia), **2016**. Archivos de Medicina (Col), 19(2),374-386.

C.K.H. Lee, K.L. Choy, Y.N. Chan, A knowledge-based ingredient formulation system for chemical product development in the personal care industry, **2014**. Computers & Chemical Engineering, Volume 65, Pages 40-53, https://doi.org/10.1016/j.compchemeng.2014.03.004.

Córdoba Susana, Borbujo Martínez Jesús M, Conceptos básicos sobre los excipientes en dermatología, **2014.** FMC - Formación Médica Continuada en Atención Primaria, Volume 21, Issue 10, Pages 606-610, https://doi.org/10.1016/S1134-2072(14)70862-X

Cornwell, P.A. A review of shampoo surfactant technology: consumer benefits, raw materials and recent developments, 2018. Int J Cosmet Sci, 40: 16-30. https://doi.org/10.1111/ics.12439

Contreras-Ramírez J., Gallegos-Infante J, Rosas-Flores W., González-Laredo R., Toro-Vázquez J., Pérez-Martínez J. Relationship of rheological and thermal properties in organogel emulsions (W/O): Influence of temperature, time, and surfactant concentration on thermomechanical behavior, **2021**. Journal of Molecular Liquids, Volume 337, 116403, https://doi.org/10.1016/j.molliq.2021.116403

Cristiana Costa, Bruno Fernandes, Diana Guimarães, Eugénia Nogueira, Madalena Martins, Teresa Matamá, Artur Cavaco-Paulo, Comparing the delivery to the hair bulb of two fluorescent molecules of distinct hydrophilicities by different nanoparticles and a serum formulation, **2021.** International Journal of Pharmaceutics, Volume 602, https://doi.org/10.1016/j.ijpharm.2021.120653.

Cunill F., Iborra M., Tejero J. Reactores Químicos Apuntes, **2010**. Universidad de Barcelona

Daneluti, André L., Velasco, Maria V., Baby, André R., Matos, Jivaldo D., Thermal Behavior and Free-Radical-Scavenging Activity of Phytic Acid Alone and Incorporated in Cosmetic Emulsions, Cosmetics, **2015.** Elsevier.

Danila Angela, Ibanescu Sorin-Alexandru, Zaharia Carmen, Muresan Emil, Popescu Alina, Maricel Danu, Vlad Rotaru. Eco-friendly O/W emulsions with potential application in skincare products, **2021**. Colloids and Surfaces A: Physicochemical and Engineering Aspects, Volume 612, 125969, https://doi.org/10.1016/j.colsurfa.2020.125969

Díaz, D. J. F. J., & Suárez, D. J. C. Plantas medicinales, **2013**.

Díaz Ramírez, Carmen Cristina, & Villafuerte Robles, Leopoldo. Elementos que influyen la medición del efecto de electrolitos sobre la extensión de una gota de champú, **2012**. Revista mexicana de ciencias fa ciencias farmacéuticas, 43(2), 31-45.

Failor, Catherine. Jabones líquidos, **2001**. Paidotribo, Barcelona

Fajardo-Romero, A. Arroyo-Rivera, A. Ramírez-Navas, J.S. Extracción de flavonoides totales de la envoltura externa de cebolla roja (Allium cepa), **2016.** UGCiencia, 22, 119-126.

Fischer, T.W., Hipler, U.C. and Elsner, P. Effect of caffeine and testosterone on the proliferation of human hair follicles in vitro, **2007**. International Journal of Dermatology, 46: 27-35. https://doi.org/10.1111/j.1365-4632.2007.03119.x

Fiume, M. M., Heldreth, B. A., Bergfeld, W. F., Belsito, D. V., Hill, R. A., Klaassen, C. D., Liebler, D. C., Marks, J. G., Shank, R. C., Slaga, T. J., Snyder, P. W., & Andersen, F. A. Safety Assessment of Citric Acid, Inorganic Citrate Salts, and Alkyl Citrate Esters as Used in Cosmetics, **2014**. International Journal of Toxicology, 33(2 suppl), 16S-46S. https://doi.org/10.1177/1091581814526891

Gani Rafiqul, Ka M. Ng, Product design: Molecules, devices, functional products, and formulated products, 2015. Computers & Chemical Engineering, Volume 81, Pages 70-79.

García Bacallao, Lourdes, Rojo Domínguez, Delia Mercedes, García Gómez, Luis Vicente, & Hernández Ángel, Maureen. Plantas con propiedades antiinflamatorias, **2002**. Revista Cubana de Investigaciones Biomédicas, 21(3), 214-216

Gil Pozo Juan Fernando, Pablo Wilson Arevalo Moscoso. Evaluación de modificadores reológicos en una formulación de champú como alternativa al uso de cloruro de sodio, **2018**. Universidad Politécnica Salesiana, Ecuador.

González Minero, Francisco José, & Bravo Díaz, Luis. History and present of skin care products, cosmetics and fragrances. Especially those derived from plants, **2017**. Ars Pharmaceutica, 58(1), 5-12.

Goreja, W. G. Shea butter: the nourishing properties of Africa's best-kept natural beauty secret, **2004**. TNC International Inc.

Grimalt Ramon, La seguridad en los cosméticos capilares, 2014. Piel, Volume 29, Issue 3, , Pages 184-189, https://doi.org/10.1016/j.piel.2013.11.005

Guerrero R, Kahn M. Alopecias, **2011**. Rev Med Clin Condes; 22:773-781.

Herman, A., Herman, A.P., Domagalska, B.W. et al. Essential Oils and Herbal Extracts as Antimicrobial Agents in Cosmetic Emulsion, **2013**. Indian J Microbiol 53, 232–237 https://doi.org/10.1007/s12088-012-0329-0

Huber P, Sensory Measurement, Evaluation and Testing of Cosmetic Products, **2017.** Cosmetic Science and Technology Chapter 37, Elsevier, pages 617-633.

