Tutora
Dra. M. Esther Santamaría

UNIVERSITAT DE BARCELONA

Grau en Enginyeria Química

Treball Final de Grau

Development of a range of products for acne treatment on sensitive skin and preliminary design of its manufacturing process.

Irene Zamora Carballo

June 2022

Antes que nada, querría agradecer a mi tutora María Esther Santamaría Hernández por su ayuda, tiempo y dedicación en el seguimiento del trabajo.

En segundo lugar, dar las gracias a las personas más importantes de mi vida y que más me han apoyado a lo largo de estos cuatro años: mis padres, mi hermano y mis abuelos, por ser un claro ejemplo de constancia y esfuerzo, así como por animarme a alcanzar mis metas.

Por último, destacar que este trabajo implica el cierre de una etapa donde he podido conocer compañeros que se han convertido en grandes amigos. Sin ellos, esta experiencia no hubiese sido lo mismo.

CONTENTS

SUMMARY

In this day and age, consumer needs are increasingly individualised, diverse and changing. Due to this fact, product development aims to satisfy these needs by transforming them into a commercial product available on the market.

Specifically, skin care products are of great relevance in today's society and therefore can be said to have had a major impact on the cosmetics industry. They are considered to be part of the daily routine of a large part of the population as, in addition to helping to achieve healthier skin, they also improve self-esteem. In relation to this fact, one of the most frequent dermatological conditions which can have a negative impact on self-esteem, is acne.

It is worth mentioning that as a result of the pandemic caused by the COVID-19 virus and the continued use of face masks, an increase and/or worsening of acne has been observed. As a result, there is a greater need for products for the treatment of this skin disease. On the other hand, its treatment can be complex specially in people with sensitive skin prone to inflammation and redness. Therefore, the present work is based on the development of a range of formulated products for the treatment of acne on sensitive skin. In particular, it includes a facial cleansing gel and a night cream to help control the appearance of pimples and reduce scarring caused by acne. The formulation of both cosmetics consists of O/W emulsions, although the cleansing gel is a microemulsion and the night cream is a macroemulsion. In addition, it should be noted that the active acne treatment ingredients used in the formulations are: salicylic acid, tea tree oil and niacinamide.

The development process includes the following stages: product conceptualisation, quality criteria, formulation and preliminary design of the manufacturing process for an annual production of 40,000 kg/year for the cleansing gel and 10,000 kg/year for the cream.

Keywords: Formulated product development, acne, sensitive skin, facial cleanser, night cream, process synthesis, quality criteria, manufacturing process design.

RESUMEN

En la actualidad, las necesidades de los consumidores son cada vez más individualizadas y diversas, así como cambiantes. Es por ello que el desarrollo de un producto pretende satisfacer dichas necesidades mediante su transformación en producto comercial disponible en el mercado.

Concretamente, los productos para el cuidado o tratamiento de la piel disponen de gran relevancia en la sociedad actual y, por tanto, se puede afirmar que han causado un gran impacto dentro de la industria cosmética. Se considera que estos son parte de la rutina diaria de gran parte de la población ya que además de colaborar con la obtención de una piel más sana, también ayudan a mejorar la autoestima. En relación a este hecho, una de las afecciones dermatológicas de mayor frecuencia y que como consecuencia cobra vital importancia, es el acné.

Cabe mencionar que a raíz de la pandemia causada por el virus COVID-19 y del reiterado uso de las mascarillas, se ha observado un aumento y/o empeoramiento de los casos de pacientes con acné, provocando una mayor necesidad de productos para su tratamiento por parte de la sociedad actual. Por otro lado, la complejidad para tratar esta afección cutánea aumenta en las personas con piel sensible propensa a la inflamación y enrojecimiento. Es por esto, que el presente trabajo se basa en el desarrollo de una gama de productos formulados para el tratamiento de acné en pieles sensibles. En concreto, se trata de un gel limpiador facial y una crema de noche para ayudar a controlar la aparición de granos y reducir las cicatrices provocadas por el acné. La formulación de ambos cosméticos consiste en emulsiones O/W, aunque siendo el gel limpiador una microemulsión y la crema de noche, por el contrario, una macroemulsión. Además, cabe destacar que los ingredientes activos para el tratamiento de acné empleados en las formulaciones son: ácido salicílico, aceite del árbol del té y niacinamida.

En el proceso de desarrollo se han tenido en cuenta las siguientes etapas: conceptualización de los productos, criterios de calidad, formulación y diseño preliminar del proceso de fabricación para una producción anual de 40.000 kg/año para el gel limpiador y 10.000 kg/año para la crema.

Palabras clave: Desarrollo de productos formulados, acné, piel sensible, limpiador facial, crema de noche, síntesis de procesos, criterios de calidad, diseño de procesos de fabricación.

IDENTIFICATION AND REFLECTION ON THE SUSTAINABLE DEVELOPMENT GOALS

The sustainable development goals (SDGs) are a collection of 17 global goals designed to achieve a better and more sustainable future. These SDGs are divided into five areas, commonly known as the 5Ps: planet, people, prosperity, peace and partnership.

Chemistry plays an essential role in helping the society to achieve these SDGs (American Chemical Society). Consequently, in the event that the project is continued and the products are launched onto the market, further actions will be carried out with the aim of enhancing sustainable development. Some examples of actions that would be taken in order to meet these criteria are:

- Develop a sustainable packaging by using 100 % post-consumer recycled (PCR) plastic, which implies a great reduction in virgin plastic and in CO_2. Furthermore, there is a possibility to return the packaging so it can either get recycled or reused. In this case, consumers would get a discount in the next purchase (SDG12: Responsible consumption and production). This meets the target 12.5: By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse.
- Increase the use of natural ingredients in the cosmetics (SDG12: Responsible consumption and production). This accomplishes the following target 12.2: By 2030, achieve sustainable management and efficient use of natural resources.
- Avoidance of microplastics in the formulation of the products like carbomer or dimethicone in order to preserve marine life (SDG14: Life below water). This is related to target 14.1: By 2025, prevent and significantly reduce marine pollution of all kinds.
- Be more energy efficient in the manufacturing process. For instance, this can be achieved by using renewable energy as it would in long term lower the costs and reduce pollution (SG7: Affordable and clean energy). In relation with the target: By 2030, ensure universal access to affordable, reliable, and modern energy services.

1. INTRODUCTION

The use of cosmetic products has increased significantly in recent years, becoming an essential part of the daily routine of a large number of people from all over the globe. However, the origin of cosmetics dates back to the first civilizations, specifically around the year 4000 BC. In ancient Egypt, cosmetics were used not only to beautify the face but also to protect oneself against the hot Egyptian sun and harsh desert conditions (Chaudhri et al., 2009). In terms of skincare, the Ancient Egyptians utilised ingredients such as castor, sesame and moringa oils. Moreover, olive oil and clay mixtures were used to cleanse the skin, milk masks to moisturize and sea salts to exfoliate (Life By LaserAway, 2022).

Similarly, Ancient Greeks made their own skin care products with an emphasis on natural ingredients like berries, olive oils or yogurt (Avail Dermatology, 2020). In Medieval Europe, people sought to achieve as white a skin as possible to resemble the aristocratic upper classes. For this purpose, white powders or white lead paint which could contain arsenic were prepared. On the other hand, aloe vera, rosemary and cucumbers began to be used for skin treatment.

In the Renaissance, women used silver mercury, lead and chalk with the aim of colouring their faces. In addition, skin care products were based on herbs and honey (Life By LaserAway, 2022). During the 1800s, cosmetics were not affordable for the majority of the population but perceived as essential for the higher classes. Nevertheless, this tendency changed in the 1900s and this type of product ceased to be a privilege. Furthermore, it is worth mentioning that at present times the importance of using natural ingredients in cosmetics has been recovered.

According to *Kirk-Othmer Chemical Technology of Cosmetics*: "Cosmetics are products created by the cosmetic industry and marketed directly to consumers. Cosmetics represent a large group of consumer products designed to improve health, cleanliness, and physical appearance of the human exterior and to protect a body part against damage from the environment."

It is also mentioned that cosmetics can be divided into different categories depending on its use: skin care and maintenance, cleansing, odour improvement, hair removal, hair care and maintenance, care and maintenance of mucous membranes and decorative cosmetics. This project focuses on skin care and maintenance, which includes products that soften (emollients and lubricants), hydrate (moisturizers), tone (astringents), protect (sunscreens) and repair (antichapping, antiwrinkling, antiacne agents). Additionally, according to the Regulation (EC) Nº 1223/2009, medicinal products, medical devices or biocidal products are not included in the cosmetic term.

Nowadays, it is of utmost importance to have a well-thought-out skin care routine in order to contribute to well-being and healthy lifestyle. Moreover, this type of products can definitely improve our mood, enhance our physical appearance and as a consequence, increase our self-esteem. For instance, a survey was conducted by the IKW, the German Cosmetic, Toiletry, Perfumery and Detergent Association, on the development of self-esteem in adolescents and young adults aged 14 to 21 years old. A 73% of the polled young people consider beauty care to be really important in their life. Furthermore, it was concluded that today's youngsters invest much more in their appearance than in the past.

In relation to self-esteem, one fact which can significantly affect it is the appearance of acne. Acne is one of the most common dermatological conditions, affecting almost every teenager to a lesser or greater degree and sometimes even into adulthood. As a result of COVID-19 and the use of masks, there has been a considerable increase and worsening of acne cases, leading to a greater need for acne treatment products by society. This was stated at the II National COVID-19 Congress held in Spain, where it was mentioned that acne consultations account for 20-25 % of total dermatological visits, whereas prior to the pandemic they were in the range of 5-7 % (AEDV, 2021).

Moreover, treating this condition can be difficult and even more so in cases of sensitive skin as these are highly prone to inflammation, redness, dryness and adverse reactions from contact with chemicals. For these reasons, the project is based on the development of a range of formulated products for the treatment of acne on sensitive skin. Specifically, two antibacterial cosmetics are developed: a facial cleansing gel to provide cleanliness while lessening skin irritation and redness and a night cream to help control the appearance of pimples and reduce acne scars and hyperpigmentation.

2. OBJECTIVES

The main objective of this work is the conceptualization and further development of a variety of formulated products for acne treatment on sensitive skin (facial cleanser and night cream). The project is divided into the five necessary stages for the product development which constitute the main sections of this work:

Product conceptualization: during the first section, a market analysis is carried out through bibliographic research (encyclopaedias, patents, scientific articles, documents, etc.) with the aim of determining the target consumer to whom it is addressed and knowing the consumer's needs. Moreover, this analysis allows to conceive the products in a more specific way in relation to the functionality, form of application, structure and packaging.

Establishment of quality factors: considering the above aspects related to product conceptualization, quality factors are established in order to guarantee the good functionality of the products. In addition, quality indexes are set to quantify compliance with quality factors.

Product formulation: in this chapter, the ingredients (active components and excipients) are selected with the object of giving the products the appropriate functionality and texture and ensure stability by achieving the previously established quality indexes. Furthermore, the quantity for each ingredient is determined. In relation to the structure, it is already defined as an emulsion for both cosmetic products.

Process synthesis for product manufacturing: the last part of the development of a product is based on a preliminary design of the production process and selection of the equipment required for an established production. Throughout this chapter, the necessary campaigns and their timing are projected.

3. PRODUCT CONCEPTUALIZATION

According to Wibowo et al. (2002) the first step into the development of a product is the definition itself, known as product conceptualization. It is required to determine the consumer needs, to whom it is addressed and the current market tendencies. At this point, it is important to be able to design a product that distinguishes in a certain way from those already existing in the market. In other words, to succeed while developing a product, innovation and creativity can be considered as essential.

In order to do so, market research is carried out which allows to conceive the products in a more detailed way about functionality, form of application and packaging.

In particular, in this project it is carried out the product conceptualization of a facial cleansing gel and a night cream for acne treatment on sensitive skin.

3.1. MARKET TRENDS

As stated in the beginning of the chapter, a market study needs to be conducted with the intention of determining the consumer needs as well as knowing some of the most used active ingredients that exist in the actual market for the same type of product.

Cosmetic products have become the fastest-growing segment of the personal care industry (Brandt et al., 2011). Furthermore, global cosmetic industry has been showing 4.5 % of average annual growth in the last twenty years. Cosmetic products can be divided into premium segment and the mass market, the premium segment represents the 28 % of total sales worldwide and the other one the 72 % (Szutowski, 2017). The products developed in this work address to the mass market.

The skincare and sun care products dominate globally the cosmetic market. According to STANPA (the National Association of Perfumery and Cosmetics in Spain), skincare products in Spain billed a total of 2,600 M € and had a growth of 5.1 % during the year 2019. Moreover, Spain

is considered to be in the top 10 global exporter of beauty products. The consumption by product category in Spain during the year 2019 can be seen in *Figure 1*:

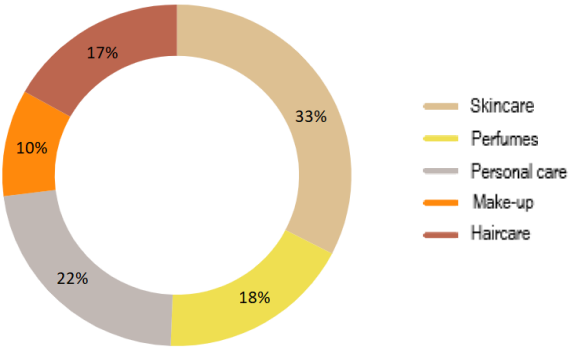

Fig. 1. Consumption by product category in Spain during 2019 (STANPA).

In Spain, the most common distribution channels in this sector are: mass consumption (47%), pharmacy (21%) and selective (21%). Recently there has been an increase in the distribution of cosmetic products in supermarkets, an example of which is clearly Mercadona's Deliplus brand. However, international companies continue to dominate the cosmetic market, such as: L'Oréal, Beiersdorf, Shiseido, Estee Lauder, Johnson & Johnson, Procter & Gamble, Colgate-Palmolive, LVMH group, Coty, Pierre Fabre, etc. National brands such as Grupo Puig, Natura Bissé, Skeyndor, ISDIN, Cantabria Labs or Babaria are becoming increasingly important.

On the other hand, it is needed to establish the target market to whom the developed products are addressed. With this purpose, the population is divided into segments: gender, age, income level and geographic location. These cosmetics products are intended for both genders; in the age range of 12 to 50 years since although acne being a prevalent problem in teenagers, it can also be extended into adulthood specially in the case of woman due to hormonal changes; with a medium socio-economic level and residents in Spain. Additionally, the target consumers should have acne-prone and sensitive skin as well as interest into skin care.

Nevertheless, with reference to skin care products it must be said that these are generally emulsions. This fact can be applied to both products, the cleansing gel and the night cream. Emulsions can be defined as an unstable system of two or more immiscible liquids which are stabilized against separation. The most common type of emulsion in cosmetics is called oil in water (O/W) where oil is the dispersed phase (forms small droplets) and water is the continuous one. O/W emulsions employ emulsifiers that are more soluble in water than in oil. They are the

most commonly used type of emulsions as they are non-greasy and can be easily removed from the skin. Furthermore, O/W emulsions are much more economical due to the high percentage of water.

According to Wibowo et al. (2002), the typical market trends to be considered can be divided into three sections:

Consumer wants and needs

Nowadays, there are typical trends in the market like offering a product which lasts longer, costs less, is safer, easier to carry while travelling and above all in the current present, it has taken a lot of importance the idea of being more environmentally friendly by preferring biodegradable products (Wibowo et al., 2002). Moreover, in the beauty sector there is a tendency gaining more and more strength, based on looking for skin care routines that involve little time.

Product safety

In terms of product safety, products should not contain toxic solvent or allergenic materials, dangerous chemical for little children and should contain more natural ingredients (C. Wibowo et al., 2002). The safety of cosmetic products is governed by specific legislation depending on the continent or country where the products are planned to be marketed. In the European Union, the main safety requirements are registered in the Regulation (EC) Nº 1223/2009. In this document, Annexes II and III list the banned and restricted substances, respectively. Moreover, cosmetics legislation at the European Union requires (European Commission):

- Production process based on Good Manufacturing Practices (GMP) in order to ensure clean environment and avoid contamination.
- Some cosmetics must be given special attention from regulators due to their complexity of higher risk for the human health. Some examples are: sunscreen products, hair dyes, endocrine disruptors, cosmetics with nanomaterials and preservatives.

Legal and environmental issues

Although there is no actual legislation on environmental issues in cosmetic products, natural ingredients are increasingly used as a result of the growing awareness of environmental problems among a high percentage of the population. Thus, motivates consumers to sought for eco-friendly skincare products.

For instance, based on market research, the most commonly used natural ingredients in cosmetic products for acne treatment are: tea tree oil (anti-inflammatory and antimicrobial), aloe vera (soothing, reducing scars and anti-inflammatory), green tea (anti-inflammatory and antimicrobial) and rosemary (antioxidant and antibacterial).

However, it can be said that the use of natural ingredients in acne treatment products is not as widespread as in other areas of cosmetics. It is also important to mention that there is a tendency towards cruelty-free products, in other words, that have not been tested on animals.

In October 2021, the European Commission adopted the EU Ecolabel criteria for cosmetics as a real proof of green products. It considers the environmental impact of a product throughout its entire life cycle, from the extraction of raw materials to its final disposal.

Broadly speaking, these are the trends that are currently applied to the cosmetic sector. Now, each product within this sector has its own tendencies, varying from one to another. These trends are explained below for the two products to be developed.

Facial cleansing gel

It is important to emphasise the value of facial cleansing, as it is the first step in the skin care routine. Nowadays, the increase in its use is due to the search for a sensation of renewal and rejuvenation. Given the situation of acne-prone skin, psychological health can be affected by this condition so the use of a facial cleansing gel can contribute to its improvement.

The future of cleansing lies in overcoming the challenge of providing excellent skin hygiene while minimizing skin barrier damage (Draelos, 2017). This fact is even more significant if the facial cleansing product is designed for use on sensitive skin as in the target of this project. In the case of facial cleansers for acne-prone skin, they are often too harsh and can result in excessive drying of the skin (Draelos, 2006).

Cleansers come in different formats: foam, gel, cream or oil. However, for acne-prone skin, gel cleansers are considered to be the best option. Their function is to unclog the pores while removing typical surface oil and acne-causing bacteria. It can be said that these products not only fight the already existing acne, but also prevent its appearance. In addition, these cleansers are widely used for sensitive skin, as they do not cause irritation and alleviate redness thanks to their soothing properties.

Night cream

The daily skin care routine for acne treatment should end with the use of a night cream whose action occurs while resting. Therefore, it is crucial in order to diminish the problem of acne. When using a cream, consumers expect it not to leave a sticky feeling, to have a pleasant texture, to penetrate quickly into the skin and to have visible efficacy after a short time of use. Moreover, its use requires little time, as there is not even the need of face washing after applying the product.

There is a wide range of night creams on the market, the purpose of which depends on the actual ingredients that form it. In this case, the function sought is to help control the appearance of pimples and reduce acne scarring and hyperpigmentation. For this purpose, during the chapter "Product formulation" ingredients will be chosen to ensure its functionality.

3.2. PRODUCT FUNCTIONALITY

The second step into product conceptualization is to describe the functionality of both products. However, before going into details, it is of utmost importance to highlight the main characteristics of the skin and to provide some brief knowledge about the acne disease.