Iglesias Sancho Maribel, Nuria Lamas Doménech, Francesc Llambí Mateos, Formulación magistral en las enfermedades del pelo, **2016.** Piel, Volume 31, Issue 2, , Pages 131-138, https://doi.org/10.1016/j.piel.2015.09.003

Jacob, Sharon E.; Amini, Sadegh. Cocamidopropyl Betaine, **2008.** Dermatitis,Volume 19, Issue 3, p 157

Jimenez Ss, Uribe C, Restrepo I. Guías para el manejo de las enermedades más frecuentes del pelo, **2012**. Rev Asoc Colomb Dermatol; 20: 54-75.

José Muñoz,M. Hidratación cutánea. Estética y salud, **2008**. Offarm vol 27, n 11.

Ken Klein, Irwin Palefsky, C.2 - Shampoo Formulation, **2007**. Handbook for leaning/Decontamination of Surfaces, Elsevier Science B.V., Pages 277-304, https://doi.org/10.1016/B978-044451664-0/50008-5.

Ken Klein. Evaluating shampoo foam, **2004**. Cosmetic & Toiletries magazine, Vol 119, No 10, p. 32-35.

Khaloud Al Badi, Shah A. Khan, Formulation, evaluation and comparison of the herbal shampoo with the commercial shampoos, **2014.** Beni-Suef University Journal of Basic and Applied Sciences, Volume 3, issue 4, Pages 301-305, https://doi.org/10.1016/j.bjbas.2014.11.005.

Kim, H.-R., Sung, Y.-W., & Choi, W.-J. Effects of Hair Treatment with Shea Butter on Bleached Hair, **2021**. Journal of Convergence for Information Technology, 11(3), 212–219. https://doi.org/10.22156/CS4SMB.2021.11.03.212´

Klaassen, C. D. Final Report on the Safety Assessment of Sodium Cetearyl Sulphate and Related Alkyl Sulfates as Used in Cosmetics, **2010**. International journal of Toxicology, 29, 2.

Lacueva, S., & Marimon, N. Los ácidos alquil éter carboxílicos y sus sales, una opción ultra-suave para formulaciones cosméticas, **2019.**

Lawan, K., Kanlayavattanakul, M., & Lourith, N. Antimicrobial efficacy of caprylyl glycol and ethylhexylglycerine in emulsion, **2009**. Journal of Health Research, 23(1), 1-3.

López Velasco, D. M., & Sabogal Forero, O. J. Gomas empleadas en la industria de alimentos, **2018**.

Martínez Aguilella, P. Diseño de un tanque mezclador con sistema de calentamiento para la producción de protectores solares, **2020**. Universitat Jaume I

Martinez, R. S. R. Laboratorio de Mecánica de Fluidos, **n.d**. Universidad autónoma metropolitana Unidad Iztapalapa.

Montalvo Ponce B., Rondan Escalante L. Tesis sobre el estudio de prefactibilidad para la fabricación y comercialización de champú de quinua en lima, **2013**. Facultad de Ciencias e Ingeniería, Pontificia Universidad Católica del Perú.

Montes, M., Navas, E., Padilla, M., & Veliz, A. Elaboración de un champú acondicionador a base de aloe vera, **2019**. Ingenium et Potentia, 1(1), 38-49.

Muñoz-Centeno, Luz. Plantas medicinales españolas: Rosmarinus officinalis L. (Lamiaceae), **2002**.

Ortiz, S. G., Facundo, S. G., Rodríguez, J. M. O., & Vicuña, A. J. Z. Manual de formulación de medicamentos individualizados en podología, **2017**. Formulario Acofarma.

Pastor-Nieto María Antonia, Francisco Alcántara-Nicolás, Virginia Melgar-Molero, Raquel Pérez-

Mesonero, Aránzazu Vergara-Sánchez, Adriana Martín-Fuentes, Patricia González-Muñoz, Ester de Eusebio-Murillo, Conservantes en productos de higiene y cosméticos, medicamentos tópicos y productos de limpieza doméstica en España,**2017**. Actas Dermo-Sifiliográficas, Volume 108, Issue 8, Pages 758-770, https://doi.org/10.1016/j.ad.2017.04.003.

Preston John C.. Pearlescent Shampoo And Method For Preparation Of Same, **1987**. Espacenet Patent. https://worldwide.espacenet.com/patent/search/family/024857259/publication/EP0215025A1?q=pn%3DEP0215025A1

Panahi Y, Taghizadeh M, Marzony ET, Sahebkar A. Rosemary oil vs minoxidil 2% for the treatment of androgenetic alopecia: a randomized comparative trial, **2015**. Skinmed. Jan-Feb;13(1):15-21.

Quiroa Muñoz, Yolanda Herminia. Identificación de las sustancias inorgánicas usadas en la Industria de Cosméticos y las consecuencias que produce en la salud, **2014**. Universidad del Callao.

Restrepo, R. Anatomía microscópica del folículo piloso, **2019**. Revista De La Asociación Colombiana De Dermatología Y Cirugía Dermatológica, 18(3), 123-138.

Rodríguez, J. R. E., González, P. E., Fernández, A. M., & Peña, J. G. Fitoterapia y sus aplicaciones, **2011**. Revista española de podología, 22(6), 258-267.

Rodríguez Orjales, Ileana. Agentes promotores de la permeación percutánea, **1998**. Revista Cubana de Farmacia, 32(1), 68-75.

Shashi Upadhyay, Kapil Bisht, Amit Bahukhandi, Monika Bisht, Poonam Mehta, Arti Bisht, Rosmarinus officinalis L. 2021. Academic Press, Chapter 3.2.6, Pages 271-281, https://doi.org/10.1016/B978-0-12-819212-2.00022-0

Solar Arcos, Rafael. Determinación de cafeína en café de grano comercial, 2018. Universidad Técnica Federico Santa María.

Taylor, K., Rego, L., & Weber, T. Recommendations to improve the EU non-technical summaries of animal experiments, **2018**. ALTEX - Alternatives to Animal Experimentation, 35(2), 193-210. https://doi.org/10.14573/altex.1708111

Teichmann, A., Richter, H., Knorr, F., Antoniou, C., Sterry, W., & Lademann, J. Investigation of the penetration and storage of a shampoo formulation containing caffeine into the hair follicles by in vivo laser scanning microscopy, **2007**. Laser Physics Letters, 4(6), 464-468.

Tintaya Allpacca, M. A., Velasquez Pinto, J. B., Curasco Usucachi, L. N., Quintana Peña, E. J., Ccahuantico-Choquevilca, L. A., & Pillco Quispe, K. H.. Revisión anatómica del cuero cabelludo, **2021**. Revista Peruana De Morfología, 1 (2).

Trueba, E. Z. Cosmecéuticos, **2021**. Universidad Católica Santa Maria de Chile.

Valderrama, J., & VENA, A. M. Y. F. A. Producto, El Aceite De Ricino, **1994**. Información Tecnológica, 5(1), 87.

Vargas, C. R. Q., Sehtman, A., & Allevato, M. Urea, **2008**. División Dermatología Hospital de Clínicas" José de San Martín"(UBA). Buenos Aires, 31, 170.

Varvaresou, A., Papageorgiou, S., Tsirivas, E., Protopapa, E., Kintziou, H., Kefala, V. and Demetzos, C. Self-preserving cosmetics, **2009**. International Journal of Cosmetic Science, 31: 163-175. https://doi.org/10.1111/j.1468-2494.2009.00492.

Z. Ding, M. Wu, Q. Guo, X. Yang and B. Zhang, Encapsulation of a flavonoid-rich Allium cepa L. var. agrogatum don extract in β-cyclodextrin for transdermal drug delivery, **2013.** J. Agric. Food Chem., 61, pp. 4914-4920

Zhang, L., Fung, K., Wibowo, C. & Gani, R. Advances in chemical product design, **2018**. Reviews in Chemical Engineering, 34(3), 319-340.

CONSULTED AND REFERENCED WEBSITE PAGES

Svenson. Consejos para favorecer la salud del cabello, **n.d**. Retrieved March 2021, from: https://www.svenson.es/todo-sobre-el-pelo/consejos-salud-de-cabello/

Herbal. ¿Para qué sirve el champú? n.d. Retrieved March 2021, from: https://herbal.es/para-que-sirve-el-champu/#

Comisión Europea. El reciclado es el futuro: así lo hacemos en la UE, **2019**. Retrieved April 2021, from: https://ec.europa.eu/spain/news/20190318_Recycling-is-the-future-we-do-it-in-the-EU_es

National Geographic España. Tipos de plástico según su facilidad de reciclaje, **2020**. Retrieved April 2021, from: https://www.nationalgeographic.com.es/ciencia/actualidad/tipos-plastico-segun-su-facilidad-reciclaje_12714/2

Plastisax. Cuándo usar Polietileno (HDPE-LDPE) o Polipropileno (PP), 2018. Retrieved April 2021, from: https://plastisax.com/cuando-usar-polietileno-hdpe-ldpe-polipropileno-pp/

Tecnosoluciones. Análisis en Cosméticos, 2020. Retrieved April 2021, from: https://tecnosolucionescr.net/blog/219-analisis-en-cosmeticos

INCY BEAUTY. Cocamidopropyl Betaine, n.d. Retrieved May 2021, from: https://incibeauty.com/es/ingredients/6903-cocamidopropyl-betaine

UAB in collaboration with Condalab. Análisis microbiológico en la industria cosmética, n.d. Retrieved May 2021, from: https://jornades.uab.cat/workshopmrama/sites/jornades.uab.cat.workshopmrama/files/industria_cosmetica.pdf

IDUN Nature. Sodium Lauryl Sulfate, Sodium Coco Sulfate y Sodium Laureth Sulfate ¿En qué se diferencian?, 2014. Retrieved May 2021, from: https://www.idun-nature.com/blog/archivos/tag/etoxilados/.

INCY BEAUTY. Cetrimonium Chloride, n.d. Retrieved May 2021, from: https://incibeauty.com/es/ingredients/5527-cetrimonium-chloride

Official Journal of the European Union. REGLAMENTO (UE) 2016/1143 DE LA COMISIÓN de 13 de julio de **2016** por el que se modifica el anexo VI del Reglamento (CE) n.o 1223/2009 del Parlamento Europeo y del Consejo, sobre los productos cosméticos. Retrieved May 2021, from: https://www.boe.es/doue/2016/189/L00040-00043.pdf

LUSH Fresh Handmade Cosmetics. Cetrimonium Chloride, n.d. Retrieved May 2021, from: https://es.lush.com/ingredients/cetrimonium-chloride-0

Instituto Dermocosmética. Aceite de ricino sulfatado, n.d. Retrieved May 2021, from: https://www.institutodermocosmetica.com/fichas-tecnicas/emulgentes-tensioactivos/aceite-de-ricino-sulfonado/#:~:text=El%20aceite%20de%20ricino%20sulfatado,sint%C3%A9tico%20despu%C3%A9s%20del%20jab%C3%B3n%20ordinario.&text=PROPIEDADES%20F%C3%8DSICAS%3A,color%20amarillo%2Danaranjado%20a%20marr%C3%B3n.

INE (National Institute of Statistics) agency on July 1, **2020**, Retrieved June 2021, from: https://www.ine.es/jaxi/Tabla.htm?path=/t20/e245/p04/provi/l0/&file=0ccaa003.px&L=0

Acofarma S.L. Fichas De Información Técnica Manteca Karité, n.d. Retrieved June 2021, from: https://formulasmagistrales.acofarma.com/idb/descarga/3/fd00518543b1e6ae.pdf

INOXPA. 500 L CMC EQUIPMENT, n.d. Retrieved June 2021, from: https://www.inoxpa.es/uploads/document/Fitxa%20tecnica/Equips/CMC/FTsolCMC.2_ES.pdf

SILVERSON. Immersion Batch Mixer FX, n.d. Retrieved June 2021, from: https://www.silverson.es/images/uploads/products/Batch-Tech-Info-Es.pdf

INOXPA. 100 L MIX-1 Batch Mixer, n.d. Retrieved June 2021, from: https://www.inoxpa.es/uploads/document/Fitxa%20tecnica/Equips/MIX%20blender%20skids/FTsolMIX.1_ES.pdf

EQUITEK. DVS volumetric packaging equipment, n.d. Retrieved June 2021, from: https://equitek.com.mx/envasadora-dvs/