The skin is the largest organ of the human body and it is divided into different layers as can be seen in *Figure 2*. The epidermis is the outer layer (0.1 to 1 mm) so its function is to protect from external agents like the environment, irritants, pathogenic microorganisms, etc. It contains keratin-producing cells which are responsible for preventing water loss and maintaining internal homeostasis (Gawkrodger, 2007). The following layer is named as dermis (1 to 5 mm) and its main roles are providing firmness and elasticity, ensuring nutrition of the epidermis, being the most important water reservoir for the skin, etc. Moreover, it also contains the sweat and sebaceous glands, which produce sebum. The last layer is the subcutaneous tissue or hypodermis and is made up of fat cells and connective tissue in charge of attaching the skin to muscles and tendons.

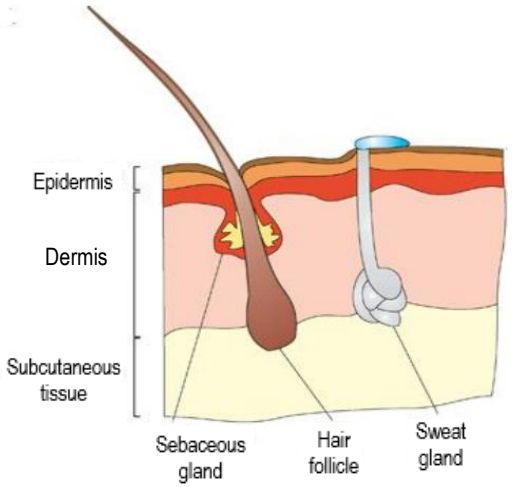

Fig. 2. Layers of human skin (K. Devitt, 2016).

On the other hand, skin disorders are a major problem affecting a high percentage of the population worldwide. Among all existing dermatological diseases, acne is the most common one as almost every adolescent suffers from it and can be extended into adulthood. Acne is considered to be a chronic inflammatory disease of the pilosebaceous unit comprising hair follicle, hair shaft and sebaceous gland (Tuchayi, et al., 2015). There are different ways in which acne manifests (*Figure 3*):

- Whitehead or closed comedones which occur when sebum and keratinous cells clog the pores and cause a bacterial infection.
- Blackhead or open comedones produced when the whitehead comedones expand themselves causing follicular opening. The typical black colour of this type of acne is originated as a result of the oxidation of lipids and melanin in the skin.
- Inflammatory lesions (nodules or cysts, pustules and papules) due to follicular rupture.

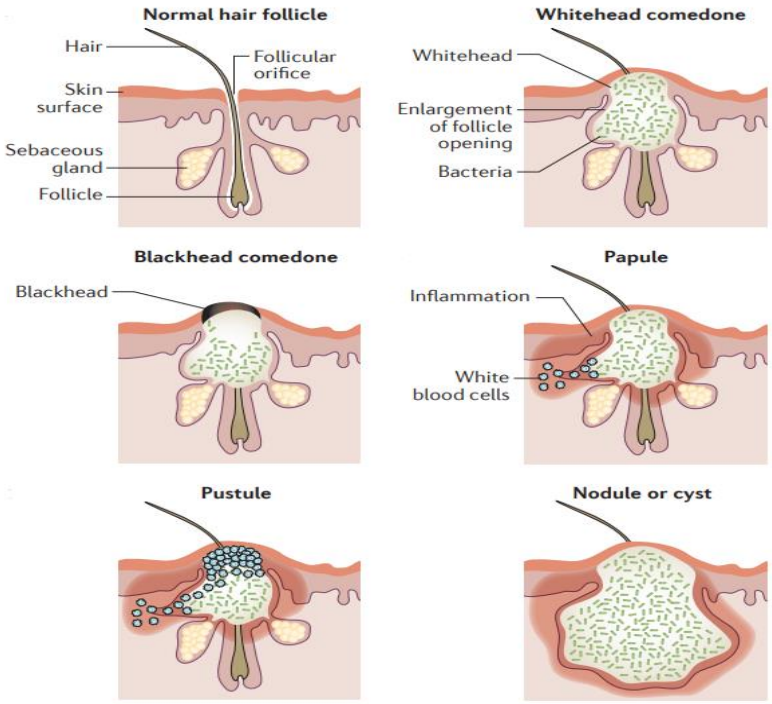

Fig. 3. Acne formation (Tuchayi et al., 2015).

Moreover, this condition affects different areas of the skin that contain a large number of sebaceous glands, although this paper focuses exclusively on acne occurring on the face. There are a wide variety of treatments for this disorder, especially topical and oral treatments with antibacterial compounds and hormones. This project is based on topical treatment, in other words, the cosmetic part is treated, leaving aside possible pharmaceutical medication.

As mentioned above, the acne treatment cosmetics developed in this work are intended to be used on sensitive skin. This condition can be defined as: "skin which exhibits a reduced tolerance to frequent or prolonged use of cosmetics with symptoms ranging from visible signs of irritation like erythema and scaling, through to more subjective neurosensory forms of discomforts such as stinging, itching, burning and tightness" (Willis et al., 2001). It can affect all parts of the body, although its greatest affection is located on the face. As it is a problem for many individuals, it is of vital importance the development of a wide range of cosmetic products designed for sensitive skin.

Facial cleansing gel

A facial cleansing gel is a skin care product used, as its name suggests, for cleansing. In other words, its main functionality is to remove oil, dirt, dead skin cells and other potential pollutants from the skin. As a result, it helps prevent clogged pores and the appearance or worsening of acne condition.

To this end, acne facial cleansers contain surfactants, a unique class of chemical compounds which have dual characteristics of hydrophilicity and hydrophobicity which in itself suggests the surface-active nature of these classes of compounds and their tendency to adsorb at interfaces (Nikunj et al., 2017). In relation to this case, surfactant can bring oil into water and water into oil, which provides the cleanser its ability to remove oil.

Moreover, this facial cleansing gel is endowed with an antibacterial function as a way to help dealing with acne disease. This is defined as the active ingredient, which tends to be salicylic acid. Nonetheless, it is important to ensure that this antibacterial ingredient does not damage or dry out the skin.

Although it is not the purpose of the product, little exfoliation can be done while cleansing. The idea is to use a scrubber suitable for all skin types, including the sensitive ones. For example, citric acid fulfils these characteristics. In addition, this component has antioxidants properties.

Finally, this cosmetic product is expected to have soothing properties which help reduce any existing redness.

Night cream

On the other hand, the purposes of the night cream need to be stated. As mentioned before, the main functionality of this acne treatment cream is to help control the appearance of pimples. The best ingredients to achieve this are: benzoyl peroxide, salicylic acid, alpha-hydroxy acids, retinol and a more natural ingredient such as tea tree oil.

Furthermore, it is also intended to reduce acne scarring and hyperpigmentation. Nevertheless, it is important to define why these marks are produced on skin. Acne scars are originated as a result of skin damage caused by inflamed blemishes with excess oil and bacteria. Although most pimples disappear without scarring, others develop these marks. Acne scars can be divided into:

- Atrophic scars: the most common type of acne scarring. They are produced due the degradation of collagen during the healing process (Connolly et al., 2017) and their appearance is like deep indentations on the face.
- Hypertrophic scars: in this opposite case, during the healing process skin creates too many fibroblasts. This fact results in a raised scar, above the surface of the skin.

On the other hand, hyperpigmentation due to acne has the appearance of dark spots when the pimples have already disappeared. This product is expected to accelerate the fading process. However, even with the use of topical products, the removal of these coloured marks requires time, usually months or even years.

3.3. PRODUCT PACKAGING

According to Wibowo et al. (2002), the last step into product conceptualization is the definition of the product packaging, as it can affect the consumer's perception of the product and therefore, should be taken carefully into consideration.

The main functionality of the packaging has always been to protect and preserve the product during its transportation and use. Nevertheless, over time it has acquired other purposes more related to marketing, especially in the cosmetics sector. It is necessary to design a packaging that attracts the attention of the potential consumer by making decisions about colour, design, material and type of container. Furthermore, the packaging should be designed as to be easily recognized by having a logo or distinctive colours or formats. Packaging should also help consumers to understand the contents of the product and usage (Topoyan et al., 2008) and be compatible with the formulation.

In the current era, many companies are opting for sustainable packaging, also called green packaging, due to the concern related to environmental issues by a high percentage of consumers. It can be said that the current packaging trend is aimed at complying with the 3R rule: reduce, reuse and recycle. In cosmetic products, reuse can turn out to be difficult as they are often contaminated by product residues that are difficult to eliminate (Cinelli et al., 2019).

According to the European Union legislation for cosmetic products, it is mandatory to provide the necessary information on the label or packaging. It must include the following data: name and

address of the company (responsible person), ingredients list, warnings for using the product safely, date of durability, product identification (batch number) and country of origin.

First of all, in order to start with the definition of the packaging of both products, the type of the container needs to be established.

Table 1. Typical Packaging for Chemical-Based Consumer Products (Wibowo et al., 2002).

Type of Packaging	Product Form/Delivery System						
	Composite	Tablet/caspule	Powder/ Granule	Cream/ Paste	Viscous liquid	Dilute liquid	Aerosol
Wrapping							
Carton box	√	√	√				
Paper/Plastic wrap	√	√					
Aluminum foil	√	√					
Bag (Paper/plastic)							
Resealable bag		√	√				
Sealed bag/sachet		√	√	√	√		
Bottle (Glass/Plastic)							
Screw cap		√	√	√	√	√	
Flip cap					√	√	
Slit orifice					√	√	
Pump top					√	√	
Tube (Metal/Plastic)							
Collapsible Tube				√	√		
Squeezable tube					√	√	
Can (Metal)							
Spray can							√

In the case of the facial cleansing gel, the product is considered to be a viscous liquid. As a consequence, the type of packaging can either be a bottle or a tube in any of its formats. On the other hand, the night cream's delivery system is a cream so the appropriate type of packaging is a bottle with screw cap or a collapsible tube. With the aim of using the same type of packaging for both products, it has been chosen a collapsible tube due to its low price and ease of handling and transport. Another clear advantage is that products supplied in tubes are less likely to become contaminated by the consumer than those supplied in jars (Croshaw, 1977). Furthermore, the type of closure is defined as a screw cap to provide both physical and chemical protection to the contents being sealed.

In terms of materials, the most common ones in the cosmetic industry are plastics, glass and metals. Plastics are undoubtedly the most widely used material in this sector since their use

provides many advantages such as: low cost, hygienic qualities, lightness, durability, inertness to many chemicals and pleasant appearance and touch among others.

Plastic packaging consists of one or more polymers together with certain additives. For plastic containers in general, additives may consist of antioxidants, antistatic agents, colours, impact modifiers, lubricants, plasticizers, and stabilizers (Shivsharan et al., 2014).

Moreover, plastics can be divided into rigid and flexible packaging. The rigid packaging normally consists of bottles, or pots and caps whereas the flexible packaging is usually a tube. The most frequently used polymers are HDPE (High density polyethylene), PP (Polypropylene) and PET (polyethylene terephthalate) (Cinelli et al., 2019). It is decided to use PP, the most common plastic in the industry, as the material for the tubes because of its low cost, high resistance to many chemicals and durability.

Finally, the volume of the containers needs to be established. The volume of the facial cleansing gel should be larger than the night cream's one. That is because the cleanser is expected to be used at least twice per day (morning and night) whereas the night cream, as its own name suggests, is intended to be utilised once per day. As a result of the market research conducted, the volumes are set as: 200 mL for the facial cleanser and 50 mL for the night cream.

Fig. 4. Collapsible tube packaging example (AliExpress).

3.4. PRODUCT CONCEPTUALIZATION SUMMARY

In order to conclude the first section of this project, the conceptualization of both products is summarised in *Table 2*.

Table 2. Summary of the conceptualization of two products for acne treatment.

PRODUCT CONCEPTUALIZATION SUMMARY		
Parameter	**Facial cleansing gel**	**Night cream**
Function	Wash facial skin Antibacterial function to deal with acne Reduce any existing redness	Help control the appearance of pimples Reduce acne scars and hyperpigmentation
Skin type	Acne-prone and sensitive skin	
Packaging design	Collapsible tube with a screw cap PP (Polypropylene) Low price Ease of handling and transport Physical and chemical protection	
Printed design	Product's name Brand's name Usage instructions Type of skin for which it is recommended Composition Volume Manufacturing place Expiration date Period after opening	
Volume	200 mL	50 mL

4. IDENTIFICATION OF PRODUCT QUALITY FACTORS

According to Wibowo et al. (2002), the next step towards the development of a product is to identify the desired performance in terms of quality factors. Aside from the product's ability to fulfil a certain function, consumer satisfaction also depends on other aspects such as convenience of use, stability, sensation and product durability. Moreover, depending on the product form or the delivery system, the desired quality factors may be different. For instance, rheology is of utmost importance in this work, as the two products to be developed are emulsions.

Most of these quality factors are qualitative. Therefore, performance indices are used to indicate the product throughput. Some examples of these typical performance indices for chemical-based consumer products are shown in *Table 3*:

Table 3. Performance indices for typical chemical-based consumer product quality factors (Wibowo et al., 2002)

	Product Form/Delivery System							
Quality Factor	*Composite*	*Tablet/capsule*	*Powder/ Granule*	*Cream/ Paste*	*Viscous liquid*	*Dilute liquid*	*Aerosol*	*Performance Index*
Sensorial Quality Factors								
Visual appearance: transparent, opaque, pearlescent, color	√	√	√	√	√	√	√	Arbitrary indices based on panelist evaluation
Smell: fragrant, odorless, stinky	√	√	√	√	√	√	√	
Taste: sweet, sour, bitter	√	√	√	√	√	√		
Sense upon application: smooth, oily, sticky				√	√	√		
Physicochemical Quality Factors								
Product stability (resistance against creaming)				√	√	√	√	Shelf life
Ability to change phase upon application	√	√	√	√	√			Melting point, glass transition temperature
Hygroscopicity	√	√	√	√	√	√		Moisture absorption rate
Ease of dispersion in a liquid			√					Wetting time
Ability to dissolve in a liquid	√	√	√					Dissolution time
Rate at which an active ingredient is released	√	√	√	√	√	√		Release time
Mechanical Quality Factors								
Resistance to failure	√	√	√					Tensile strength
Resistance to indentation (hardness)	√	√	√					Hardness numbers
Ease of failure by fracture (toughness)	√	√	√					Fracture energy
Elasticity	√	√	√					Young's modulus
Ease of flow			√					Flow number
Rheological Quality Factors								
Ease of spreading when rubbed onto a surface, applied by brush, or shaken				√	√			Viscosity at application shear rate
Ability to flow under gravity				√	√			Yield value
Ability to provide even coating when applied on a surface				√	√			Minimum thickness at which even coating is observed

Sensorial quality factors are defined as perceptions and can therefore be quantified by means of an arbitrary scale on which an index is established to express the level of satisfaction. This index is related to material properties and structure. However, some other quality factors can be quantified by using physical properties like viscosity or melting point. In addition, some others can also be quantified with dimensionless numbers (Wibowo et al., 2002).

Quality factors can be divided into four groups: functional, rheological, physical and sensorial. Each of these is developed in more detail below.

4.1. FUNCTIONAL QUALITY FACTORS

Functional quality factors, as the name itself indicates, are related to the proper functions of the products. These quality factors are of major importance, as functionality is always considered the main concern when developing a product.

Facial cleansing gel

The main purpose of a cleanser is undoubtedly to cleanse parts of the body, in this case the face. As has been mentioned, this is done in order to remove dead skin cells, oil, dirt, pollutants, etc. to keep the pores unclog and reduce or prevent some skin conditions like acne. Consequently, the most important functional quality factor of this cosmetic is the ability to perform proper cleansing.

However, as a cleanser indicated for acne-prone skin, it contains active ingredients (salicylic acid and tea tree oil) that provide an antibacterial function to help deal with this condition. As well, this product is used for sensitive skin. Therefore, it turns out to be necessary to have a soothing effect which decreases skin irritation and the possible redness.

Some of the most commonly used soothing ingredients in cosmetic formulations are: bisabolol, aloe vera, green tea, allantoin, licorice root, colloidal oats, PHA (Polyhydroxy acids), chamomile, panthenol, etc. Some of these excipients can provide other functions involving a direct benefit like antioxidant, moisturizing or exfoliant effect. Nonetheless, although appreciated, these additional functional quality factors are not considered mandatory in the context of product quality.

Night cream

As mentioned in the previous chapter, the main objective of the night cream is to reduce the appearance of pimples. In addition, it is meant to lessen acne scars and hyperpigmentation. For

that reason, the principal functional quality factor of this product is related to skin condition treatment, specifically acne.

In contrast to the facial cleanser, which is rinsed off after application, the night cream requires to be maintained in the skin surface. As a consequence, consumers expect this type of product to be rapidly absorbed.

4.2. RHEOLOGICAL QUALITY FACTORS

Rheology is defined as the knowledge and understanding of the flow behaviour of liquids, dispersions, and stable phases with different structures (Gräbner et al., 2017). In accordance to the International Federation of the Societies of Cosmetic Chemists (1997), it must be taken into account the variable desired flow characteristics during processing, packaging, transport, storage, and consumer use. Moreover, rheology is essential to assess the long-term stability of the cosmetic.

It is necessary to carry out a rheological evaluation of the application behaviour of the cosmetic as well as the manufacturing process. According to Wibowo et al. (2001), in relation to the manufacturing process, both energy consumption and mixing time depend on the rheological properties of the emulsion. On the other hand, with regard to the application behaviour, the cream and gel are expected to spread easily when rubbed into the skin, although not flowing by itself while handling. Furthermore, these cosmetics should be able to be poured out of the container without any difficulty.

Fluids are divided into Newtonian and non-Newtonian depending on their viscosity behaviour. Viscosity is defined as the resistance of a material to flow and is obtained from the ratio between shear stress (force applied) and shear rate (movement). The different types of fluids are defined below (Nae, 2016):

- Newtonian fluids: viscosity is constant (depends on state variables such as, for example, temperature) and therefore, independent of the shear rate.
- Non-Newtonian fluids: the viscosity is dependent of the shear rate as the relation between this shear rate and shear stress is not proportional. According to the behaviour, there are different types of non-Newtonian fluids:
    - Pseudoplastic fluids (shear-thinning fluids): they exhibit a decrease in apparent viscosity as a function of the increasing shear rate.

- Dilatant fluids (shear-thickening fluids): their apparent viscosity rises due to the increase in shear rate.
- Bingham plastic fluids: they require a minimum yield stress before starting to flow. Once the flow begins, they are considered to act as Newtonian fluids. In other words, they can be said to act like a rigid body at low stress but as a viscous liquid at high stress.

All these different flow behaviours can be appreciated in the rheological diagram exposed in *Figure 5*. In addition, *Figure 6* shows the relation between viscosity and shear rate previously mentioned for Newtonian, shear-thickening and shear-thinning fluids

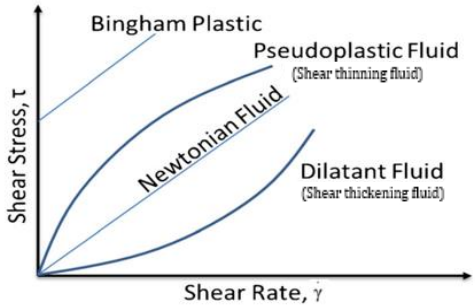

Fig. 5. Rheological diagram showing relation between shear stress and shear rate for different fluids (Pinto et al., 2016).

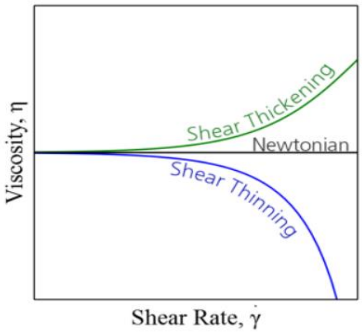

Fig. 6. Rheological diagram showing relation between viscosity and shear rate for different fluids (RheoSense, 2019).