EQUITEK. SERIE ERS cap packaging equipment, n.d. Retrieved June 2021, from: https://equitek.com.mx/tapadora-ers/

EQUITEK. SERIE ESZ bottle labelling equipment, n.d. Retrieved June 2021, from: https://equitek.com.mx/etiquetadora-esz/

ACRONYMS

HDP: High-Density Polyethylene

PET: Polyethylene Terephthalate

EC: European Commission

ISO: International Organization for Standardization

FDA: Food and Drug Administration

AGA: Androgenetic alopecia

VEG: Vascular endothelial growth factor

EDTA: Ethylenediaminetetraacetic acid

EGDS: Ethylene glycol distearate

VCRP: Voluntary Cosmetic Registration Program

UV: Ultraviolet

INCI: International Nomenclature of Cosmetic Ingredients)

O/W: Oil-in-water emulsion

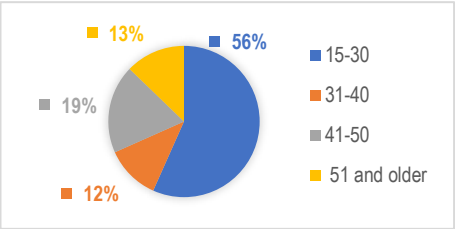
INE: National Statistics Institute

APPENDICES

APPENDIX A: MARKET ANALYSIS TRENDS

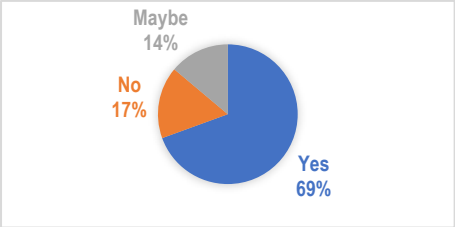
The questions were multiple-choice and single-choice responses. In some questions, depending on the choice of the respondent, they were led by one way or another in the survey. That is, the 180 respondents did not answer the same questions, so it can be seen that not all questions have the same number of responses. All the graphs that will be exposed were of own realization.

Figure A1. Ages of the respondents.



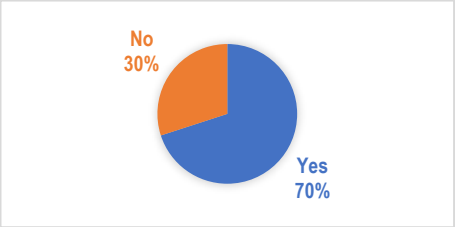
Age	
Options	**Population**
15-30	102
31-40	21
41-50	34
51 and older	23

Figure A2. Opinion on baldness in personal image.



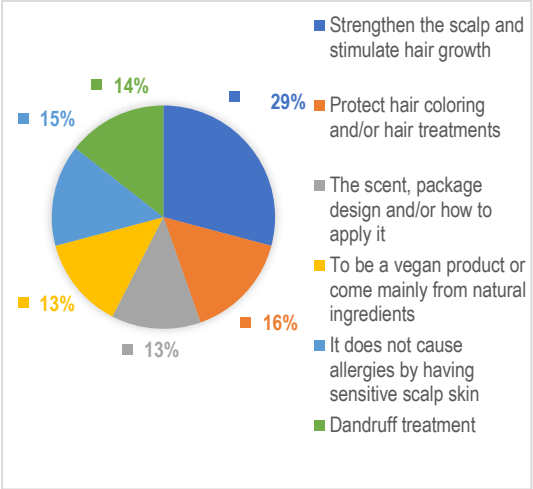
Question 2: Have you consider that baldness or hair loss affects your personal image?	
Options	**Population**
Yes	125
No	30
Maybe	25

Figure A3. Use of specific hair products.



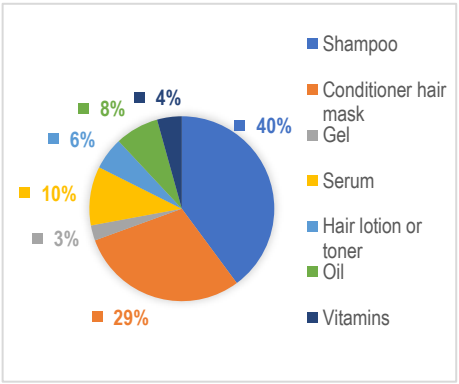
Question 3: Do you consume, or have you consumed products for your hair's specific needs (hair loss, color protection, etc.) in the form of shampoo, lotion, spray, mask, serum or vitamins?	
Options	**Population**
Yes	126
No	54

Figure A4. Purpose of the specific hair products.



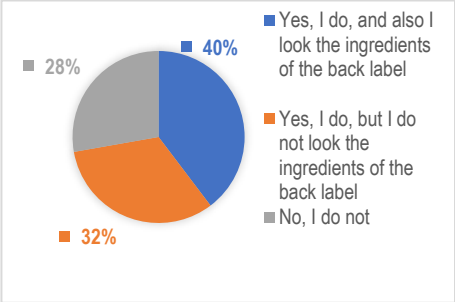
Question 4: What do you usually prioritize in these products?	
Option	**Population**
Strengthen the scalp and stimulate hair growth	81
Protect hair coloring and/or hair treatments	43
The scent, package design and/or how to apply it	36
To be a vegan product or come mainly from natural ingredients	37
It does not cause allergies by having sensitive scalp skin	41
Dandruff treatment	40

Figure A5. Format of the specific hair products.



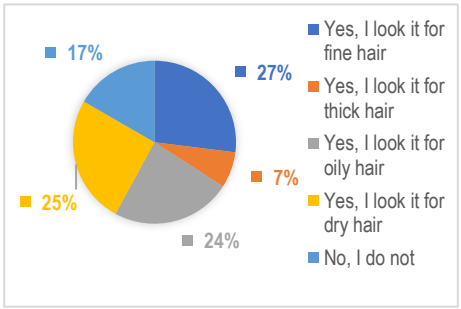
Question 5: In what format do you use this specific product for that need of your hair?	
Option	**Population**
Shampoo	120
Conditioner hair mask	89
Gel	8
Serum	31
Hair lotion or toner	17
Oil	23
Vitamins	13

Figure A6. Priority in the use of natural ingredients in specific hair products.



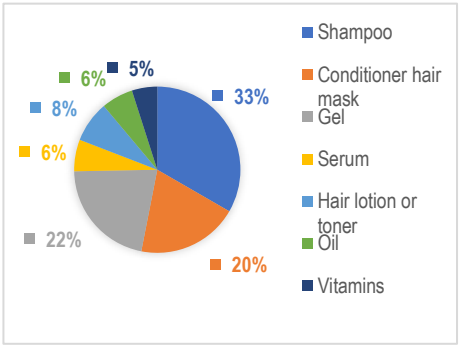
Question 6: Do you prioritize that the ingredients are of natural origin?	
Option	**Population**
Yes, I do, and also I look the ingredients of the back label	50
Yes, I do, but I do not look the ingredients of the back label	41
No, I do not	35

Figure A7. Hair type in the use of specific hair products.



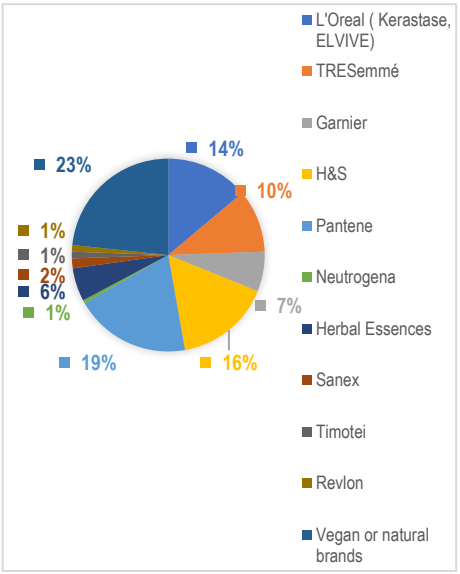
Question 7: Do you usually look for specific products for your hair type?	
Option	**Population**
Yes, I look it for fine hair	34
Yes, I look it for thick hair	9
Yes, I look it for oily hair	30
Yes, I look it for dry hair	32
No, I do not	21

Figure A8. Format of generic hair products.



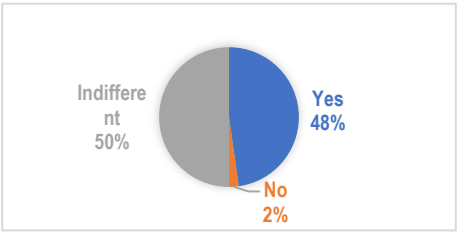
Question 8: In what format do you use generic hair products?	
Option	**Population**
Shampoo	54
Conditioner hair mask	32
Gel	35
Serum	10
Hair lotion or toner	13
Oil	10
Vitamins	8

Figure A9. Shampoo brand.



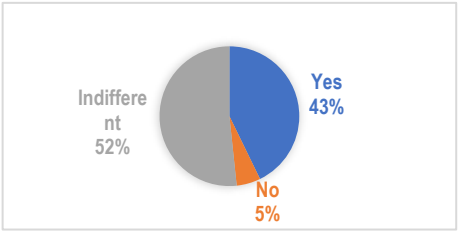
Question 9: What is your brand preference in shampoo?	
Option	**Population**
L'Oreal (Kerastase, ELVIVE)	25
TRESemmé	19
Garnier	12
H&S	29
Pantene	35
Neutrogena	1
Herbal Essences	10
Sanex	3
Timotei	2
Revlon	2
Vegan or natural brands	42

Figure A10. Use of sulphates in shampoo.



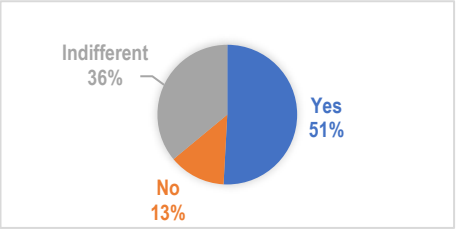
Question 10: Is it your preference that your shampoo does not contain sulphates?	
Option	**Population**
Yes	86
No	4
Indifferent	90

Figure A11. Use of silicones in shampoo.



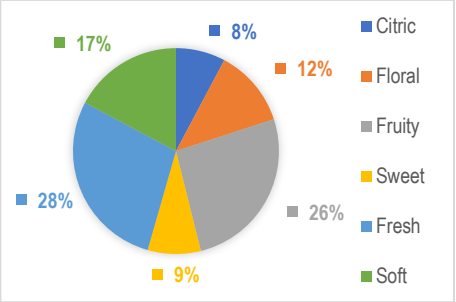
Question 11: Is it your preference that your shampoo does not contain silicones?	
Option	**Population**
Yes	77
No	10
Indifferent	93

Figure A12. Preference on a lather of the shampoo.



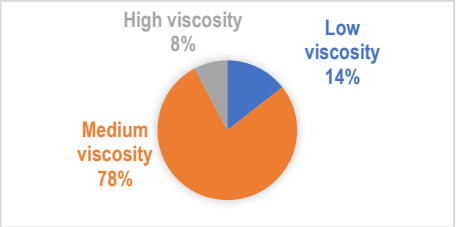
Question 12: Is it your preference that your shampoo generates good lather?	
Option	**Population**
Yes	89
No	23
Indifferent	63

Figure A13. Preference on scent of the shampoo.



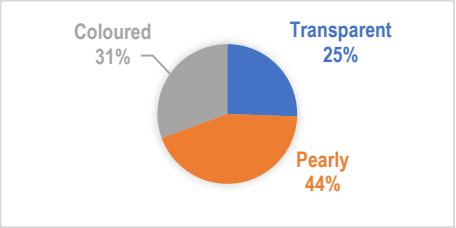
Question 13: What scent do you prefer in your shampoo?	
Option	**Population**
Citric	14
Floral	22
Fruity	47
Sweet	15
Fresh	51
Soft	31

Figure A14. Preference on viscosity of the shampoo.