In this project, both the cream and gel are expected to have a pseudoplastic behaviour. They should have low viscosity at high shear in order to flow easily when applied to the skin. Moreover, their viscosity should increase at low shear so as to not spill (Wibowo et al., 2001).

The rheological behaviour of a pseudoplastic fluid can be represented by the power law, also known as the Ostwald-de Waele model, equation:

$$\tau = K \cdot \dot{\gamma}^n$$

Where: τ: shear stress.

K: consistency index.

γ: shear rate.

n: flow behaviour index (n<1 in case of pseudoplastic fluids).

There are typical shear rates of cosmetic actions, the ones related to gels and creams are exposed (Ward et al., 1974):

- Suspending pigments and active ingredients: 10^{-3}-10^{-1} s^{-1}
- Pouring from a bottle: 10^{1}-10^{2} s^{-1}
- Extrusion from a tube: 10^{2} s^{-1}
- Topical application: 10^{2}-10^{4} s^{-1}

When developing a product for topical application, Brummer and Godersky (1999) recommend a viscosity of about 0.025 Pa·s at high shear rate (about 5000 s^{-1} for creams) during application. However, at very low shear rates, the viscosity can be as high as 1000 Pa·s (Wibowo et al., 2001).

With the objective of testing the rheological properties of the developed cosmetic products, a rheometer should be used. This is a laboratory instrument which measures how a fluid flows in response to applied force. Therefore, it provides a shear profile.

Finally, it has to be said that with the purpose of achieving a desired flow profile, thickeners might be added into the product formulation. This will be further developed in the next chapter of this work.

4.3. PHYSICOCHEMICAL QUALITY FACTORS

As defined in the previous chapter, both products to be developed are emulsions. According to Barel et al. (2009), emulsions are mixtures of two insoluble materials that are stabilized against separation during a period of time. There are different types of emulsions which can be formulated: water in oil (W/O), oil in water (O/W), aqueous gel and silicone in water. However,

O/W are the most commonly formulated and are therefore the chosen emulsion type for these cosmetic products.

Oil-in-water emulsions consist of oil droplets dispersed in water. Depending on the size of the dispersed particles in the continuous phase, they are differentiated into: macroemulsions (droplet size >200 nm) and nanoemulsions (20-200 nm) (Karunaratne et al., 2017). In relation to this, in O/W emulsions droplets are about 1–20 μm (Brummer, 2013).

It is also important to mention the existence of microemulsions, which consist in a single stable phase and are thermodynamically stable systems whereas macroemulsions are kinetically stable systems (Moulik et al., 2006). Moreover, macroemulsions are characterized by being opaque and of relatively high viscosity. In contrast, microemulsions are transparent and of relatively low viscosity. In cosmetics, microemulsions are used mainly for skin cleansing. Hence, the developed facial cleansing gel is intended to be a microemulsion, while the cream is a macroemulsion.

As has been well mentioned, macroemulsions are thermodynamically unstable systems that tend towards phase separation. For this reason, it is necessary to use emulsifying agents or emulsifiers to produce reasonably stable emulsions, in other words, to maintain the phases of the emulsion mixed together and their properties.

Emulsifying agents are substances that form a film around the dispersed drops or decrease the interfacial tension in an emulsion. In relation to their structure, these agents have two parts: hydrophilic head and hydrophobic tail (Mousumi et al., 2019). Therefore, when an emulsifier is added in the formulation, it is disposed at the interface with the hydrophilic part into water and the lipophilic part into oil. In the next chapter, this will be further developed in order to select the right emulsifier or mixture of emulsifiers.

On the other hand, the stabilizing mechanism is considered to be complex and may vary depending on the system. Nevertheless, the most common and important ones are (Chang, 2016):

- Low interfacial tension: adsorption of surfactants at the phase interface leads to a decrease in the interfacial energy, enhancing therefore the stability of the emulsion.
- A mechanically strong interfacial film: emulsion stability improves due to the mechanical protection provided by the adsorbed films around the droplets.

There are different mechanisms which destabilize a formulation:

- Gravitational separation: this is divided into sedimentation (downward) and creaming (upward). The separation occurs as a result of density differences and creates a vertical

concentration gradient of the droplets without any change in size. As a consequence, this phenomenon results in a droplet-rich layer and a droplet-deficient aqueous layer (Mao et al., 2015). It should be noted that creaming is often a precursor to coalescence.

- Flocculation: the process in which droplets are attracted to each other resulting in adhesion between them, creating flocs (larger particles) without the rupture of the stabilising layer at the interface (De Gruyter, 2016). Flocculation has two effects on the emulsion stability: (i) an enlargement of the effective particle size, thus increasing the creaming rate and; (ii) increased coalescence possibilities since it is preceded by flocculation (Pawignya et al., 2018).
- Coalescence: the destabilization mechanism where droplets come into contact and merge, creating larger droplets (Y. Maphosa et al., 2018). Therefore, particle size tends to increase over time and, as a consequence, reduces the stability of the emulsion.
- Ostwald ripening: describes the evolution of inhomogeneous structure through time. In this case, molecules on the surface of a small particle will tend to detach from the particle and diffuse into the solution to enlarge the bigger droplets. Consequently, there is an increase on the concentration of free molecules in solution which have a tendency to condense on the surface of larger droplets. As a result, the overall size of the particles increases (Ratke et al., 2012).

All these destabilizing phenomena can be appreciated in *Figure 7*:

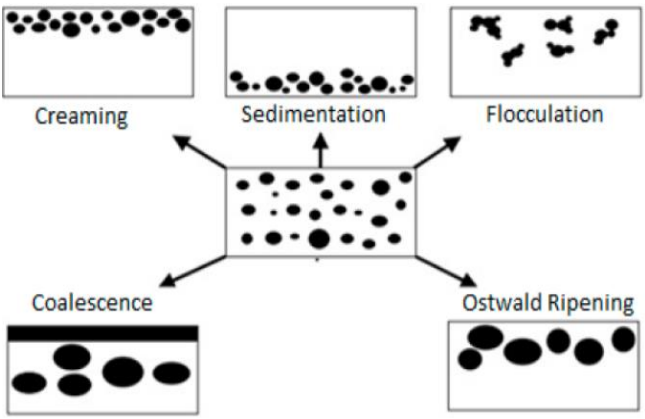

Fig. 7. Destabilizing mechanisms of emulsions (Saad et al., 2019).

However, it is sometimes necessary to add a thickening agent with the aim of maintaining stability, as it can be insufficient with the emulsifiers. Its main purpose is to regulate the product's viscosity, but also to improve the rheological properties of stability, feel and flow (Karsheva et al., 2007). Moreover, according to patent WO2007004882A2, creaming can be prevented by the addition of a thickener to the water phase.

For many years, the cosmetic industry has been concerned with preventing deterioration and prolonging the shelf life of cosmetics. Shelf life can be defined as the specific time during which the product is able to maintain certain properties. The stability of these cosmetic products must be in line with the expected period of use and the consumer needs. Additionally, it is of utmost importance to ensure the safety of use of the product for the duration of its shelf life.

In the case of skin care products, it is vital to determine changes in texture, such as extensibility and stickiness, cleansing ability, lathering, etc. There are many different tests which can be applied to determine the stability and thus, the shelf life of a cosmetic. Some of the most frequently used are (Mitsui, 1997):

- Temperature test: cosmetics are tested at different temperatures to observe and measure the changes in the properties of samples with a lapse of time. Some of the properties analysed are: colour, suspended materials, gelling, fragrance, pH, viscosity, turbidity, particle diameter, etc.). For example, changes in particle diameter may indicate coalescence, creaming, flocculation or Ostwald ripening. Therefore, testing these data can help to achieve a more stable formulation.
- Photostability test: cosmetic products can be exposed to different lights. Consequently, it is important to develop a photo-stable product.
- Stress test: this test takes into consideration the overall stress and time period of usage in order to predict the stable life span of the product. It is usually applied to liquid emulsions and paste products. This test can be divided into different other tests, like the centrifugal separation method or vibrational test.

In accordance to the EU Cosmetics Regulation (EC) Nº 1223/2009, in case the shelf life is below 30 months, an expiration date must be indicated on the packaging. However, if its longer than 30 months, it is not necessary. In this case, the packaging label must include the Period After Opening (PAO), which is the period during which the cosmetic is stable and can therefore be used. The symbols for both cases are given below:

Fig. 8. Expiration date.

Fig. 9. Period After Opening.

After market research, it has been determined that both facial cleansers and night creams tend to have a shelf life of about 3 years and a PAO of about 1 year.

4.4. SENSORIAL QUALITY FACTORS

Sensorial quality factors greatly influence the consumer's decision to purchase any skin care product. Therefore, it is of major relevance to study this type of quality factors in order to increase product competitiveness. During cosmetic products development, the most important senses are touch, sight and smell.

According to Wibowo et al. (2001), typical examples of sensorial quality factors for creams are: non-irritating, smooth feeling, non-greasy feeling and appearance.

Visual appearance

Cosmetics can have different appearances: transparent, opaque, pearlescent and coloured. Colourants are added to cosmetics as a means of colouring the cosmetic itself and/or to impart colour to the skin of consumers (Valet et al., 2007).

Related to this fact, there are two types of colouring agents: colourants, also known as dyes, and pigments. Dyes are defined as synthetic organic colouring agents which are soluble in both water and oil. Pigments, on the other hand, are divided into mineral and organic in relation to their origin and are considered to be insoluble colouring agents that remain in the form of particles or crystals.

Consequently, the choice of the most suitable colouring agent depends on the cosmetic product. Dyes are most commonly used in skin care products and toiletries, whereas pigments are mostly used in make-up.

The EU Regulation (EC) Nº 1223/2009, sets out a list of permitted colouring agents in Annex IV. There are different classes of usage restrictions depending on the agent:

- No restriction.
- Rinse-off products.
- Not to be used in products applied on mucous membranes.
- Not to be used in eye products.

However, although these agents are regulated and can be used safely without negative health effects, it has been considered that for the development of these two products there is no need for colour as it does not provide any substantial benefit. Thus, the cleansing gel will have a transparent appearance while the night cream will be white-coloured. It should be noted that even not being coloured, their visual appearance will be pleasing to the consumer.

Fragrance

Odours play a crucial role in human behaviour. A good fragrance can bring benefits such as a sense of calm, a feeling of cleanliness or simply improve your mood. Conversely, an unpleasant scent can produce discomfort or even anxiety, altering your mood in an undesired manner.

According to the FDA (U.S. Food and Drug Administration), fragrance is defined as a combination of chemicals that gives each perfume or cologne (including those used in other products) its distinct scent. Fragrance ingredients can be derived from petroleum or natural raw materials (essential oils) from plants or animals.

The majority of cosmetics contain fragrances, since they influence the purchase decision and consumer acceptance of the product (Gonçalves et al., 2013). Moreover, it is important to note that fragrances are also used in these types of products to mask undesirable smells derived from fatty acids, oils and surfactants commonly found in cosmetic formulations (Sharmeen et al., 2021). Therefore, fragrances are widely used to conceive a more attractive product.

Fragrance content depends on the type of cosmetic, this can be seen in *Table 4* (Salvador et al., 2007):

Table 4. Perfume contents usually found in cosmetic products.

Cosmetic product	Content (%)
Fine fragrances	
Baby cologne	1-2
Cologne	2-3
Eau de Cologne	3-4
Eau Fraiche	4-5
Eau de Toilet	5-8
Eau de Parfum	8-12
Parfum	12-18
Skin care products	0.01-0.5
Hair care products	0.01-1
Bath preparations	0.1-3
Toothpastes	0.5-1

From the table it is determined that the perfume content in the products to be developed in this work (skin care products) should be in a range between 0.01 and 0.5 %. When referring to facial creams, this content is reduced to 0.1-0.2 % (Díez, 1998). In addition, the fragrance needs to have different characteristics based on the type of cosmetics. For instance, for fine fragrances the perfume employed should be pungent and elegant or on the contrary, it might be sweet or refreshing, depending on each case; for skin and hair care products sweet and tenuous scents are commonly used whereas for toothpastes, high refreshing aromas are preferred (Salvador et al., 2007).

In relation to this, the aromas of the two acne-prone skin care products have been defined. The facial cleansing gel will have a similar odour to bergamot oil, described as a fresh, clear, lively odour, somewhat fruity and sweet. On the other hand, the night cream will possess a lavender-like smell, which is defined as a dry–fresh, sweet, balsamic, herbaceous odour with floral, woody undertones (Müller, 1992).

Last but not least, according to article 19 of the Regulation (EC) Nº 1223/2009 of the European Union, cosmetic products must list their ingredients on the packaging. However, fragrance compositions and their raw materials are defined as either “parfum” or “scent”. At present, there are 26 fragrance allergens subjected to individual labelling which can be found in Annex III of this regulation.

Sense upon application

Both products to be developed are used for acne treatment, a condition which can be aggravated due to excess of oil as it can clog pores and lead to increased acne breakouts. Therefore, it is necessary to avoid an oily sensation on the skin. Besides, it is also important to ensure a smooth application and a rapidly absorption.

On the other hand, as mentioned before, these cosmetics are indicated for sensitive skin. Hence, it is crucial to develop a range of products that causes no irritation by using mild ingredients in the formulation.

Sensory analysis

ISO 6658:2017 provides general guidance on the use of sensory analysis. It describes tests for the examination of food and other products like cosmetics by sensory analysis, and includes some general information on the techniques to be used if statistical analysis of the results is required.

In the event that these cosmetics were produced as a result of this work, an analysis would be carried out through two sensory panels. The first one will be made up of certain experts in the field whereas the second one will be composed by consumers, optimally more than 30, without any training.

There are different types of acceptance tests in which consumers rate the product based on their response. However, one of the most common is the 9-point hedonic scale. General guidance for hedonic tests is given in ISO 11136. The categories are labelled with phrases representing various degrees of affect and those labels are arranged successively to suggest a single continuum of likes and dislikes (Peryam & Pilgrim, 1957). This can be appreciated in *Table 5*:

Table 5. Categories of the 9-point hedonic scale.

9-point hedonic scale	
9	Like extremely
8	Like very much
7	Like moderately
6	Like slightly
5	Neither like nor dislike
4	Dislike slightly
3	Dislike moderately
2	Dislike very much
1	Dislike extremely

The panellists will receive samples of both products and a sensory test with the aspects to be evaluated. An example of a sensory test with the hedonic scale has been elaborated and can be found in Appendix I.

4.5. QUALITY FACTORS SUMMARY

To sum up, *Table 6* shows the quality factors discussed throughout this fourth section for both products.

Table 6. Summary of the quality factors of two products for acne treatment.

QUALITY FACTORS SUMMARY		
Quality factors	**Facial cleansing gel**	**Night cream**
Functional	Facial skin cleansing	Reduce appearance of pimples
	Antibacterial function for acne treatment	
	Lessen skin irritation and redness	Lessen acne scars and hyperpigmentation
		Rapidly absorption
Rheological	Pseudoplastic rheological behaviour	
	Lower viscosity	Higher viscosity
	Ease of spreading	
	Does not flow by itself while handling	
	Ease of pouring out of the container	
Physicochemical	Microemulsion	Macroemulsion (droplet size>200 nm)
	Shelf life: 3 years	
	Period After Opening: 1 year	
Sensorial	Transparent	White-coloured
	Bergamot oil fragrance	Lavender fragrance
	Avoidance of oily sensation	
	Smooth application	
	No skin irritation	

5. PRODUCT FORMULATION

In the previous chapters the conceptualization of the product has been established as well as the quality criteria. The purpose of this section is to select both active ingredients and excipients along with their quantity. Ingredients are chosen in accordance to their capacity of developing a specific function. The selection of ingredients is carried out by the analysis of different product formulations, scientific articles and patents. Two different formulations are developed, one for each product (the facial cleanser and the night cream).

5.1. SELECTION OF INGREDIENTS

First of all, it is important to select the active ingredients in order to accomplish the functionality requirements. In addition, to achieve other needs such as appearance and ease of application, which will increase the cosmetic acceptability, other ingredients (excipients) are needed in the product (Wibowo et al., 2001).

Furthermore, according to Wibowo et al., there is an extended preference to multifunctional ingredients. This fact implies choosing ingredients, whenever it is possible, that provide more than one function at a time. It is also of utmost importance to ensure that ingredients are compatible with each other.

It is worth mentioning that in accordance with Regulation (EC) Nº 1223/2009, all these ingredients are identified by the INCI name and listed in the packaging in desceanding order of concentration. During the market research, different facial cleansing gels for acne-prone and sensitive skin were investigated: Bioderma-Sebium, Eucerin-DermoPure Oil Control Gel, La Roche-Posay-Effaclar, Avène-Cleanance and Vichy-Normaderm Gel. Likewise, different night creams for acne treatment were researched: Cantabria labs-Biretix Tri Active, Eucerin-DermoPure Oil Control 10% hydroxiacids, La Roche-Posay-Effaclar Duo+, Bioderma-Sebium Night and SVR-Sebiaclear active. The ingredients of these market cosmetics as well as their respective function are listed in Appendix II and III.

5.1.1. ACTIVE INGREDIENTS

ACNE TREATMENT INGREDIENTS

In the actual market there are a large number of acne treatment products, which means that there is a wide variety of active ingredients for this purpose. There are some common ingredients found in acne treatment formulations regulated by prescription like: topical tretinoin and adapalene, as well as topical antibacterials, like clindamycin and erythromycin. However, in cases of mild to moderate acne, people tend to opt for Over-the-Counter acne products which need no prescription.

The following ingredients and concentrations are currently allowed in OTC acne products in the USA (Draelos et al.,2006):

- Salicylic acid 0.5–2 %
- Sulphur 3–10 % alone, or 3–8 % in combination with resorcinol
- Resorcinol 2 % or resorcinol monoacetate 3 % in combination with sulphur 3–8 %
- Benzoyl peroxide 2.5–10 %

Among all these ingredients, salicylic acid and benzoyl peroxide are the most frequently used. Both are topical comedolytics that help dry excess sebum and make the excreted sebum less sticky. This prevents occlusion of the pores and consequent formation of comedones (Draelos et al.,2006).

However, in the European Union benzoyl peroxide is banned in OTC products and limited to prescription. In addition, this active ingredient causes skin irritation in the form of redness, stinging and dryness, which is definitely not suitable for sensitive skins (Draelos, 2022). As a result, benzoyl peroxide is discarded as the active ingredient for the formulations in the present work.

Therefore, it has been decided to develop both formulations with salicylic acid, which is less irritating, as the active ingredient. In the Regulation (EC) Nº 1223/2009, it is found in Annex III with a maximum concentration of 3 % for rinse-off hair products and 2 % for other products.

Nevertheless, although being less irritating than benzoyl peroxide, acne treatment products containing salicylic acid are generally formulated with ingredients which help sooth the skin and reduce irritation. This will be further developed during this chapter.

After market research, it has been determined that salicylic acid is commonly found in both cleansers and creams for acne-prone skin. Its efficacy has been demonstrated by several studies. For instance, Shalita in 1989 carried out a cross-over study where a 2 % salycilic acid cleanser

and a 10 % benzoyl peroxide wash were compared in 30 subjects. After 2 weeks, the patients changed the treatment. The study concluded that only the salycilic acid cleanser reduced significantly the comedones.

It is worth mentioning that leave-on products reduce acne counts more efficiently than the washes due to the contact time, although both significantly reduce acne on the skin (Draelos, 2022). Some products containing salicylic acid in their formulation overcome the brief contact by the use of smaller particle size and depositing the material into the pores during facial rinsing (Chen et al., 2006).