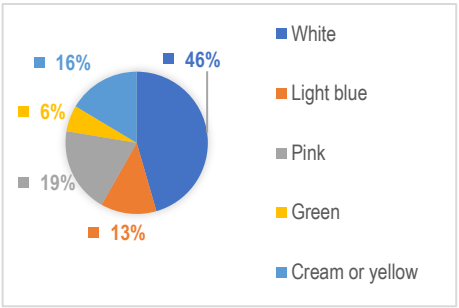
Question 14: How do you prefer the viscosity of your shampoo to be?	
Option	**Population**
Low viscosity	26
Medium viscosity	140
High viscosity	14

Figure A15. Preference on the appearance of the shampoo.



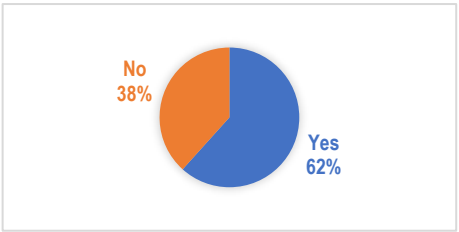
Question 15: How do you prefer the appearance of your shampoo to be?	
Option	**Population**
Transparent	46
Pearly	79
Coloured	55

Figure A16. Preference on color of the shampoo.



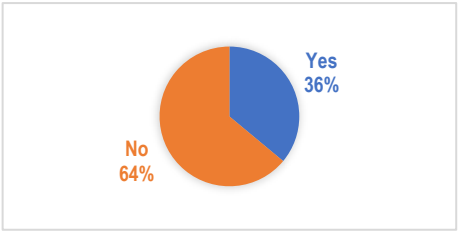
Question 16: What color would you prefer in your shampoo?	
Option	**Population**
White	61
Light blue	17
Pink	26
Green	8
Cream or yellow	22

Figure A17. Use of hair growth stimulation products.



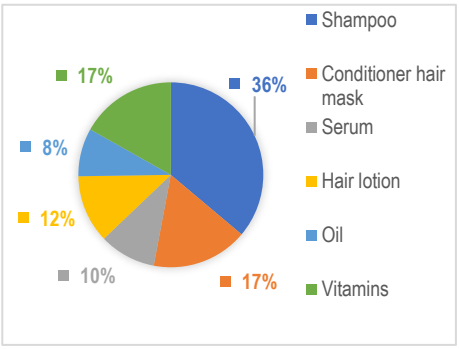
Question 17: Have you used hair growth stimulation products?	
Option	**Population**
Yes	111
No	69

Figure A18. Use of products to prevent hair loss and strengthen it.



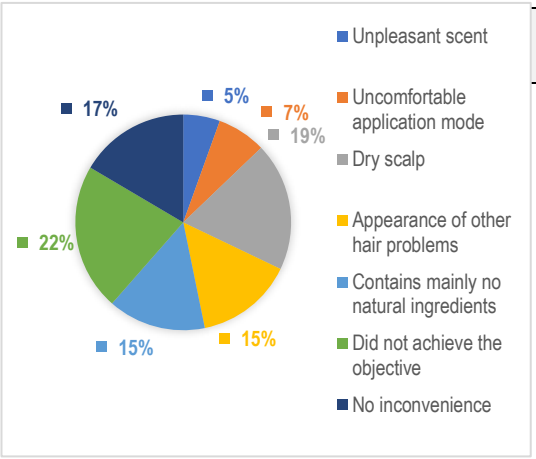
Question 18: Have you used products to prevent hair loss and strengthen it?	
Option	**Population**
Yes	40
No	71

Figure A19. Format of products to prevent hair loss and strengthen it, or hair growth stimulation products.



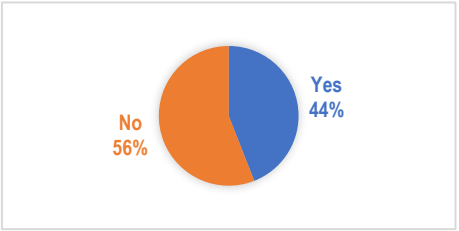
Question 19: In what format do you use this hair product?	
Option	**Population**
Shampoo	73
Conditioner hair mask	34
Serum	20
Hair lotion	24
Oil	17
Vitamins	34

Figure A20. Negative opinion of those products.



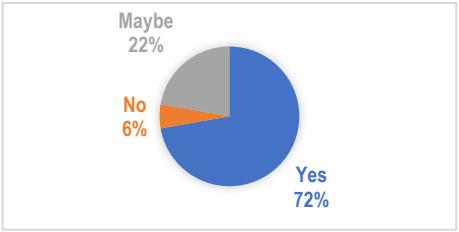
Question 20: What negative opinion about these products that you have used do you have?	
Option	**Population**
Unpleasant scent	6
Uncomfortable application mode	8
Dry scalp	21
Appearance of other hair problems	16
Contains mainly no natural ingredients	16
Did not achieve the objective	24
No inconvenience	18

Figure A21. Use of hair homemade treatments.



Question 21: Have you used natural or homemade treatments to have healthy hair?	
Option	**Population**
Yes	48
No	61

Figure A22. Use of products formulated with natural ingredients to stimulate hair growth and prevent hair loss.



Question 22: Would you use a product made mainly with natural ingredients to stimulate hair growth and prevent hair loss?	
Option	**Population**
Yes	130
No	10
Maybe	40

APPENDIX B: INGREDIENTS OF THE 3 MOST COMMONLY USED SHAMPOOS

Shampoo	Ingredients
Pantene Repair & Care	Water, Sodium Laureth Sulfate, Sodium Citrate, Cocamidopropyl Betaine, Sodium Xylenesulfonate, Stearyl Alcohol, Sodium Lauryl Sulfate, Sodium Chloride, Cetyl Alcohol, Parfum, Citric Acid, Sodium Benzoate, Polyquaternium-6, Guar Hydroxypropyltrimonium Chloride, Tetrasodium EDTA, Sodium Hydroxide, Trisodium Ethylenediamine Disuccinate, Trihydroxystearin, Panthenol, Panthenyl Ethyl Ether, Hexyl Cinnamal, Hydroxycitronellal, Magnesium Nitrate, Methylchloroisothiazolinone, Magnesium Chloride, Methylisothiazolinone
L'Oréal Color Vive Protect	Water, Sodium Laureth Sulfate, Dimethicone, Coco-betaine, Sodium Chloride, Glycol Distearate, Guar hydroxypropyltrimonium, Chloride, Cocamide Mipa, Tocopherol, Cocos Nucifera Oil/Coconut Oil, Sodium Benzoate, Sodium Hydroxide, Ethylhexyl Methoxycinnamate, Salicylic Acid, Poly (Linseed Oil), Fumaric Acid, Benzophenone- 4, Benzyl Alcohol, Benzyl Salicylate, Linalool, Alpha-Isomethyl Ionone, Carbomer, Geraniol, Butylphenyl Methylpropional, Citronellol, Bht, Citric Acid, Hexylene Glycol, Hexyl Cinnamal, Parfum.
H&S Citrus Fresh	Water, Sodium Laureth Sulfate, Sodium Lauryl Sulfate, Cocamidopropyl Betaine, Glycol Distearate, Sodium Chloride, Parfum, Piroctone Olamine, Citric Acid, Sodium Citrate, Menthol, Dimethiconol, Sodium Benzoate, Guar Hydroxypropyltrimonium Chloride, Dimethicone, Sodium Xylenesulfonate, Tetrasodium EDTA, Sodium Hydroxide, TEA-Dodecylbenzenesulfonate, Trideceth-10,Hexyl Cinnamal, Limonene, Benzyl Salicylate, Propylene Glycol, Citronellol, Magnesium Nitrate, Citrus Limon Fruit Extract, CI 19140, Methylchloroisothiazolinone, Magnesium Chloride, Triethylene Glycol, Methylisothiazolinone, CI42090

APPENDIX C: MAIN DIFFERENCES BETWEEN THE MOST USED HAIR PRODUCTS

- Shampoo: A shampoo has the main purpose of washing the scalp, so it is a rinse product. This function is carried out by surfactants, allowing the oil on the scalp to wash off with the water, forming an emulsion. In the cosmetic industry, active ingredients are added, so they also provide a differential quality.
- Conditioner hair mask: It is a product that closes the cuticles of the hair fiber, leaving a soft sensation on the hair. Usually, this effect is carried out through the use of emollient ingredients that provide hydration and shine to the hair fibers. It is also a rinse product.
- Hair lotion: It is a product intended to treat a hair or scalp problem, it is generally not oily in texture and its viscosity is low, so it resembles water. They are usually products that are absorbed quickly.
- Serum: It is a product that solves a hair problem, as it contains high concentrations of active ingredients. It is of low-medium viscosity. It can be a product with a non-greasy texture that is absorbed into the scalp or a product that is applied to the hair. Depending on the ingredients, the absorption time may vary.
- Oil: They are usually extracts of plant oils, so it is a product with an oily texture, it is generally applied to the hair and not to the scalp. Unlike serum, oil is of higher viscosity. It also solves a specific hair problem.
- Gel: It is a product used for combing, as it helps to maintain a specific hairstyle as it contains gelling ingredients that, in contact with air and hair, fix the position of the fibers.

APPENDIX D: TYPES OF PLASTICS COMMONLY USED AND RECYCLABLE

Recyclable plastic type	Characteristics	Common uses
PET (Polyethylene Terephthalate)	It is a transparent plastic and is one of the most used and recycled plastics. It is very strong and lightweight and hence easy and efficient to transport. Also, it has broad range of use temperature, from -60 to 130°C. It has low gas permeability and is suitable for transparent applications, when quenching during processing.	Beverage bottles, food containers, clothing and carpet fibers, shampoo bottles, mouthwashes, etc.
HDPE (High Density Polyethylene)	Flexible, translucent/waxy, weatherproof, good low temperature toughness (to -60 ºC), easy to process by most methods, low cost, good chemical resistance.	Milk cartoons, shampoo bottles, detergent, food containers, storage boxes, toys, buckets, pots, garden furniture, etc.
PP (Polypropylene)	Semi-rigid, translucent, good chemical resistance, hard, good resistance to fatigue, good heat resistance. It has no stress cracking problems and offers excellent electrical and chemical resistance at higher temperatures.	Prepared food trays, bottle caps, straws, lunch boxes, coolers, fabric and carpet fibers, tarps, diapers.
PVC (Polyvinyl Chloride)	It is an electrical and thermal non-conductive material, it is a light, chemically inert and harmless material. Thanks to this,	Credit cards, window and door frames, gutters, pipes, cable

	it is widely used with various uses in the health and food industry. Its good impact strength and weatherproof attributes make it ideal for construction products.	sheathing, synthetic leather. It is used for healthcare products used in surgery, pharmaceuticals, drug delivery, and medical packaging due to its features and cost effectiveness.
LDPE (Low Density Polyethylene)	Low density, excellent resistance to acids, alcohols, bases and esters. Excellent electrical properties and limited resistance, but good resistance to aldehydes, ketones and vegetable oils.	Food bag, plastic wrap, shopping bags, bubble wrap, flexible bottles, cable insulators
PS (Polystyrene)	It is a hard and solid material; two main types are distinguished: Expanded polystyrene: foamy material, good resistance to humidity and its lightness. Extruded polystyrene: rigid material, it has cushioning and insulation properties, it is a material most probably used in construction, especially as a floor insulation, cold rooms, etc.	Plastic cutlery, insulated cups, egg cups, food trays, packing filler, yogurt containers, hangers, insulation.
Others: Polyethylene, ABS (Acrylonitrile butadiene styrene), Polystyrene, Nylons, Polycarbonate, Acrylic, Acetal		

APPENDIX E. COMPLEMENTARY INFORMATION OF THE MANUFACTURING PROCESS

This appendix contains images of the equipment mentioned in chapter 6 “PRELIMINARY DESIGN OF THE MANUFACTURING PROCESS”.