On the other hand, for both formulations tea tree oil will be as well used as an active ingredient for acne treatment. It has been utilised medicinally for about 70 years because of its antimicrobial and antifungal properties (Cox et al., 2000).

In 1997, Smith et al. carried out a comparison of the efficacy between tea tree oil and benzoyl peroxide for treatment of mild to moderate acne on 124 patients. It was concluded that both ingredients provide similar efficacy. However, the onset of action proves to be slower for tea tree oil.

Therefore, regarding Swanepowl (2005) for both formulations (cleansing gel and night cream), the composition of the active ingredients includes: 2 % of salicylic acid and 3 % of tea tree oil. This also meets the criteria established by patent KR20190114921A where it is mentioned that salicylic acid and tea tree oil should be added preferably in a weight ratio of 1:1.5 respectively.

In relation to the night cream, it is as well expected to be able to reduce acne scarring and hyperpigmentation. According to Ghunawat et al. (2019), salicylic acid already decreases postacne hyperpigmentation and scars by its anti-inflammatory effects.

However, the main active ingredients in the creams listed in Appendix III are: salicylic acid, niacinamide and glycolic acid. Salicylic acid has already been added to the formulation, but in addition, niacinamide has been selected for the night cream.

Several studies, such as Tanno et al. (2000), showed that niacinamide, which is a form of vitamin B3, provides highly efictivness in reducing redness and hyperpigmentation produced by acne. In this study, hyperpigmentation was treated in 18 women with 5 % niacinamide on one side of the face and vehicle on the other side. After 8 weeks of treatment, it was observed that there was a significant lightening of hyperpigmentation. As a result, niacinamide is added in a 5%.

SURFACTANTS OF THE FACIAL CLEANSER

With the idea of fullfilling its main cleansing function, all types of cleansers contain surfactants, which are a group of chemicals of various structures. As mentioned in the previous chapter, these surface active agents help to mantain product stability by preventing phase separation. One of the most widely used applications of surfactants is for cleansing formulations as they help to get rid of the sebum, bacteria and environmental dirt. In addition, surfactants also give the cleanser its foaming action when mixed with water (Benson et al., 2019).

In terms of the effect of these agents on sensitive skin, surfactants are considered to be amongst the most common causes of contact allergy dermatitis due to skin care products and cosmetics (González-Muñoz et al., 2014). Some symptoms of skin incompatibility with surfactants are: itching, dryness, erythema and tightness. These conditions can be prolonged and develop into long-term effects. As a consequence, it is essential to formulate a product which contains a surfactant (or mix of surfactants) that is described as less irritating.

In relation to their chemical structure, surfactants can be divided into: anionic, cationic, non-ionic and amphoteric.

Anionic surfactants

Anionic surfactants are negatively charged surfactant ions. They can be found in a wide variety of skin care cleansers, specifically they account for about 50 % of the worldwide surfactant production (Draelos et al., 2006). The most commonly known anionic surfactant is soap (the alkali salt of a fatty acid). However, synthetic anionic surfactants are also widely used in cosmetic formulations. They include: acyl isethionates, alkyl sulphates and alkyl ether sulphates (AES).

This type of surfactants is considered the most suitable for removing oil and dirt, produces pleasant foam and is not expensive. Nevertheless, the main drawback is their potential to irritate skin. Due to this fact, they are often mixed with amphoteric surfactants (P. Romanowski, 2015).

Sodium lauryl sulphate and ammonium lauryl sulphate (alkyl sulphates) are found in many skin care products. Nonetheless, as mentioned, alkyl sulphates are described as irritants. Another example is sodium laureth sulphate, an AES, which is also frequently used in cosmetics, but is, by contrast, less irritating.

Cationic surfactants

Cationic surfactants are positively charged surfactant ions. These agents are incompatible with the anionic ones. Moreover, cationic surfactants are, in general terms, not good detergents

or foaming agents as well as being more irritating (P. Romanowski, 2015). Therefore, they are not used for cleansing formulations. Some examples are: fatty amine, ammonium salts and quaternary ammonium salts (Draelos et al., 2006).

Non-ionic surfactants

Non-ionic surfactants are neutral surfactant ions. Due to their uncharged nature, non-ionic surfactants are compatible with other surfactant types. Furthermore, this type of surfactant tends to exhibit good skin compatibility.

They are good foam enhancers (used with anionics) and can reduce irritation. However, non-ionic surfactants are not utilised on their own in most formulas as they don't produce as much foam as anionics and are more expensive (P. Romanowski, 2015). Two common examples are the sorbitan esters (Spans) and their ethoxylated analogues (Tweens) (Draelos et al., 2006).

Amphoteric surfactants

Amphoteric or zwitterionic surfactants can be negatively or positively charged depending on the pH. They provide a good cleansing function and are less irritating than anionic surfactants (P. Romanowski, 2015). Consequently, a mixture of anionic and amphoteric surfactants can help lessen the potential irritation caused by anionic surfactants.

Some examples of the most commonly amphoteric surfactants found in cleansing cosmetics are: cocamidopropyl betaine, cocoamphopropionate and sodium lauraminopropionate. Betaines are used to enhance foam quality or to increase the viscosity of liquids (Draelos et al., 2006).

In conclusion, in order to perform effectively and have minimal undesirable effects on the skin, the best options for a facial cleanser are: a mixture between anionic and non-ionic surfactants or between anionic and amphoteric surfactants.

The choice has been made to add a mixture between anionic and amphoteric surfactants in the formulation. Skin cleansing gel formulations tipically contain ethoxylated alkyl sulphates in combination with other surfactants (amphoteric in this case) and/or conditioning agents (e.g., fatty acid esters or polymeric additives) in order to achieve a desirable balance between cleansing and mildness (Thau, 2017). Specifically, Sodium Laureth Sulfate has been selected as the primary surfactant and will provide the main cleansing function as well as being an emulsifier.

With the purpose of lessening the possible irritation caused by the primary surfactant and enhancing mildness, a secondary surfactant is selected. After carrying research among the most generally used mild surfactants, Cocamidopropyl Betaine is chosen. It is increasingly used in shampoos and liquid cleansers because of its moderate irritancy potential. As well as that, this amphoteric surfactant is also considered to be a viscosity builder, a foam booster and emulsifier (Fisher, 1995). It is important to note that it has good skin compatibility with anionic surfactants.

According to Patent CN107308043A for an acne removal facial cleanser, the formulation should contain 12-15 % of Sodium Laureth Sulfate and 8-12 % of Cocamidopropyl Betaine. Specifically, it is established a 12 % for the primary surfactant and an 8 % for the secondary one.

Finally, an important factor when describing the emulsifiers is the hydrophilic-lypohilic balance number (HLB). The HLB value of surfactants in an oil-in-water emulsion should be between 8 and 18. When the HLB values of the surfactant and oil phase are closer, it is easier to form the microemulsion (Chen et al., 2012). However, in order to establish the concentration of the surfactants in a proper manner, the optimum HLB from the oily phase should be determined and based on this, proceed to rectify the concentrations or even change the emulsifiers if required.

5.1.2. EXCIPIENTS

5.1.2.1. FACIAL CLEANSING GEL

EMOLLIENTS

Emollients are moisturing ingredients, mainly lipids and oils, widely used in the formulation of cosmetics. They are designed with the aim of making the stratum corneum, the outermost layer of the epidermis, softer and more pliant by an increase in the hydratation of the skin (Nola et al., 2003). Therefore, the sensory properties and skin performance of emulsions are highly dependent on the emollients present in the formulation (Salka, 1997) These ingredients are intended to improve the spreadibilty when applying the product, as well as to enhance the skin barrier function and to provide a feeling of softness which is vital for consumers suffering from sensitive skin. In addition, emollients also increase the penetration of active ingredients into the skin and act as emulsifiers and co-solvents (Pedro et al., 2019).

It has to be said that, originally, emollients were developed for leave-on skincare products as the feeling can remain after usage. However, as they also influence to the skin feel while application, it is important to take these ingredients into consideration while developing the formula of the facial cleanser.

Emollients are generally long-chain organic molecules which contain small and polar functional groups. They can be divided into four main groups in accordance to their chemical family: hydrocarbons, fatty alcohols, esters and silicone derivates (Chao et al., 2017). The most commonly emollients used for this purpose are long chain saturated fatty acids like stearic, linoleic, oleic and lauric and fatty alcohols. Emollients classification is shown in *Table 7* as well as some examples (Kraft et al., 2005).

Table 7. Common examples of emollients.

Types of emollients	Examples
Dry emollients	Isopropyl palmitate, isostearyl alcohol, decyl oleate
Fatty emollients	Propylene glycol, octyl stearate, glyceryl stearate, jojoba oil, castor oil
Astringent emollients	Dimethicone, cyclomethicone, octyl octanoate, isopropyl myristate
Protective emollients	Isopropyl isostearate, diisopropyl dilinoleate

The emollient for the facial cleansing gel is considered to be myristic acid which is a vegetable based and relatively inexpensive fatty acid. Their main functions are to form a protective layer on the skin while preserving the natural moisture barrier, as well as to provide a smooth and soft application. Moreover, it is a common ingredient in facial cleansers because of its ability to wash away oils from the skin. This choice has been made in compliance with Patent CN109157451A where the main emollient of the facial cleanser for acne treatment is myristic acid.

Finally, in regard of the concentration of the emollient, it must be taken into account that in O/W emulsions, the concentrations of emollients can be found in a range of 5-30 % (Chao et al., 2017). In addition, in the patent above mentioned the content of this acid is expected to be in a range between 10 to 14 % by weight. Thus, the myristic acid is found in a concentration of 10 % in the formulation.

SOLVENT

As the active ingredient salicylic acid is not readily soluble in water at room temperature, a solvent needs to be added into the formulation. A study was carried out by Jouyban et al. (2011) where the solubility of salicylic acid in ethanol, propylene glycol and N-methyl-2-pyrrolidone at different temperatures and their binary mixtures at 298,2 K was studied. The results can be appreciated in *Figure 10*:

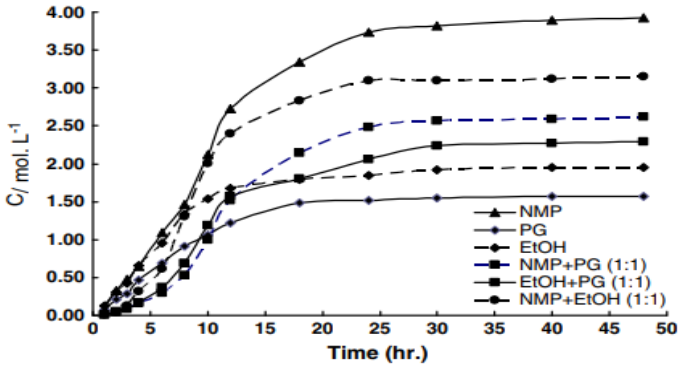

Fig. 10. Dissolution rate profile of salicylic acid in different solvent systems (Jouyban et al., 2011).

It can be concluded that the maximum solubility was observed for N-methyl-2-pyrrolidone. However, the SCCS (Scientific Committee on Consumer Safety) exposed that the presence of this substance with a maximum of 5 % is not safe for the consumer. As a result, it is discarded, as well as its binary mixtures. It has been selected a mixture of ethanol and propylene glycol 1:1. From the patent CN107184458A of an acne treatment facial cleanser, the percentage for both ingredients are set on 3 %.

HUMECTANTS

Humectants are a series of ingredients which provide hydratation effects as a result of their hygroscopicity (Oshimura et al., 2017). Water absorption can be achieved by two sources: from the dermis and from the environment when it is in humid conditions. Most of the humectants also provide emollient properties. Some examples of the most commonly found humectants in cosmetic formulations are: glycerin, gelatin, honey, hyaluronic acid, panthenol, sorbitol, urea, AHA, propylene glycol (Purnamawati et al., 2017).

According to Kraft et al. (2005), the most effective humectant is the trihydroxylated molecule glycerin. Consequently, it is used as a humectant in many leave-on cosmetics. Nonetheless, as glycerin is water soluble, it is difficult to deposit an effective level of this ingredient on the skin in a rinse-off product like a facial cleanser (Erthel, 2006). Therefore, in this case its use has other more remarkable effects like providing a moisturization feeling that remains after application (Dahlgren et al., 1987). As a result, according to VCRP database of 2014, glycerin was reported to be used in 15654 cosmetic products, of which 5441 were rinse-off cosmetics (34.76 %).

For a further improvement of the moisturization efficacy of the facial cleanser, caprylyl glycol is added to the formulation. It acts as a humectant and skin conditioning agent which provides emollience in many skincare products. Furthermore, as will be discussed later, it increases the antimicrobial activity of preservatives.

The concentration of glycerin has been established at a 5 % by weight by the study of the following patents where a facial cleanser is formulated: CN109125160A, CN104069027A and CN103599055A. On the contrary, the percentage of caprylyl glycol is 1 % as it has been determined that this percentage is safe and non-irritant for consumers (Johnson et al., 2012).

Finally, it should be noted that humectants are usually found in cosmetic formulations as a combination with occlusives to both enhance epidermal hydration and barrier function. Nonetheless, in the case of rinse-off products, like the facial cleansing gel, occlusive agents are generally not found in their formulations. This has been proven by research on several patents for facial gels and in the current market.

THICKENERS

Thickening agents are important when formulating a cosmetic as they help regulate the viscosity as well as improving the rheological properties of stability, feel and flow (Karsheva et al., 2007). The requierements for flow properties are different regarding the product. Therefore, the thickener to be added depends on the type of cosmetic. There are more than 500 thickening agents listed in the INCI dictionary.

It has to be said that there are different ways to increase viscosity like addition of solids, increase of the internal phase ratio, homogenization or adittion of thickeners (Laba, 2001). However, as already mentioned, in this work it has been opted for the use of a thickening agent.

Firstly, the selection of the thickener is influenced by the compatibility with the vehicle, either water or oil. In this case, an aqueous thickener needs to be chosen. Furthermore, another criteria in order to choose the most suitable thickening agent is to consider the viscosity range of the product. In accordance to the rheologycal quality factors previously exposed, both the cream and gel are expected to have a pseudoplastic behaviour with low viscosity at high shear and high viscosity at low shear. These facts are shown in *Table 8* as well as the most commonly used thickening agents:

Table 8. Common examples of thickeners and comparison of their properties (Laba, 2001).

Type of thickener	Example	Compatibility	Rheology
Aqueous thickeners	Cellulose gum	Water	Thixotropic
	Xanthan gum		Pseudoplastic
	Methylcellulose		Pseudoplastic
	Carbomers		Pseudoplastic
	Polyethylene glycols		Newtonian
	Clays		Thixotropic
Non-aqueous thickeners	Polyethylene	Oil	Pseudoplastic
	Trihydroxystearin		Thixotropic
	Organoclays		Thixotropic
	Fumed silica		Thixotropic

The most common way to thicken a surfactant-based formula, like the case of the cleanser, is to use sodium chloride. This fact can clearly be appreciated in Appendix II, where all five market formulations studied contain this thickening agent. In addition, this thickener provides really good results in surfactant systems based on Sodium Laureth Sulfate and Cocamidopropyl Betaine (Kortemier et al., 2010) which are the surfactants added in this product. With all the above in mind, sodium chloride is the thickener selected for the formulation.

Regarding patent CN104095763A of a facial cleanser formulation, the content of sodium chloride as a thickener should be in a range of 1-3 % whereas in patent CN105726372A of an acne-removal facial cleanser its percentage is between 0.5-2.1 %. As a consequence, a concentration of 1.5 % of sodium chloride is chosen.

GELLING AGENTS

A gel mainly contains an aqueous vehicle and a gelling agent which needs to be transparent, non-greasy and provide a cooling sensation when applied to the skin (Bushe et al., 2005). Common examples of these compounds include: tragacanth, pectin, starch, carbomer, sodium alginate, gelatine, cellulose derivatives, polyvinyl alcohol clays, etc.

Furthermore, the most frequently used are carbomers, which are synthetic macromolecular polymers of acrylic acid. They show high gelling and thickening efficacy in a wide range of pH

(Kar et al., 2019). According to CIR (Cosmetic Ingredient Review), carbomers are considered safe for health in cosmetics.

Above all the carbomers on the actual market, it has been decided to use Carbopol 940. Its low flow and non-drip properties are ideal for applications like clear gels. In terms of the concentration, the recommended percentage of usage is between 0.2-1 % by weight. In this case, it has been opted for a 0.5 % of concentration.

PRESERVATIVES

The purpose of preservatives is to prevent the growth of microorganisms during the product's shelf life, as it can spoil the cosmetic and produce skin or eye infections (Benson et al., 2019). Therefore, microbial contamination can definitely imply a risk for the consumer's health. It should be stated that most cosmetic formulations, due to their organic composition and high-water content, are products which can be easily degraded by microorganisms (Alvarez-Rivera et al., 2018). Microbial growth can imply chemical changes such as: hydrolysis, oxidation, reduction causing off-odours, change in colour, adverse changes in pH, breakdown of the emulsion or change in texture of the product. However, the antimicrobial function is not the only one, preservatives can also be added with the aim of persevering cosmetic products from the degradation caused by oxygen (antioxidant function).

A preservative should have the following properties: effective at low levels, tasteless, odourless, colourless, effective against both Gram-positive and Gram-negative bacteria and fungi and stable in the pH range from 2,5 to 10,5, acceptable for the regulatory agencies worldwide and cost-effective (Polati et al., 2007). In the Regulation (EC) Nº 1223/2009, Annex V lists 59 preservatives which are allowed in cosmetic formulations as well as their limit concentration.

In *Table 9*, examples of common antimicrobial preservatives widely used in the cosmetic market are shown (Polati et al., 2007):

Table 9. Common examples of antimicrobial preservatives.

Types of antimicrobial preservatives	Examples
Organic acids and their salts and esters	Sorbic acid, propionic acid, benzoic acid and parabens
Alcohols and derivates	Benzyl alcohol, phenoxyethanol, chlorobuthanol,
Aldehydes	Formaldehyde
Amines, amides, pyridines and benzalkonium salts	Triclocarban, hexamidine, dibromopropamidine, chlorhexidine, benzalkonium chloride
Phenols and derivatives	Phenol, o-Phenylphenol, chlorophene, triclosan

Moreover, according to research carried out by Pastor-Nieto et al. in 2017, the most frequently used preservatives in dermocosmetics are: phenoxyethanol (43.09 %), citric acid (23.69 %), methylparaben (14.54 %), sodium benzoate (13.81 %) and propylparaben (10.79 %).

Parabens are frequently utilised for the preservation of cosmetics as their antimicrobial activity is powerful against an extremely broad spectrum of microorganisms. Nonetheless, there is a general concern about their effects on human health, especially as several studies link parabens to breast cancer. For instance, a study published in 2004 by Darbre et al. detected parabens in breast tissue from patients with breast cancer. Furthermore, parabens have also been reported as a cause of some type of allergies (Savage et al., 2012). Therefore, there is currently a market trend towards increased consumption of paraben-free products.

Sodium benzoate is mainly used for its antifungal properties. Consequently, as it is not a broad-spectrum preservative it should be combined with other preservatives. Its use as preservative is allowed in the European Union at a maximum concentration of 2.5 % (acid) for rinse-off products like this actual case.

Hence, it will be combined with phenoxyethanol which as well as parabens has a large spectrum of antimicrobial activity and is effective over a wide range of temperature and pH. In addition, it is both water and oil soluble and is compatible with other preservatives. According to the European Scientific Committee on Consumer Safety, this preservative is safe for all consumers when used in a maximum concentration of 1 %.