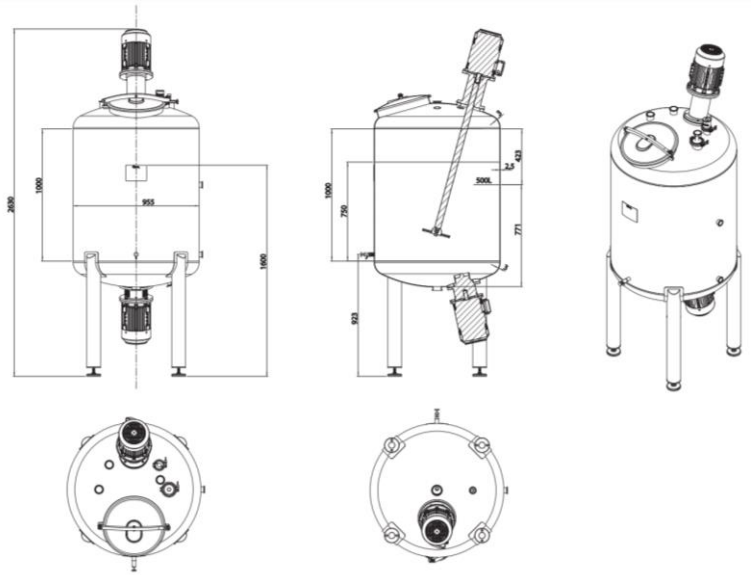


Figure E1. 500 L CMC EQUIPMENT, INOXPA ®

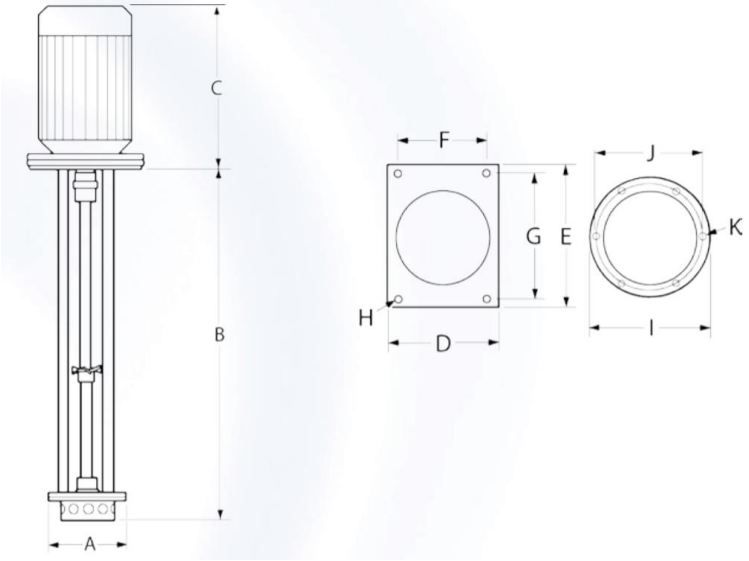


Figure E2. Immersion Batch Mixer FX, Silverson®

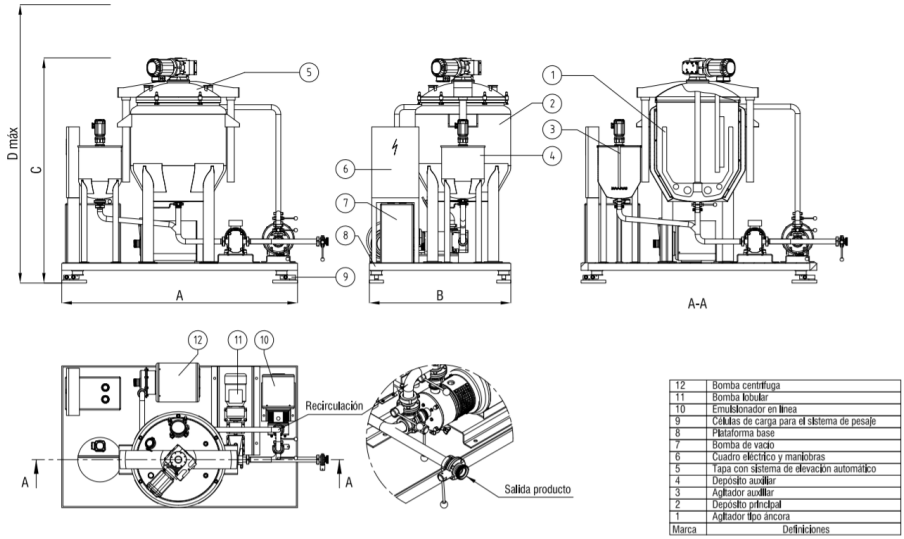


Figure E3. 100 L MIX-1 Batch Mixer, INOXPA ®

Figure E4. DVS volumetric packaging equipment, EQUITEK.

Figure E5. SERIE ERS cap packaging equipment, EQUITEK.

Figure E6. SERIE ESZ bottle labelling equipment, EQUITEK.

Rough estimation of the heat flow and water flow to be supplied by the heating jacket.

The 100 L MIX-1 Batch Mixer tank, INOXPA ®, has a heating jacket since in the proposed manufacturing process it is desired to raise the temperature of the mixtures that are carried out in this equipment to 50 ºC. For this reason, the calculations carried out to roughly estimate the heat flow and the required water flow, which it has been decided to use at 80ºC, are exposed below.

The heat to be delivered can be calculated as the mass of liquid to be heated multiplied by the heat capacity of the mixture, multiplied by the temperature change of the mixture as follows in equation (1). The density and heat capacity of the mixture has been approximately to be about that of water.

$$Q = m_{mixture} \cdot Cp_{mixture} \cdot (T_{final,mixture} - T_{initial,mixture}) \quad (1)$$

It was decided to heat and blend the mixture for 5 minutes for the oily mixture, and 20 minutes for the stabilizing mixture, so that the heat flow rate to be supplied at this time can be obtained. This heat flow will be supplied by a stream of liquid water at 80ºC, which will lose heat throughout the process so its final temperature could be 75ºC, so the necessary water flow can be estimated as follows in equation (2).

$$Q_{flow} = m_{water} \cdot Cp_{water} \cdot (T_{final,water} - T_{initial,water}) \quad (2)$$

Isolating the mass of water needed per minute, equation (3) is obtained.

$$m_{water} = \frac{Q_{flow}}{Cp_{water} \cdot (T_{final,water} - T_{initial,water})} \quad (3)$$

Table E1. Heat flow to be supplied by the heating jacket and water flow.

	Stabilizing base (100 L)	Oily phase (60 L)
Q (kJ)	12,558	7,535
Q_{flow} (kJ/min)	628	1,507
Q_{water} (L/min)	15	36