In relation to the concentration of phenoxyethanol, a survey of 43 cosmetic products including leave-on and rinse-off products demonstrated that only 25 % of these cosmetics had levels of this preservative ≥ 0.60 % and the average concentration was 0.46 % (ANSM, 2012). Therefore, it has been opted for a concentration of 0.5 % of phenoxyethanol. On the contrary, sodium benzoate in cosmetics is normally used in a range of concentrations between 0.5-1.5 % and it has been established for this formulation a concentration of 1 %.

It is also important to note that caprylyl glycol, which has been established as humectant of the formulation, enhances the activity of chemical preservatives (Herman A., 2019).

On the other hand, an antioxidant needs to be selected to prevent the degradation of the cosmetic ingredients by oxidation. Some examples are: butylated hydroxytoluene (BHT), butylated hydroxyanisole (BHA), citric acid, glycolic acid and vitamins like retinol (vitamin A), tocopherol (vitamin E) and ascorbic acid (vitamin C).

The use of mixtures between BHT and BHA is really common as it improves the antioxidant efficacy of the formulation (Polati et al., 2007). However, these compounds are also considered to cause serious long-term side effects. In particular, BHA can act as a modulator and disruptor of the endocrine system as well as having the capacity to cause damage to the lung tissues and deficiencies in the reproductive system development (Hung et al, 2005; Jeong et al., 2005). As for BHT, this compound can modify the genotoxicity of other agents (Lanigan et al., 2002). Consequently, these antioxidants are discarded for the development of the formulation.

Citric acid is generally used in skincare formulations because of its protective antioxidant effects. Moreover, this substance belongs to the AHA (Alpha Hydroxy Acid) family and can therefore provide a gentle exfoliation which helps to remove the upper layer of dead skin cells in order to unclog the pores. As a result, it can be found mostly in facial cosmetics.

In relation to its concentration, as specified by the PCPC (Personal Care Products Council) in 2011, concentrations up to 4 % in leave-on formulations and 10 % in rinse-off products are reported. Patent CN105213285A of a facial cleanser for acne treatment, suggests a concentration of citric acid between 1-3 %. Accordingly, 2 % by weight of citric acid is included in this formulation.

pH ADJUSTER

During the formulation of a topical product, it is of utmost importance to ensure that it is compatible with the physiological skin pH. Studies in this area have determined that the pH of the skin ranges from 4.1 to 5.8 (Segger et al., 2008). In consequence, there is an agreement that skincare products should be sufficiently acified to possess a pH between 4 and 6.

If the formulation requires a pH adjustment some frequently used ingredients are: citric acid, lactic acid, sodium acetate, sodium lactate, sodium citrate, etc (Lukić et al., 2021). In this case, citric acid has already been selected as an antioxidant and therefore, will also provide the function of pH adjuster.

In addition, sodium hydroxide will be added to the formulation to help mantain the pH of the cosmetic within a certain range. In accordance to Patents of facial cleansers: CN104095763A (1-3 % NaOH), CN107375146A (0.5-1.5 % NaOH) and CN107890452A (1-2 % NaOH), a sodium hydroxide concentration of 1 % has been selected. Nonetheless, the percentage of these two pH regulating agents may require adjustment once the cosmetic is produced to bring it into the desired range.

FRAGRANCE

The fragrance of the facial cleansing gel is given by 0.2 % of citrus bergamia peel oil, which is the INCI's (International Nomenclature of Cosmetic Ingredients) name of the substance.

FORMULATION SUMMARY

In *Table 10*, the formulation of the facial cleansing gel is summarised:

Table 10. Facial cleanser formulation.

Ingredient (INCI)	Nº CAS	Concentration [%]	Function
Aqua	7732-18-5	46.3	Vehicle
Sodium Laureth Sulfate	9004-82-4	12	Primary surfactant
Myristic acid	544-63-8	10	Emollient
Cocamidopropyl Betaine	86438-79-1	8	Secondary surfactant
Glycerin	56-81-5	5	Humectant
Melaleuca alternifolia leaf oil	85085-48-9	3	Active ingredient
Ethanol	64-17-5	3	Solvent
Propylene glycol	57-55-6	3	Solvent
Salicylic acid	69-72-7	2	Active ingredient
Citric acid	77-92-9	2	Antioxidant, exfoliator and Ph adjuster
Sodium chloride	7647-14-5	1.5	Thickener
Caprylyl glycol	1117-86-8	1	Humectant and preservative
Sodium benzoate	532-32-1	1	Preservative
Sodium hydroxide	1310-73-2	1	Ph adjuster
Phenoxyethanol	122-99-6	0.5	Preservative
Carbomer	9003-01-4	0.5	Gelling agent
Citrus bergamia peel oil	89957-91-5	0.2	Fragrance

5.1.2.2. NIGHT CREAM

EMULSIFIERS

With the purpose of providing good stability to the O/W emulsion, a mixture of non-ionic surfactants is chosen. The selected emulsifiers are: glyceryl stearate and PEG-100 stearate. This combination can be found in several cosmetic formulations like in the night creams: DermoPure Oil Control 10% hydroxiacids by Eucerin and Sebiaclear active by SVR listed in Appendix II.

Although there are sources claiming that PEGs are not safe for human health, a study published in the journal Toxicology in 2005, entitled "Evaluation of the safety of polyethylene glycols (PEG) and their derivatives in cosmetics", concluded that: PEGs of a wide range of molecular weights, their ethers and fatty acids are safe for cosmetics.

In order to determine the composition of glyceryl stearate, Patent CN108066229A, which describes the formulation of an acne treatment cream, is consulted. This ingredient is considered to be in a range of 3-8 %, so it has been decided to add it at 7 %. On the other hand, according to Patent CN105997629A, PEG-100 stearate should have a concentration of about 3.5-5.5 %, being 5 % the one selected in this case.

For O/W emulsions macroemulsions, the HLB value should be in a range between 8-18 (Tadros, 2013). Regarding *Convergent Cosmetics*, the mixture of glyceryl stearate and PEG-100 stearate has an HLB= 11 ± 1.

SOLVENT

For the reasons stated above the solvent mixture is also ethanol and propylene glycol with the same composition.

EMOLLIENTS

In this case, as the night cream is a leave-on skincare product the use of emollients becomes more relevant and of greater importance as the feeling of moisturise remains after application.

The emollient chosen is glyceryl stearate, which is a natural glyceryl ester of glycerin and stearic acid. It is used in skin care creams in order to offer excellent hydratation and moisturization. Furthermore, as already mentioned, it provides an emulsifying function and helps to stabilize O/W emulsions by a reduction of the surface tension. Its composition has already been defined in the emulsifiers section.

HUMECTANTS

Along with the case of emollients, the use of humectants plays a major role in leave-on cosmetics like the night cream. As discussed above, glycerin is the most effective humectant. As a result, it will be chosen as the main humectant in this formulation. According to acne creams Patents: CN103610612A (6-8 %), CN105520897A (4-8 %) and CN107184448A (6 %), the glycerin concentration is set at 6 %.

Zinc PCA, on the other hand, is a natural humectant which helps to lessen the appearance of excess sebum on the skin. In other words, it is considered to be a humectant and skin conditioning agent. Additionally, it has been extensively used both topically and systemically for the management of acne vulgaris (Gupta et al., 2014). A study carried out by Andrade et al. (2018), showed that the combination of this humectant and niacinamide, an active ingredient selected for this formulation, has multiple benefits for acne treatment such as: normalization of follicular desquamation, prevention of new microcomedones and reduction of comedones and mild inflammatory lesions. The designated percentage for zinc PCA is 1 % as this is the actual concentration applied in the study.

OCCLUSIVES

Occlusives are defined by the CTFA dictionary as cosmetic ingredients which retard the evaporation of water from the skin surface. Therefore, these ingredients, in combination with humectants, increase epidermal hydration. In order to do so, they create a thin, continuous and water-resistant coating on the skin surface. This film can provide a greasy feeling to touch, which is not desired for acne-prone skin, as it already tends to an oily sensation. Consequently, only a small amount is used in such formulations (Romanowksi, 2015). The additional moisturising effect provided by these ingredients improves the appearance of skin and can also reduce redness.

Some of the most typical components used to impart occlusive properties to a cosmetic are: petrolatum, lanolin, mineral oil, isopropyl myristate and dimethicone (Yokota et al., 2006). Dimethicone, which is a silicone, is added to the formulation as an occlusive agent as well as an emollient with soothing properties. This choice is also based on its efficacy in reducing scarring, which reinforces a desired functionality of this cream. An investigation executed by Puri et al. (2009), concluded that topical silicone treatments significantly reduce hypertrophic scars, a type of acne scarring. Its composition is determined by different Patents of acne treatment creams: KR20130015339A (1-2 %), CN111000776A (1 %), CA3067924A1 (1 %), selecting 1 %.

THICKENERS

The most suitable thickening agent for the night cream is xanthan gum, which is an exopolysaccharide (polysaccharide of microbial origin), since it is appropiate for formulations with pseudoplastic behaviour and water compatibility. Furthermore, it is a natural ingredient considered non-toxic and non-irritating.

The high viscosity of xanthan gum at low shear rates effectively stabilizes creams which are oil-in-water emulsions, as well as delivering the active ingredients to the skin uniformly (Jungbuzlauer, 2017). Even at low concentrations, this thickening agent offers a higher degree of viscosity than other polysaccharides. Another advantage of using xanthan gum is its resistance to pH variations and thus its stability in both alkaline and acidic conditions.

According to Wibowo et al. (2001), the percentage of thickener in creams is expected to be between 0.1 % and 2 %. Specifically, Patent CN105520897A indicates that xantham gum should be in a range of 0.4-0.6 %. Bearing that in mind, the night cream will have 0.5 % of xanthan gum.

PRESERVATIVES

The considerations set forth during the selection of preservatives for the facial cleanser can be applied as well for this case. Consequently, sodium benzoate and phenoxyethanol act as antimicrobial preservatives and citric acid as an antioxidant. In relation to the concentration of phenoxyethanol, since the survey conducted by ANSM (2012) also included leave-on cosmetics, it is decided to use the same concentration (0.5 %) for both formulated products developed in this work. In contrast, the recommended usage level for sodium benzoate is up to 0.5 % in leave-on products. Lastly, the percentage of citric acid is decided according to the following Patents: CN102973424A (0.2-0.6 %) and CA3067924A1 (0.05-1 %), with 0.4 % being the selected composition.

pH ADJUSTER

As for the facial cleanser, citric acid and sodium hydroxide are chosen to fulfill the functionality of pH regulators. The composition of the citric acid has already been stablished, whereas sodium hydroxide is included at 0.4 % with respect to Patent CN105250189A (0.4-0.5 %).

FRAGRANCE

The parfum to achieve the expected scent is lavandula angustifolia oil (INCI's name) and its content has a percentage of 0.2 %. This ingredient is found in about the 5.66 % of the cosmetic creams available on the market.

FORMULATION SUMMARY

In *Table 11*, the formulation of the night cream is summarised:

Table 11. Night cream formulation.

Ingredient (INCI)	Nº CAS	Concentration [%]	Function
Aqua	7732-18-5	61.5	Vehicle
Glyceryl stearate	31566-31-1	7	Emulsifier and emollient
Glycerin	56-81-5	6	Humectant
PEG-100 stearate	9004-99-3	5	Emulsifier
Niacinamide	98-92-0	5	Active ingredient
Melaleuca alternifolia leaf oil	85085-48-9	3	Active ingredient
Ethanol	64-17-5	3	Solvent
Propylene glycol	57-55-6	3	Solvent
Salicylic acid	69-72-7	2	Active ingredient
Zinc PCA	68107-75-5	1	Humectant and skin conditioning agent
Dimethicone	9006-65-9	1	Occlusive, emollient and skin conditioning agent
Phenoxyethanol	122-99-6	0.5	Preservative
Sodium benzoate	532-32-1	0.5	Preservative
Xanthan gum	11138-66-2	0.5	Thickener
Citric acid	77-92-9	0.4	Antioxidant, exfoliator and pH adjuster
Sodium hydroxide	1310-73-2	0.4	pH adjuster
Lavandula angustifolia oil	8000-28-0	0.2	Fragrance

6. PRELIMINARY DESIGN OF THE MANUFACTURING PROCESS

Once the conceptualization, quality criteria and formulation of both cosmetics have been defined, the last step towards the development of this range of products is the preliminary design of its manufacturing process. This step involves three key aspects (Wibowo et al., 2001):

- A synthesized process flowsheet capable of producing the desired product.
- Appropriate equipment selection.
- Order of addition of the ingredients and equipment operating conditions.

Nonetheless, it is first necessary to establish an annual production of both the facial cleansing gel and the night cream.

6.1. ANNUAL PRODUCTION

This range of cosmetic products is aimed at a target group of about 100,000 consumers. The consumption per person is set at 2 products of each type per year. Taking into account that the volumes are: 200 mL of the facial cleansing gel and 50 mL of the night cream, it is required to produce 40,000 L of the gel and 10,000 L of the cream per year. Then, from the different ingredients and their densities and percentages by weight, the densities of the two formulations are calculated, as shown in the Appendix IV, being 1.05 kg/L for the facial cleanser and 1.03 kg/L for the cream. As can be seen, the densities of the two products are clearly close to 1 kg/L, so this value is selected for both. Therefore, it is concluded that the annual mass productions of the facial cleanser and cream are 40,000 kg/year (or 40 tons/year) and 10,000 kg/year (or 10 tons/year) respectively.

On the other hand, manufacturing processes can be divided into continuous, semi-continuous (semi-batch) and discontinuous (batch), depending on how the raw material is charged and the product is discharged. Most cosmetics and toiletries are manufactured by batch processing methods due to the wide variety and relatively small quantities of finished products (Whalley, 2001). Therefore, it has been opted to carry out the manufacturing of both products by using a

discontinuous or batch process, defined as a series of operations executed over a period of time on a separate and identifiable item or parcel of material (Sharratt, 1997).

Its main advantage is that batch equipment can be multi-purpose, as they can be used for several batch processing steps and can also support multi-product manufacturing within the facility. In addition, a batch manufacturing facility is easier to scale up depending on market demand (Barker et al., 2005). Moreover, the capital cost required for this type of manufacturing process is significantly lower than in continuous processes.

It has been established that the desired annual production will be manufactured in 400 kg batches for the two cosmetics in order to use the same equipment in both cases and to reduce plant costs. Consequently, the number of batches per year is 100 batches/year for the cleanser and 25 batches/year for the cream. Nonetheless, this scheduled production might vary in accordance to consumer's demand. These specifications are listed in *Table 12*:

Table 12. Production specifications.

Specifications	Facial cleansing gel	Night cream
Annual product units manufactured [unit/year]	200,000	200,000
Volume per unit [mL/unit]	200	50
Annual mass production [kg/year]	40,000	10,000
Batch capacity [kg]	400	400
Annual number of batches [batches/year]	100	25

6.2. SYNTHESIS OF THE MANUFACTURING PROCESS

There are five major steps in manufacturing chemical-based consumer products: pre-treatment, mixing, structure formation or homogenization, post-treatment and packaging or filling (Wibowo et al., 2002). The general structure of the manufacturing process of the skin care products developed in this work is shown in *Figure 11*. Taking into account that it is a batch process; this flow diagram should be interpreted as a series of sequential actions.

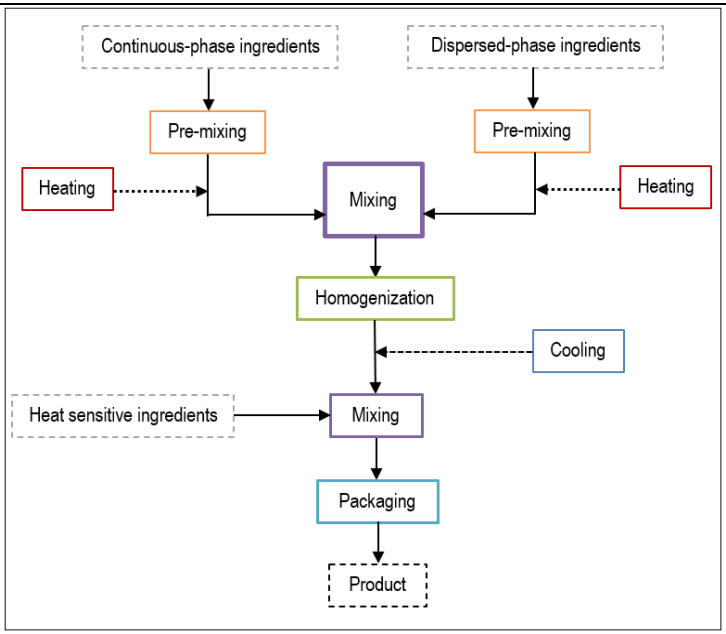

Fig. 11. Synthesis of the process flowsheet of the developed cosmetics.

These steps will be further developed in this section when describing the production of both cosmetics which follows, in general terms, the same procedures. Note that liquids and creams should be produced with particular attention to protection from contamination (HSA, 2018).

PRE-TREATMENT (PRE-MIXING AND HEATING)

From the figure above, it can be observed that the pre-treatment step is based on pre-mixing and heating operations. This step is of utmost importance as it is necessary to condition the ingredients before moving on to the mixing step. Regarding the pre-mixing treatment, compatible ingredients can be processed together to form a mixture. Accordingly, ingredients are divided into continuous-phase ingredients (water soluble) and dispersed-phase ingredients (oil soluble).

In the event that insoluble solid ingredients were present, they should be mixed separately and may be in need of further pre-treatment operations such as drying, humidification, washing, dissolution, surface modification, or particle-size change (Wibowo et al., 2002). However, as will be seen below, this type of ingredients is not present in either of the two formulations.

On the other hand, it is important to point out that solid ingredients with low melting temperatures might require to be heated in order to be dissolved and provide good mixing. Therefore, the temperature of the pre-mixing unit needs to be higher than the melting point of

these substances. In the case of the dispersed-phase solids at room temperature, the melting point is indicated below.

A study conducted by Lin (1968) on the effect of the initial surfactant location on the viscosity of emulsions, concluded that if it is intended to produce an O/W emulsion with fine droplet size, it is preferred to place the surfactants in the continuous phase. Furthermore, phase inversion can be prevented by increasing the viscosity of the continuous phase (Norato et al., 1998). As a result, thickeners are introduced into the aqueous-phase vessel to improve the stability of the emulsion. In order to make a correct division of the remaining ingredients, the solubilities of the substances in water have been researched. The ingredients of the facial cleanser and the night cream are classified in *Table 13* and *Table 14* respectively.

Table 13. Classification of the ingredients of the facial cleanser according to the appropriate phase.

Continuous-phase ingredients		**Dispersed-phase ingredients (melting point)**	
Aqua	Glycerin	Myristic acid (53,9 ºC)	Ethanol
Sodium Laureth Sulfate	Citric acid	Salicylic acid	Propylene glycol
Cocamidopropyl Betaine	Carbomer	Caprylyl glycol	
Sodium chloride	Sodium hydroxide		

Table 14. Classification of the ingredients of the night cream according to the appropriate phase.

Continuous-phase ingredients		**Dispersed-phase ingredients (melting point)**	
Aqua	Glycerin	Glyceryl stearate (55-60 ºC)	Ethanol
PEG-100 stearate	Zinc PCA	Salicylic acid	Propylene glycol
Niacinamide	Citric acid	Dimethicone	
Xanthan gum	Sodium hydroxide		

Note that ethanol and propylene glycol, although being miscible in water, are added into the dispersed-phase vessel as they provide the solubilization of salicylic acid. Moreover, preservatives, fragrance and essential oils are not included in this step. These substances will be added after cooling, as they are considered to be heat sensitive (Wibowo et al., 2001).

Both pre-mixing units are heated with the aim of easing the mixture and minimizing viscosity (Wibowo et al., 2001). To prepare O/W emulsions, both phases should be heated to 70-80 ºC and mixed by continuous stirring (Bouwman-Boer et al., 2015). Proper agitation promotes uniform composition and temperature throughout the vessel (Cunill et al., 2010).

Finally, an example of operating conditions is exposed. In accordance with Patent CN108294989A of an anti-acne facial cleanser, both the continuous and dispersed phase are heated and mixed at 80 ºC during 30 min and a constant speed of 30 rpm. However, this is only an approximate guideline since the formulation is not the same and therefore, when it comes to actually manufacturing the product, modifications to the operation conditions must be made.

MIXING

The following step is considered to be a pre-emulsion. Firstly, the continuous phase is added to the main vessel. Next, the dispersed phase is slowly transferred while stirring constantly with the purpose of preventing phase inversion and coalescence. According to Patent US5938581A, the ratio between the introduction of the hydrophobic phase and the volume of the continuous phase should be maintained throughout the complete addition at 10 to 100 times lower than the stirring speed.

The dispersed phase is found in the mixture as relatively large droplets (d_p>100 μm) (Wibowo et al., 2002). As well as that, it appears to be macroscopically homogeneous. The formed mixture is heated in a temperature range between 70-80 ºC. In relation to Patent CN112933006A, the mixture of phases should be stirred at 80 ºC during 40-60 min, being 60 min the selected time.

HOMOGENIZATION

The mixture obtained in the previous step might not possess the desired microstructure and consequently, the expected level of homogeneity. Therefore, a homogenization procedure is necessary to reduce the droplet size at least until the diameter is smaller than 100 μm, but the product remains viscous (Bornfriend, 1978). As mentioned during this work, lessening the droplet size is vital as it provides an improvement in emulsion stability. This step should be carried out at temperatures between 70-80 ºC, likewise the previous ones (Wibowo et al.,2001). The time required for this step will be established once the equipment is selected.

POST-TREATMENT (COOLING AND MIXING)

After homogenization, the formed emulsion with finer droplet size, is cooled until the temperature is below 40- 50 ºC (Wibowo et al., 2001). The heat-sensitive ingredients (fragrances, preservatives and essential oils) are then added to the mixture. In the case of the two skin care products developed, these ingredients are: tea tree oil, sodium benzoate, phenoxyethanol and fragrance. Lastly, the emulsion continues to be stirred until it reaches room temperature, at which

point the product is ready for packaging. The time for this operation is set at approximately 25 min in accordance to the Patent CN107496267A of an acne-removing cosmetic.

PACKAGING

The emulsions are transferred to a filling machine which performs the packaging of the acne treatment products. As determined in section 3.3., the developed cosmetics are packaged in 200 mL (facial cleanser) and 50 mL (night cream) collapsible PP tubes. During packaging, random samples are taken and controlled. This quality control shall be carried out while packaging is still going on, so that no additional time is spent in the process. Moreover, it is important to mention that every finished product should bear a production identification number which enables the history of the product to be traced (HSA, 2018).

With a production of 400 kg of each product, 2,000 units of facial cleanser and 8,000 units of the night cream can be packaged. The estimated packaging time of the cleanser is 100 min and for the cream 400 min, considering a filling and sealing speed of 3 s per tube. Finally, an additional time of two hours must be considered for in-plant operations or in case any adjustment is required.

6.3. SELECTION OF EQUIPMENT UNITS

Once the manufacturing process is synthetized, the appropriate equipment units are selected for the different stages of production. It is ought to seek for equipment with wide range of capacity and little energy consumption (Wibowo et al., 2001).

PRE-MIXING AND MIXING

Additionally, in accordance to these authors, for the operations of pre-mixing, pre-emulsification and dispersion of solids in liquids, the most suitable option is an agitated vessel in turbulent shear as it meets the above condition. This fact can be appreciated in *Figure 12*.

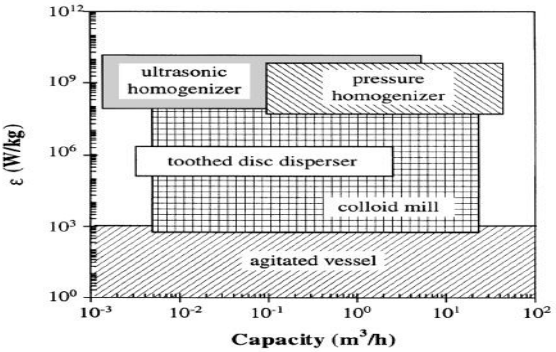

Fig. 12. Typical capacity and energy consumption for selected emulsification units (Wibowo et al., 2001).

The type of flow produced in an agitated tank depends on the impeller, the characteristics of the fluid and the size and proportions of the tank, baffle plates and agitator (McCabe et al., 2007).

Turbulent impellers are classified in relation to their primary flow direction, being axial and radial flow the most commonly used. Axial flow impellers have an up-down flow pattern whereas radial flow impellers have a side-to-side flow pattern (Euromixers). An axial flow impeller has been chosen as it is frequently used for low to medium viscosity products and high speed (Paul et al.,2004).

Some typical examples of axial flow impellers are (Crane Engineering):

- Propeller: widely utilised in portable mixers due to its small size and high efficiency. However, it is quite expensive for large vessels.
- Pitched blade turbine: used when a balance of flow and shear is required. In particular, it is of great use in applications where two or more liquids are blended.
- Hydrofoil: generates less shear stress in comparation with the other types.

It has been decided to use a pitched blade turbine as the impeller due to its characteristics.

In a vessel without baffle plates, there is a strong tangential flow as well as vortex formation for moderate stirrer rotation speeds. However, when baffle plates are installed, the vertical flow increases and a faster mixing of the liquid occurs (McCabe et al., 2007). Therefore, the selected vessels are required to have baffles.

Finally, as mentioned above, a temperature increase is needed for mixing operations. As a consequence, vessels with a heating jacket are chosen. This will provide uniform heat exchange through the vessel walls.

Taking into consideration that the batch volume is expected to be 400 L, the continuous phase of the facial cleanser is about 305 L and the dispersed one 76 L. On the other hand, for the night cream the volume of the aqueous phase is 319 L and 64 L for the hydrophobic one. Hence, it has been decided that the agitated vessel for pre-mixing the oily phase has a volume of 100 L, while the tank for pre-mixing the continuous phase and the one to mix both phases present a capacity of about 500 L. The supplier De Dietrich Process Systems provides a wide range of tanks in the DIN Range that meet the criteria stablished. In *Figure 13* a diagram of a DIN Range agitated vessel is shown.

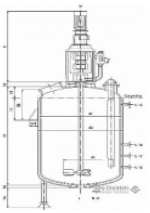

Fig. 13. Agitated vessel (De Dietrich Process Systems).

HOMOGENIZATION

An emulsification equipment is required to lessen the droplet size and consequently, enhance the stability of the emulsion. In general, the most typical equipment for homogenization used in the industry sector are: colloid mill, pressure homogenizer and ultrasonic homogenizer.

A pressure homogenizer has been selected. The usage of a colloid mill has been discarded because although its energy consumption is the lowest of all, it is not the most suitable option if the formation of very small droplets is needed, like in the case of the cleansing gel, which is a microemulsion. Furthermore, according to Wibowo et al. (2002), the most appropriate homogenizers are the pressure and the ultrasonic ones.

A pressure homogenizer consists of two main parts: a high-pressure pump and a homogenization valve which is composed of a seat, valve and impact ring (*Figure 14*). The premix fluid (feed) passes through the valve, increasing its velocity and generating turbulence as a result. Due to the gap between the seat and the valve, strong shearing forces are created which help disrupting the substances. In addition, upon exiting the gap, cavitation occurs. This phenomenon enhances the efficacy of the homogenization process (Industrial Quick Search).

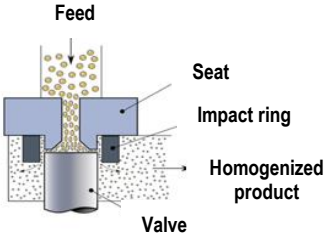

Fig. 14. Diagram of a pressure homogenizer (MGNewell).

HOMMAK F-HM20 from the supplier company HOMMAK has been selected as the industrial high-pressure homogenizer (*Figure 15*). This machine can be used for the following applications: alimentary products, cosmetics, chemical industry, pharmaceutical industry and biotechnology. Furthermore, it comprises a range of capacities between 2000 L/h at a pressure of 200 bar and 160 L/h at 2100 bar. Regarding Patent CN111529440A of an acne-removing emulsion, the

homogenizer's pression is set at 300 bar which implies 1000 L/h in the selected equipment. Accordingly, the time required for this operation is about 25 min in both cases.

Fig 15. High-pressure homogenizer (HOMMAK).

POST-TREATMENT (COOLING AND MIXING)

As the homogenized product leaves the previous treatment unit, it is directed to a heat exchanger in order to cool the mixture to a value below 40-50 ºC. In particular, a spiral heat exchanger has been chosen as it is considered ideal for though fluids like sludge, media with suspended solids or fibres or viscous substances, like in this case (Gooch Thermal). The SONDEX® Spiral heat exchanger (*Figure 16*) design allows for a countercurrent flow that makes it possible to achieve very close temperature approaches within a range of -20 to 200 ºC. It is important to mention that fresh water will be used as the cooling fluid.

Fig. 16. Spiral heat exchanger (SONDEX®).

The final mixing unit is characterized as the previous ones with a volume of 500 L.

PACKAGING

As already mentioned, the last step in the manufacturing process consists in packaging the product in the respective tube, 200 mL for the cleanser and 50 mL for the night cream. With this in mind, the automatic tube filling and sealing machine from the supplier company VKPAK is selected (*Figure 17*). Based on information provided by the supplier, this machine is widely used in toothpaste, cosmetics, pharmaceutical and alimentary industries. Its operation comprises the filling of ointments, creams, gels or fluids with high viscosity into the tube, folding and sealing the tail of the tube and printing the code and batch number into the finished product.

This equipment can be used for laminated, metal and plastic tubes as in this case. Therefore, not only can it be used for the production of the cosmetics developed in this work, but can also meet the criterion of having the plant available for other processes. In addition, it is possible to adapt the filling capacity to a volume between 5 and 250 mL, as well as to regulate the running speed.

Fig. 17. Tube filling and sealing machine (VKPAK).

6.4. MANUFATURING CAMPAIGNS

Next, the production campaigns to be carried out are proposed. In order to establish these manufacturing campaigns, it is necessary to estimate how long it takes to produce each batch. Adding the time required for each operation, plus the time for field operations and possible unforeseen events, results in a production time of 6 hours for the gel and 11 hours for the cream.

Nevertheless, it is also important to determine the time needed for the clean-up of the equipment. This, as well as the other procedures, needs to follow the cGMP (Current Good Manufacturing Practices) to enhance effective and safe cosmetics. It has been decided to use a CIP (Clean In Place) system which are specifically designed for cosmetic industry (Bachiller Barcelona). In particular, this CIP program is divided in 3 steps for each equipment: hot purified water at 80 ºC for 10 min, a low foaming detergent during 30 min commonly used in CIP systems (Alconox Inc.) and fresh water for rinsing for 10 min.

The proposed annual distribution for the year 2023 is divided into four quarters, each of 3 months, and is shown in *Figures 18* and *19*. In the case of the facial cleanser, 2 batch per day from Monday to Friday are produced and as a result, it requires 5 weeks of production in each of the two quarters. On the contrary, the night cream is manufactured in a batch per day from Monday to Friday and thus, it is needed two weeks plus 2 or 3 days in the quarters. Nevertheless, this plant is not only expected to produce these two products and consequently, as can be appreciated in *Figure 19*, it will be free for other manufacturing processes during certain times of the year. Nonetheless, this fact goes beyond the scope of the project.

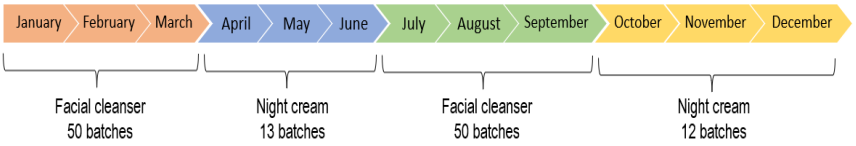

Fig. 18. Batch distribution throughout the year.

January

Mo	Tu	We	Th	Fr	Sa	Su
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31					

February

Mo	Tu	We	Th	Fr	Sa	Su
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28					

March

Mo	Tu	We	Th	Fr	Sa	Su
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31		

April

Mo	Tu	We	Th	Fr	Sa	Su
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30

May

Mo	Tu	We	Th	Fr	Sa	Su
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

June

Mo	Tu	We	Th	Fr	Sa	Su
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30		

July

Mo	Tu	We	Th	Fr	Sa	Su
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30
31						

August

Mo	Tu	We	Th	Fr	Sa	Su
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31			

September

Mo	Tu	We	Th	Fr	Sa	Su
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	

October

Mo	Tu	We	Th	Fr	Sa	Su
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31					

November

Mo	Tu	We	Th	Fr	Sa	Su
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30			

December

Mo	Tu	We	Th	Fr	Sa	Su
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

Fig. 19. Calendar distribution of the campaigns throughout the year 2023.

6.5. PROCESS FLOW DIAGRAM

Finally, the process flow diagram of both cosmetics has been elaborated (*Figure 20*). It shows the representation of the different units of the process with the most relevant data of each stage, such as operation time or temperature. In addition, it can be observed that the main streams are numbered as well as the existence of services like hot and fresh water.

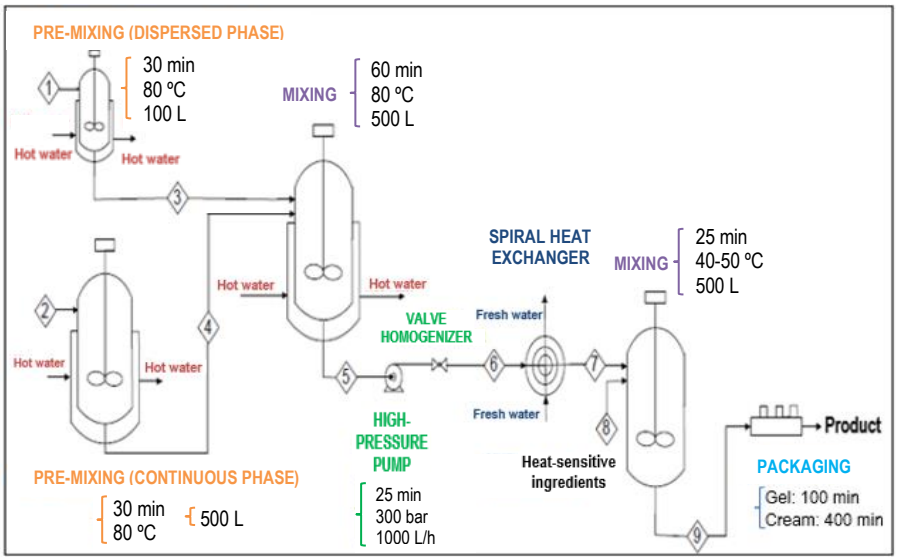

Fig. 20. Process flow diagram.

7. CONCLUSIONS

The development of two products, a facial cleanser and a night cream, for acne treatment on sensitive skin has been carried out on the basis of bibliographic research. To this end, both products were initially conceptualized and the quality factors were established. Next, the most suitable ingredients were selected for their respective formulations and finally, their manufacturing process was designed in a synthesized form while choosing as well the equipment for this purpose.

Initially, their functions were stated: the facial cleanser provides the required cleansing to remove oil, dirt and dead skin cells as well as lessen skin irritation and redness, which are typical on sensitive skin. On the other hand, the night cream is expected to reduce the appearance of pimples and reducing acne scars and hyperpigmentation. Note that both products improve the acne condition due to their antibacterial function. In relation to the delivery vehicle, it is an O/W emulsion, although the cleansing gel is a microemulsion and the night cream is a macroemulsion. It is important to highlight that their shelf life is 3 years and their Period After Opening is 1 year.

Salicylic acid, tea tree oil and niacinamide were selected as active ingredients for acne treatment. In addition, the facial cleanser required surfactants not only to emulsify the product but also to provide its cleansing function. The remaining ingredients in the formulations and their concentrations were selected from commercially available products, articles and patents in an attempt to avoid ingredients that could cause irritation to sensitive skin.

Regarding the manufacturing process, it was decided to operate by batches of 400 kg with a total production of 40,000 kg/year for the cleanser and 10,000 kg/year for the night cream. Nonetheless, changes in production may be required in order to adjust to the consumer's demand. The selected equipment consists of agitated vessels for pre-mixing and mixing steps, a homogenizer to obtain the emulsion, a spiral heat exchanger to cool it down and a tube filling and sealing machine. The same equipment is intended to be used for both manufacturing processes.

REFERENCES AND NOTES

ACS. (n.d.). Chemistry & Sustainable Development Goals. Retrieved June 2022, from: https://www.acs.org/content/acs/en/sustainability/chemistry-sustainable-development-goals.html

AEDV. (2021). Los problemes dermatológicos que se están produciendo en esta pandemia por COVID-19. Retrieved March 2022, from: https://aedv.es/los-problemas-dermatologicos-que-se-estan-produciendo-en-esta-pandemia-por-covid-19/

Alvarez-Rivera, G., Llompart, M., Lores, M., & Garcia–Jares, C. (2018). Preservatives in Cosmetics. *Analysis of Cosmetic Products*, 175–224. https://doi.org/10.1016/b978-0-444-63508-2.00009-6

Andrade, J. P., L. Wagemaker, T. A., Mercurio, D. G., & B. G. Maia Campos, P. M. (2018). Benefits of a dermocosmetic formulation with vitamins B3 and a B6 derivative combined with zinc-PCA for mild inflammatory acne and acne-prone skin. *Journal Biomedical and Biopharmaceutical Research*, *15*(2), 214–223. https://doi.org/10.19277/bbr.15.2.188

ANSM. (2012). Evaluation due risqué lié á l'utilisation du phénoxyéthanol dans les produits cosmètiques.

Avail Dermatology. (2020). History of Skincare Products. Retrieved March 2022, from: https://availdermatology.com/history-of-skincare-products/

Bachiller Barcelona. (n.d.). CIP (Clean In Place): Stages washing unit for process tanks. Retrieved June 2022, from: https://bachiller.com/en/cip-clean-in-place-system/

Barel, A. O., Paye, M., & Maibach, H., I. (2009). *Handbook of Cosmetic Science and Technology (English Edition)* (3.ª ed.). CRC Press.

Barker, M., Rawtani, J., & Mackay, S. (2005). Introduction. *Practical Batch Process Management*, 1–16. https://doi.org/10.1016/b978-075066277-2/50001-3

Benjamins, J., Zoet, F. D., & Van Aken, R. H. (2007). *Thickened emulsions and method for the preparation thereof* (WO2007004882A2).

Benson, H. A. E., Roberts, M. S., Leite-Silva, V. R., & Walters, K. (2019). *Cosmetic Formulation Principles and Practice*. Amsterdam University Press.

Bibette, J. M., & Mason, T. (1999). *Emulsion manufacturing process* (US5938581A).

Bornfriend, R. (1978). Effects of Processing on the Rheological Behaviour of Emulsions. *Cosmetics and Toiletries*, 93.

Bouwman-Boer, Y., Fenton-May, V., & Brun, L. P. (2015). *Practical Pharmaceutics: An International Guideline for the Preparation, Care and Use of Medicinal Products*. Springer.

Brown, L. (2020). Acne and its management. *South African pharmaceutical journal*, *87*(5), 37a-37h.

Brummer, R., & Godersky, S. (1999). Rheological studies to objectify sensations occurring when cosmetic emulsions are applied to the skin. *Colloids and Surfaces A: Physicochemical and Engineering Aspects*, *152*(1–2), 89–94. https://doi.org/10.1016/S0927-7757(98)00626-8

Chang, Q. (2016). Emulsion, Foam, and Gel. *Colloid and Interface Chemistry for Water Quality Control*, 227–245. https://doi.org/10.1016/b978-0-12-809315-3.00011-6

Chao, C., Génot, C., Rodriguez, C., Magniez, H., Lacourt, S., Fievez, A., Len, C., Pezron, I., Luart, D., & van Hecke, E. (2018). Emollients for cosmetic formulations: Towards relationships between

physico-chemical properties and sensory perceptions. *Colloids and Surfaces A: Physicochemical and Engineering Aspects*, *536*, 156–164. https://doi.org/10.1016/j.colsurfa.2017.07.025

Chaudhri, S.K. & Jain, N.K. (2009) History of Cosmetics. *Asian Journal of Pharmaceutics*. 3, 164-167. https://doi.org/10.4103/0973-8398.56292

Chen, L., Tan, F., Wang, J., & Liu, F. (2012). Assessment of the percutaneous penetration of indomethacin from soybean oil microemulsion: Effects of the HLB value of mixed surfactants. *Die Pharmazie*, *67*(1), 31–36.

Chen, T., & Appa, Y. (2006). Over-the-Counter Acne Medications. In *Cosmetic Formulation of Skin Care Products* (1.ª ed., pp. 251–271). CRC Press.

Chen, X. (2017). *Acne-removing cosmetic and preparation method thereof* (CN107496267A).

Chin, J., Jiang, B., Mufidah, I., Persada, S., & Noer, B. (2018). The Investigation of Consumers' Behavior Intention in Using Green Skincare Products: A Pro-Environmental Behavior Model Approach. *Sustainability*, *10*(11), 3922. https://doi.org/10.3390/su10113922

Cinelli, P., Coltelli, M. B., Signori, F., Morganti, P., & Lazzeri, A. (2019). Cosmetic Packaging to Save the Environment: Future Perspectives. *Cosmetics*, *6*(2), 26. https://doi.org/10.3390/cosmetics6020026

Cox, S. D., Mann, C. M., Markham, J. L., Bell, H. C., Gustafson, J. E., Warmington, J. R., & Wyllie, S. G. (2000). The mode of antimicrobial action of the essential oil of Melaleuca alternifolia (tea tree oil). *Journal of applied microbiology*, *88*(1), 170–175. https://doi.org/10.1046/j.1365-2672.2000.00943.x

Crane Engineering. (2015). Introduction to mixer impellers & flow patterns. Retrieved June 2022, from: https://blog.craneengineering.net/introduction-mixer-impellers-flow-patterns

Croshaw, B. (1977). Preservatives for cosmetics and toiletries. *Journal of the Society of Cosmetic Chemists*, *28(1)*, 3–16.

Cunill F., Iborra M., & Tejero J. (2010). Reactores Químicos Apuntes. Universidad de Barcelona

Dahlgren R. M., Lukacovic M. F., Michaels S. E., & Visscher M. O. (1987). Effects of bar soap constituents on product mildness. In: A. R. Baldwin (Ed.), Second World Conference on Detergents (127– 134). A.O.C.S.

Darbre, P. D., Aljarrah, A., Miller, W. R., Coldham, N. G., Sauer, M. J., & Pope, G. S. (2004). Concentrations of parabens in human breast tumours. *Journal of Applied Toxicology*, *24*(1), 5–13. https://doi.org/10.1002/jat.958

De Gruyter. (2016). Flocculation of emulsions. *Emulsions: Formation, Stability, Industrial Applications*, 113–128. https://doi.org/10.1515/9783110452242-010

Díez, O. (1998). *Manual de cosmetología*. Videocinco.

Draelos, Z. D. (2022). Cosmetic Dermatology: Products and Procedures (3rd ed.). Wiley-Blackwell.

Draelos, Z. D. (2017). The science behind skin care: Cleansers. *Journal of Cosmetic Dermatology*, *17*(1), 8–14. https://doi.org/10.1111/jocd.12469

Draelos Z. D. (2006). The effect of a daily facial cleanser for normal to oily skin on the skin barrier of subjects with acne. *Cutis*, *78*(1 Suppl), 34–40.

Draelos, Z. D., & Thaman, L. A. (2006). *Cosmetic Formulation of Skin Care Products* (1.ª ed.). CRC Press.

Euromixers. (n.d.). Impeller types. Retrieved June 2022, from: https://www.euromixers.co.uk/impeller-types/#:~:text=Axial%20flow%20impellers%20have%20an,blending%2C%20solids%20suspension%20and%20stratification.

Feng, D. (2016). *Acne-removal facial cleanser* (CN105726372A).

Fisher, A. A., Rietschel, R. L., & Fowler, J. F. (1995). *Fisher's Contact Dermatitis* (4.ª ed.). Williams & Wilkins.

Fox, L., Csongradi, C., Aucamp, M., du Plessis, J., & Gerber, M. (2016). Treatment Modalities for Acne. *Molecules (Basel, Switzerland)*, *21*(8), 1063. https://doi.org/10.3390/molecules21081063

Fu, S. (2013). *Acne cream and preparation method thereof* (CN102973424A).

Gan, Y. (2018). *Acne cream and preparation method thereof* (CN108066229).

Ghunawat, S., Sarkar, R., & Garg, V. (2019). Comparative study of 35% glycolic acid, 20% salicylic–10% mandelic acid, and phytic acid combination peels in the treatment of active acne and postacne pigmentation. *Journal of Cutaneous and Aesthetic Surgery*, *12*(3), 158. https://doi.org/10.4103/jcas.jcas_135_18

Gonçalves, G. M. S., Srebernich, S. M., Vercelino, B. G., & Zampieri, B. M. (2013). Influence of the presence and type of fragrance on the sensory perception of cosmetic formulations. *Brazilian Archives of Biology and Technology*, *56*(2), 203–212. https://doi.org/10.1590/s1516-89132013000200005

González-Muñoz, P., Conde-Salazar, L., & Vañó-Galván, S. (2014). Dermatitis alérgica de contacto a cosméticos. *Actas Dermo-Sifiliográficas*, *105*(9), 822–832. https://doi.org/10.1016/j.ad.2013.12.018

Gooch Thermal. (n.d.). Spiral heat exhanger: Design features & benefits. Retrieved June 2022, from: http://www.goochthermal.com/spiral-heat-exchanger/design

Gupta, M., Mahajan, V. K., Mehta, K. S., & Chauhan, P. S. (2014). Zinc Therapy in Dermatology: A Review. *Dermatology Research and Practice*, *2014*, 1–11. https://doi.org/10.1155/2014/709152

He, T., Ai, Y., Zhu, S., & Shao, Z. (2016). *Acne treatment essence cream and preparing method thereof* (CN105250189A).

He, Z. (2019). *Acne-removing facial cleanser* (CN109157451A).

Herman, A. (2018). Antimicrobial Ingredients as Preservative Booster and Components of Self-Preserving Cosmetic Products. *Current Microbiology*, *76*(6), 744–754. https://doi.org/10.1007/s00284-018-1492-2

HOMMAK. (n.d.). HOMMAK F-HM20 Homogenizer. Retrieved June 2022, from: https://www.hommak.com/en/product/hommak-f-hm20-homogenizer/

Hong, I. K., Lim, C. M., Choi J. H., & Mok, S. H. (2019). *Ph-sensitive cosmetic composition for improving acne and manufacturing method thereof* (KR20190114921A).

HSA. (2018). GMP Guidelines for Manufacturers of Cosmetic Products.

Hung, H., Blanchard, P., Halsall, C., Bidleman, T., Stern, G., Fellin, P., Muir, D., Barrie, L., Jantunen, L., Helm, P., Ma, J., & Konoplev, A. (2005). Temporal and spatial variabilities of atmospheric polychlorinated biphenyls (PCBs), organochlorine (OC) pesticides and polycyclic aromatic hydrocarbons (PAHs) in the Canadian Arctic: Results from a decade of monitoring. *Science of The Total Environment*, *342*(1–3), 119–144. https://doi.org/10.1016/j.scitotenv.2004.12.058

Huo, Z. (2018). *Facial cleanser containing cypress pythoncidere, and preparation method thereof* (CN107890452A).

Industrial Quick Search. (n.d.). Homogenizer. Retrieved June 2022, from: https://www.iqsdirectory.com/articles/mixer/homogenizer.html

Ishizaki, T., Shimada, Y., Tsunakawa, M., Lee, H., Yokomizo, T., Hisada, S., & Nakamura, K. (2017). Rapid Fabrication of a Crystalline Myristic Acid-Based Superhydrophobic Film with Corrosion Resistance on Magnesium Alloys by the Facile One-Step Immersion Process. *ACS Omega*, *2*(11), 7904–7915. https://doi.org/10.1021/acsomega.7b01256

Jeong, S. H., Kim, B. Y., Kang, H. G., Ku, H. O., & Cho, J. H. (2005). Effects of butylated hydroxyanisole on the development and functions of reproductive system in rats. *Toxicology*, *208*(1), 49–62. https://doi.org/10.1016/j.tox.2004.11.014

Jiang, G. (2014). *Facial cleanser* (CN104069027A).

Johnson, W., Bergfeld, W. F., Belsito, D. V., Hill, R. A., Klaassen, C. D., Liebler, D., Marks, J. G., Shank, R. C., Slaga, T. J., Snyder, P. W., & Andersen, F. A. (2012). Safety Assessment of 1,2-Glycols as Used in Cosmetics. *International Journal of Toxicology*, *31*(5_suppl), 147S-168S. https://doi.org/10.1177/1091581812460409

Jung, E. Y. (2013). *Cream composition for treating acne* (KR20130015339A).

Kar, M., Chourasiya, Y., Maheshwari, R., & Tekade, R. K. (2019). Current Developments in Excipient Science: Implication of Quantitative Selection of Each Excipient in Product Development. *Basic Fundamentals of Drug Delivery,* 29–83. https://doi.org/10.1016/B978-0-12-817909-3.00002-9

Karsheva, M., Georgieva, S., & Handjieva, S. (2007). Thickener choice - A way to improve cosmetics sensory properties. *Journal of the University of Chemical Technology and Metallurgy*, *42*(2), 187–194.

Karunaratne, D. N., Pamunuwa, G., & Ranatunga, U. (2017). Introductory Chapter: Microemulsions. *Properties and Uses of Microemulsions*. https://doi.org/10.5772/intechopen.68823

Kirk, R. E., Othmer, D. F., Grayson, M., & Eckroth, D. (1985). *Kirk-Othmer Concise encyclopedia of chemical technology*. New York: Wiley.

Kortemeier, U., Venzmer, J., Howe, A., Grüning, B., & Herrwerth, S. (2010). Thickening Agents for Surfactant Systems. *SOFW Journal*, *136*, 30–38.

Kraft, J. N., & Lynde, C. W. (2005). Moisturizers: what they are and a practical approach to product selection. *Skin therapy letter*, *10*(5), 1–8.

Laba, D. (2001). How do I thicken my cosmetic formula? Cosmetics & Toiletries, 116(11), 35–44.

Lanigan, R. S., & Yamarik, T. A. (2002). Final Report on the Safety Assessment of BHT. *International Journal of Toxicology*, *21*(2), 19–94. https://doi.org/10.1080/10915810290096513

Life By LaserAway. (2022). A Brief History of Skincare. Retrieved March 2022, from: https://life.laseraway.com/skincare/a-brief-history-of-skincare

Lin, L. (2021). *Facial cleanser containing a time rhythm regulating composition and a preparation method of facial cleanser* (CN112933006A).

Lin, T. J. (1968). Effect of initial surfactant location on the viscosity of emulsions. *Journal Society of Cosmetic Chemists*. 19, 683–697.

Liu, S. (2014). *Facial cleanser* (CN104095763A).

Lukić, M., Pantelić, I., & Savić, S. D. (2021). Towards Optimal pH of the Skin and Topical Formulations: From the Current State of the Art to Tailored Products. *Cosmetics*, *8*(3), 69. https://doi.org/10.3390/cosmetics8030069

Manoj, M. A., Patel, A. M., Sharma, N., Bhattacharya, B., & Mangi, R. K. (2014). A Brief Review on Acne Vulgaris: Pathogenesis, Diagnosis and Treatment. *Research & Reviews: Journal of Pharmacology*, *4*, 1–12.

Mao, L., & Miao, S. (2015). Structuring Food Emulsions to Improve Nutrient Delivery During Digestion. *Food Engineering Reviews*, *7*(4), 439–451. https://doi.org/10.1007/s12393-015-9108-0

Maphosa, Y., & Jideani, V. A. (2018). Factors Affecting the Stability of Emulsions Stabilised by Biopolymers. *Science and Technology Behind Nanoemulsions.* https://doi.org/10.5772/intechopen.75308

McCabe, W. L., Smith, J. C., & Harriot, P. (2007). *Operaciones Unitarias En Ingeniería Química* (7.ª ed.). MCGRAW HILL EDDUCATION.

MG Newell. (2016). Homogenization Overview. Retrieved June 2022, from: https://www.mgnewell.com/wp-content/uploads/2016/05/Homogenizer-Overview.pdf

Mitsui, T. (1997). *New Cosmetic Science* (1.ª ed.). Elsevier.

Moulik, S. P., & Rakshit, A. K. (2006). Physicochemistry and applications of microemulsions. *Journal of Surface Science and Technology*. https://doi.org/10.18311/jsst/2006/1965

Müller, J., & Haarmann, J. (1992). *The H&R book of perfume: Understanding fragrance; origins, history, development; guide to fragrance ingredients*. Glöss Verlag.

Nae, H. (2016). Basic Principles of Rheology: Grow with the Flow. Retrieved April 2022, from: http://www.thecosmeticchemist.com/education/formulation_science/basic_principles_of_rheology_grow_with_the_flow.html

Nikunj, D., & Tejas, J. (2017). A Concise Review on Surfactants and Its Significance. *International Journal of Applied Chemistry*, *13*(3), 663–672.

Nola, I., Kostović, K., Kotrulja, L., & Lugović, L. (2003). The use of emollients as sophisticated therapy in dermatology. *Acta dermatovenerologica Croatica : ADC*, *11*(2), 80–87.

Norato, M. A., Tavlarides, L. L., & Tsouris, C. (1998). Phase inversion studies in liquid-liquid dispersions. *The Canadian Journal of Chemical Engineering*, *76*(3), 486–494. https://doi.org/10.1002/cjce.5450760319

ONU. (n.d.). Take action for the sustainable development goals. Retrieved June 2022, from: https://www.un.org/sustainabledevelopment/sustainable-development-goals/

Oshimura, E., & Sakamoto, K. (2017). Amino Acids, Peptides, and Proteins. *Cosmetic Science and Technology*, 285–303. https://doi.org/10.1016/b978-0-12-802005-0.00019-7

Paul, E. L., Antiemo-Obeng, V. A., & Kresta, S. M. (2004). *Handbook Of Industrial Mixing Science And Practice*. Wiley India Exclusive (Cbs).

Pawignya, H., Kusworo, T. D., & Pramudono, B. (2019). Kinetic Modeling of Flocculation and Coalescence in the System Emulsion of Water-Xylene-Terbutyl Oleyl Glycosides. *Bulletin of Chemical Reaction Engineering & Catalysis*, *14*(1), 60–68. https://doi.org/10.9767/bcrec.14.1.2594.60-68

Pedro, R. & Walters, K.A. (2019). Surfactants in Cosmetic Products.In *Cosmetic Formulation: Principles and Practices*. CRC Press: Boca Raton.

Personal Care Products Council (PCPC). (2011). Updated concentration of use by FDA product category: Citric acid and its salts and esters.

Peryam, D. R., & Pilgrim, F. J. (1957). Hedonic scale method of measuring food preferences. *Food Technology, 11, Suppl.,* 9–14.

Pinto, F., & Meo, M. (2016). Design and Manufacturing of a Novel Shear Thickening Fluid Composite (STFC) with Enhanced out-of-Plane Properties and Damage Suppression. *Applied Composite Materials*, *24*(3), 643–660. https://doi.org/10.1007/s10443-016-9532-1

Polati, S., Gosetti, F., & Gennaro, M. (2007). Preservatives in Cosmetics. Regulatory Aspects and Analytical Methods. *Analysis of Cosmetic Products*, 211–241. https://doi.org/10.1016/b978-044452260-3/50034-6

Puri, N., & Talwar, A. (2009). The efficacy of silicone gel for the treatment of hypertrophic scars and keloids. *Journal of Cutaneous and Aesthetic Surgery*, *2*(2), 104. https://doi.org/10.4103/0974-2077.58527

Purnamawati, S., Indrastuti, N., Danarti, R., & Saefudin, T. (2017). The Role of Moisturizers in Addressing Various Kinds of Dermatitis: A Review. *Clinical Medicine & Research*, *15*(3–4), 75–87. https://doi.org/10.3121/cmr.2017.1363

Ratke, L., & Voorhees, P. W. (2002). Growth and Coarsening. *Engineering Materials*. https://doi.org/10.1007/978-3-662-04884-9

Ravisankar, P., Sai Koushik, O., Himaja, V., Ramesh, J., & Pragna, P. (2015). Acne-causes and amazing remedial measures for acne. *Indo American Journal of Pharm Research*, *5*(7).

Regulation (EC) Nº 1223/2009 of the European Parliament and of the Council of 30 November 2009 on cosmetic products.

RheoSense. (n.d.). Viscosity of Newtonian and Non-Newtonian Fluids. Retrieved March 2022, from: https://www.rheosense.com/applications/viscosity/newtonian-non-newtonian

Romanowski, P. (2015). An introduction to cosmetic technology. *INFORM: International News on Fats, Oils, and Related Materials*, *26*(4), 200–204. https://doi.org/10.21748/inform.04.2015.200

Saad, M. A., Kamil, M., Abdurahman, N. H., Yunus, R. M., & Awad, O. I. (2019). An Overview of Recent Advances in State-of-the-Art Techniques in the Demulsification of Crude Oil Emulsions. *Processes*, *7*(7), 470. https://doi.org/10.3390/pr7070470

Salka, B.A. (1997). Choosing emollients : Four factors will help you decide. *Cosmetics and toiletries, 112*, 101-106.

Salvador, A., & Chisvert, A. (2007). *Analysis of Cosmetic Products* (1.ª ed.). Elsevier Science.

Savage, J. H., Matsui, E. C., Wood, R. A., & Keet, C. A. (2012). Urinary levels of triclosan and parabens are associated with aeroallergen and food sensitization. *The Journal of allergy and clinical immunology*, *130*(2). https://doi.org/10.1016/j.jaci.2012.05.006

Schramm, L. L., Stasiuk, E. N., & Marangoni, D. G. (2003). 2 Surfactants and their applications. *Annu. Rep. Prog. Chem., Sect. C: Phys. Chem.*, *99*, 3–48. https://doi.org/10.1039/b208499f

Segger, D., Aßmus, U., Brock, M., Erasmy, J., Finkel, P., Fitzner, A., Heuss, H., Kortemeier, U., Munke, S., Rheinländer, T., Schmidt-Lewerkühne, H., Schneider, W., & Weser, G. (2008). Multicenter study on measurement of the natural pH of the skin surface. *International Journal of Cosmetic Science*, *30*(1), 75. https://doi.org/10.1111/j.1468-2494.2007.00403_1.x

Sellito, S. P., Sajic, D., & Breslavets, M. (2020). *Topical dermatologic acne treatment cream composition and method of manufacture* (CA3067924A1).

Shalita A. R. (1989). Comparison of a salicylic acid cleanser and a benzoyl peroxide wash in the treatment of acne vulgaris. *Clinical therapeutics*, *11*(2), 264–267.

Shao, J. (2017). *Anti-acne facial cleanser and preparation method thereof* (CN107184458A).

Sharmeen, J. B., Mahomoodally, F. M., Zengin, G., & Maggi, F. (2021). Essential Oils as Natural Sources of Fragrance Compounds for Cosmetics and Cosmeceuticals. *Molecules (Basel, Switzerland)*, *26*(3), 666. https://doi.org/10.3390/molecules26030666

Sharratt, P. N. (1997). Chemicals manufacture by batch processes. *Handbook of Batch Process Design*, 1–23. https://doi.org/10.1007/978-94-009-1455-1_1

Shivsharan, U. S., Raut, E. S., & Shaikh, Z. M. (2014). PACKAGING OF COSMETICS: A REVIEW. *Journal of Pharmaceutical & Scientific Innovation*, *3*(4), 286–293. https://doi.org/10.7897/2277-4572.034158

Smith, M. D., & Navilliat, P. L. (1997). A new protocol for antimicrobial testing of oils. *Journal of Microbiological Methods*, *28*(1), 21–24. https://doi.org/10.1016/s0167-7012(96)00958-x

SONDEX®. (n.d.). SONDEX® spiral heat exchangers. Retrieved June 2022, from: https://heatexchangers.danfoss.com/welded-heat-exchangers/sondex-spiral-heat-exchangers/

STANPA. (2020). Estudio del mercado de perfumería y cosmética en España: Resultados económicos de 2019 y perspectivas de 2020.

Szutowski, D., & Szułczyńska, J. (2017). Product innovation in cosmetic industry- case study of major cosmetic companies. *GISAP:Economics, Jurisprudence and Management*, *12*. https://doi.org/10.18007/gisap:ejm.v0i12.1620

Tadros, T. F. (2013). Emulsion Formation, Stability, and Rheology. *Emulsion Formation and Stability*, 1–75. https://doi.org/10.1002/9783527647941.ch1

Tanno, O., Ota, Y., Kitamura, N., Katsube, T., & Inoue, S. (2000). Nicotinamide increases biosynthesis of ceramides as well as other stratum corneum lipids to improve the epidermal permeability. *Br J Dermatol*, 143, 524–531.

Thau, P. (1997). Surfactants for Skin Cleansers. In *Surfactants in Cosmetics* (2.ª ed., pp. 285–307). Routledge.

Tuchayi, S. M., Makrantonaki, E., Ganceviciene, R., Dessinioti, C., Feldman, S. R., & Zouboulis, C. C. (2015). Acne vulgaris. *Nature Reviews Disease Primers*, *1*(1). https://doi.org/10.1038/nrdp.2015.29

VKPAK. (n.d). Tube filling and sealing machine. Retrieved June 2022, from: https://www.vkpak.com/tube-filling-sealing-machine.html

Walstra, P. (2005). Emulsions. *Fundamentals of Interface and Colloid Science*, *5*(C), 8.1-8.94. https://doi.org/10.1016/S1874-5679(05)80012-1

Walters, R. M., Khanna, P., Hamilton, M., Mays, D. A., & Telofski, L. (2015). Human Cumulative Irritation Tests of Common Preservatives Used in Personal Care Products: A Retrospective Analysis of Over 45 000 Subjects. *Toxicological Sciences*, *148*(1), 101–107. https://doi.org/10.1093/toxsci/kfv158

Wang, F., Huang, Q., Liu, T., Zhang, S., & Su, N. (2016). *Anti-acne facial cleanser and preparation method thereof* (CN105213285A).

Wang, Z. (2016). *Acne treatment cream and preparation method thereof* (CN105997629A).

Wei, Z. (2017). *Oil-controlling facial cleanser* (CN107375146A).

Whalley, G. R. (2001). Process Control during Cosmetic Manufacture. *Household & Personal Products Industry*.

Wibowo, C., & Ng, K. M. (2001). Product-Oriented Process Synthesis and Development: Creams and Pastes (Vol. 47). *AIChE Journal*.

Wibowo, C., & Ng, K. M. (2002). Product-Centered Processing: Manufacture of Chemical-Based Consumer Products (Vol. 48). *AIChE Journal.*

Willis, C. M., Shaw, S., De Lacharrière, O., Baverel, M., Reiche, L., Jourdain, R., Bastien, P., & Wilkinson, J. D. (2001). Sensitive skin: an epidemiological study. *The British journal of dermatology*, *145*(2), 258–263. https://doi.org/10.1046/j.1365-2133.2001.04343.x

Wu, Y. (2014). *Pearl barley acne cream and preparation method thereof* (CN103610612A).

Xie, Q. (2020). *Acne-removing skin cream and preparation method thereof* (CN111000776A).

Yamashita, Y., Miyahara, R., & Sakamoto, K. (2017). Emulsion and Emulsification Technology. *Cosmetic Science and Technology: Theoretical Principles and Applications,* 489–506. https://doi.org/10.1016/B978-0-12-802005-0.00028-8

Yang, L. (2017). *Acne-removing and oil-controlling facial cleanser and preparation method thereof* (CN107308043A).

Yin, C., & Du, Y. (2017). *Acne removal cream with acne mark prevention function* (CN107184448A).

Zeng, Y. (2020). *Preparation method of acne-removing emulsion* (CN111529440A).
Zhang, G. (2016). *Acne removing and skin clarifying cream* (CN105520897A).
Zhang, Y. (2014). *Spot removing facial cleanser* (CN103599055A).
Zhang, Z. (2019). *Facial cleanser* (CN109125160A).

ACRONYMS

SDGs: Sustainable Development Goals

AEDV: Academia Española de Dermatología y Venereología

O/W: Oil in Water emulsions

W/O: Water in Oil emulsions

EC: European Commission

EU: European Union

GMP: Good Manufacturing Practices

HDPE: High density polyethylene

PP: Polypropylene

PET: Polyethylene terephthalate

PHA: Polyhydroxy acids

PAO: Period After Opening

ISO: International Organization for Standardization

FDA: Food and Drug Administration

INCI: International Nomenclature of Cosmetic Ingredients

OTC: Over The Counter

AES: Alkyl Ether Sulphates

CIR: Cosmetic Ingredient Review

BHT: Butylated hydroxytoluene

BHA: Butylated hydroxyanisole

AHA: Alpha Hydroxy Acid

SCCS: Scientific Committee on Consumer Safety

PSPC: Personal Care Products Council

ANSM: Agence nationale de sécurité du médicament et des produits de santé

CAS: Chemical Abstracts Service

HLB: Hydrophilic-Lyophilic Balance

CTFA: Cosmetic Toiletry and Fragrance Association

HSA: Health Sciences Authority

cGMP: Current Good Manufacturing Practices

APPENDICES

APPENDIX I: SENSORY TEST

FACIAL CLEANSING GEL

Please rate different aspects of the sample provided by using the following rating scale. For each parameter, write down a score from 1 to 9.

Rating scale	1	2	3	4	5	6	7	8	9
	Dislike extremely	Dislike very much	Dislike moderately	Dislike slightly	Neither like nor dislike	Like slightly	Like moderately	Like very much	Like extremely

Parameter	Score
Overall liking of the product	
Texture at application	
Feeling on the skin after application	
Fragrance	
Visual appearance (colour)	

Now, please evaluate the following parameters based on your level of agreement by marking with a cross the chosen answer.

Parameter	Totally disagree	Partially agree	Agree	Totally agree
Smoothness while application				
Low oiliness				
No skin irritation				
Ease of spreading				
Ease of pouring out of the container				
Ease of rinsing				
Feeling of cleanliness				

If necessary, fill in the comments section:

Comments	

NIGHT CREAM

Please rate different aspects of the sample provided by using the following rating scale. For each parameter, write down a score from 1 to 9.

Rating scale	1	2	3	4	5	6	7	8	9
	Dislike extremely	Dislike very much	Dislike moderately	Dislike slightly	Neither like nor dislike	Like slightly	Like moderately	Like very much	Like extremely

Parameter	Score
Overall liking of the product	
Texture at application	
Feeling on the skin after application	
Fragrance	
Visual appearance (colour)	

Now, please evaluate the following parameters based on your level of agreement by marking with a cross the chosen answer.

Parameter	Totally disagree	Partially agree	Agree	Totally agree
Smoothness while application				
Low oiliness				
No skin irritation				
Ease of spreading				
Ease of pouring out of the container				
Rapidly absorbed				

If necessary, fill in the comments section:

Comments	

APPENDIX II: MARKET FORMULATIONS OF FACIAL CLEANSING GELS FOR ACNE-PRONE SKIN

Product	Sébium gel moussant	
Brand	Bioderma	

Ingredient (INCI)	**Function**
AQUA	Vehicle
SODIUM COCOAMPHOACETATE	Surfactant (Cleansing and foaming)
SODIUM LAURETH SULFATE	Surfactant (Cleansing and emulsifying)
METHYLPROPANEDIOL	Solvent
DISODIUM EDTA	Chelating agent
MANNITOL	Humectant
XYLITOL	Humectant
RHAMNOSE	Humectant
FRUCTOOLIGOSACCHARIDES	Humectant
ZINC SULFATE	Antimicrobial
COPPER SULFATE	Skin conditioning agent
GINKGO BILOBA LEAF EXTRACT	Skin conditioning agent
PEG-90 GLYCERYL ISOSTEARATE	Humectant and solvent
LACTIC ACID	pH adjuster and humectant
LAURETH-2	Surfactant (Cleansing and emulsifying)
POTASSIUM SORBATE	Masking agent and preservative
SODIUM CHLORIDE	Thickener
SODIUM HYDROXIDE	pH adjuster
FRAGRANCE	Fragrance

Product	DermoPure Oil Control Gel	
Brand	Eucerin	

Ingredient (INCI)	Function
AQUA	Vehicle
SODIUM COCOAMPHOACETATE	Surfactant (Cleansing and foaming function)
PROPYLENE GLYCOL	Humectant, solvent and thickener
SODIUM LAURETH SULFATE	Surfactant (Cleansing and emulsifying)
SODIUM CHLORIDE	Thickener
CITRIC ACID	Antioxidant, exfoliator and pH adjuster
SODIUM BENZOATE	Preservative
SALICYLIC ACID	Active ingredient for acne treatment

Product	Effaclar Purifying Cleansing Gel	
Brand	La Roche-Posay	

Ingredient (INCI)	**Function**
AQUA	Vehicle
SODIUM LAURETH SULFATE	Surfactant (Cleansing and emulsifying)
PEG-8	Humectant
COCO-BETAINE	Surfactant (Cleansing) and thickener
HEXYLENE GLYCOL	Solvent and surfactant (Cleansing and emulsifying)
SODIUM CHLORIDE	Thickener
PEG-120 METHYL GLUCOSE DIOLEATE	Surfactant (Emulsifying)
ZINC PCA	Humectant and skin conditioning agent
SODIUM HYDROXIDE	pH adjuster
CAPRYLYL GLYCOL	Humectant and preservative
CITRIC ACID	Antioxidant, exfoliator and pH adjuster
SODIUM BENZOATE	Preservative
PHENOXYETHANOL	Preservative
FRAGRANCE	Fragrance

Product	Cleanance Cleansing Gel	
Brand	Avène	

Ingredient (INCI)	Function
AQUA	Vehicle
ZINC COCETH SULFATE	Surfactant (Cleansing and emulsifying)
LAURYL BETAINE	Surfactant (Cleansing)
DECYL GLUCOSIDE	Surfactant (Cleansing)
CETEARETH-60 MYRISTYL GLYCOL	Surfactant (Cleansing and emulsifying)
PEG-7 GLYCERYL COCOATE	Surfactant (Cleansing and emulsifying)
POLYSORBATE 20	Surfactant (Cleansing and emulsifying)
CITRIC ACID	Antioxidant, exfoliator and pH adjuster
FRAGRANCE	Fragrance
GREEN 5 (CI 61570)	Colourant
ISOPROPYL ALCOHOL	Solvent and thickening
PEG-40 HYDROGENATED CASTOR OIL	Surfactant (Cleansing and emulsifying)
PEG-6	Humectant and solvent
PPG-26-BUTETH-26	Skin conditioning agent
SILYBUM MARIANUM FRUIT EXTRACT	Skin conditioning agent
SODIUM BENZOATE	Preservative
SODIUM CHLORIDE	Thickener
SODIUM HYDROXIDE	pH adjuster
TRISODIUM ETHYLENEDIAMINE DISUCCINATE	Chelating agent
YELLOW 5 (CI 19140)	Colourant
ZINC GLUCONATE	Anti-acne and emollient

Product	Normaderm Deep Cleansing Purifying Gel	
Brand	Vichy	

Ingredient (INCI)	**Function**
AQUA	Vehicle
COCO-BETAINE	Surfactant (Cleansing) and thickener
PROPANEDIOL	Solvent and thickener
PEG-120 METHYL GLUCOSE DIOLEATE	Surfactant (Emulsifying)
SODIUM CHLORIDE	Thickener
SODIUM COCOYL GLYCINATE	Surfactant (Cleansing)
DIPROPYLENE GLYCOL	Masking agent, solvent and thickener
ZINC GLUCONATE	Anti-acne and emollient
SALICYLIC ACID	Active ingredient for acne treatment
BIFIDA FERMENT LYSATE	Skin conditioning agent
SODIUM HYDROXIDE	pH adjuster
SODIUM BENZOATE	Preservative
PHENOXYETHANOL	Preservative
COPPER GLUCONATE	Skin conditioning agent
CAPRYLYL GLYCOL	Humectant and preservative
TETRASODIUM GLUTAMATE DIACETATE	Chelating agent
FRAGRANCE	Fragrance

APPENDIX III: MARKET FORMULATIONS OF NIGHT CREAMS FOR ACNE TREATMENT

Product	Sébium Night	
Brand	Bioderma	

Ingredient (INCI)	Function
AQUA	Vehicle
GLYCOLIC ACID	Active ingredient for acne treatment
SODIUM HYDROXIDE	pH adjuster
PANTHENOL	Humectant
AMMONIUM ACRYLOYLDIMETHYLTAURATE/VP COPOLYMER	Thickener
DIPROPYLENE GLYCOL	Solvent, masking agent and thickener
HYDROXYETHYLCELLULOSE	Thickener
MANNITOL	Humectant
PROPYL GALLATE	Antioxidant
XYLITOL	Humectant
SODIUM METABISULFITE	Preservative and antioxidant
RHAMNOSE	Humectant
FRUCTOOLIGOSACCHARIDES	Humectant
CAPRYLIC/CAPRIC TRIGLYCERIDE	Emollient
LAMINARIA OCHROLEUCA EXTRACT	Skin conditioning agent
FRAGRANCE	Fragrance

Product	DermoPure Oil Control 10% hydroxiacids	
Brand	Eucerin	

Ingredient (INCI)	**Function**
AQUA	Vehicle
GLYCOLIC ACID	Active ingredient for acne treatment
DIMETHICONE	Emollient, occlusive and skin conditioning
GLYCERIN	Humectant
TAPIOCA STARCH	Thickener
CETEARYL ALCOHOL	Surfactant (Emulsifying), emollient and thickener
GLYCERYL STEARATE	Emollient and emulsifier
SODIUM HYDROXIDE	pH adjuster
GLUCONOLACTONE	Chelating agent
PEG-100 STEARATE	Emulsifier, solvent and humectant
SALICYLIC ACID	Active ingredient for acne treatment
PEG-150 DISTEARATE	Surfactant (Emulsifying)
GLYCYRRHIZA INFLATA ROOT EXTRACT	Skin conditioning agent
PANTHENOL	Humectant
XANTHAN GUM	Thickener
TRISODIUM EDTA	Chelating agent
PHENOXYETHANOL	Preservative
FRAGRANCE	Fragrance

Product	Biretix Tri-Active	
Brand	Cantabria labs	

Ingredient (INCI)	Function
AQUA	Vehicle
ALCOHOL DENAT	Antimicrobial, solvent and thickener
GLYCOLIC ACID	Active ingredient for acne treatment
NIACINAMIDE	Active ingredient for acne treatment
PROPYLENE GLYCOL	Humectant, solvent and thickener
SALICYLIC ACID	Active ingredient for acne treatment
AMMONIUM HYDROXIDE	pH adjuster
POLYQUATERNIUM-10	Thickener
RETINOL	Skin conditioning agent
HYDROXYPINACOLONE RETINOATE	Skin conditioning agent
OLIGOPEPTIDE-10	Antimicrobial
ORYZA SATIVA BRAN EXTRACT	Skin conditioning agent
BOSWELLIA SERRATA EXTRACT	Skin conditioning agent
HONEYCOMB EXTRACT	Skin conditioning agent and antimicrobial
BUTYLENE GLYCOL	Humectant, solvent and thickener
ETHYLHEXYLGLYCERIN	Preservative
TETRASODIUM EDTA	Chelating agent
PENTYLENE GLYCOL	Humectant and solvent
PALMITOYL HYDROXYPROPYLTRIMONIUM AMYLOPECTIN/GLYCERIN CROSSPOLYMER	Skin conditioning agent
DIMETHYL ISOSORBIDE	Solvent and thickener
1,2-HEXANEDIOL	Solvent

POLYSORBATE 20	Surfactant (Emulsifying)
CAPRYLYL GLYCOL	Humectant and preservative
HYDROGENATED LECITHIN	Surfactant (Emulsifying) and emollient
BHT	Antioxidant
BHA	Antioxidant

Product	Effaclar Duo+	
Brand	La Roche-Posay	

Ingredient (INCI)	Function
AQUA	Vehicle
GLYCERIN	Humectant
DIMETHICONE	Emollient, occlusive and skin conditioning
ISOCETYL STEARATE	Emollient
NIACINAMIDE	Active ingredient for acne treatment
ISOPROPYL LAUROYL SARCOSINATE	Emollient
SILICA	Thickener
AMMONIUM POLYACRYLOYLDIMETHYL TAURATE	Thickener and emulsifier
METHYL METHACRYLATE CROSSPOLYMER	Occlusive
POTASSIUM CETYL PHOSPHATE	Surfactant (Emulsifying)
SORBITAN OLEATE	Surfactant (Emulsifying)
ZINC PCA	Humectant and skin conditioning agent
GLCERYL STEARATE SE	Surfactant (Emulsifying)
ISOHEXADECANE	Emollient and solvent
SODIUM HYDROXIDE	pH adjuster
MYRISTYL MYRISTATE	Emollient
2-OLEAMIDO-1,3-OCTADECANEDIOL	Skin conditioning agent
ALUMINUM STARCH OCTENYLSUCCINATE	Thickener
MANNOSE	Humectant
POLOXAMER 338	Surfactant (Emulsifying)
DISODIUM EDTA	Chelating agent
CAPRYLOYL SALICYLIC ACID	Exfoliant

CAPRYLYL GLYCOL	Humectant and preservative
VITREOSCILLA FERMENT	Skin conditioning agent
XANTHAN GUM	Thickener
POLYSORBATE 80	Surfactant (Emulsifying)
ACRYLAMIDE/SODIUM ACRYLOYLDIMETHYLTAURATE COPOLYMER	Thickener and emulsifier
SALICYLIC ACID	Active ingredient for acne treatment
PIROCTONE OLAMINE	Preservative
FRAGRANCE	Fragrance

Product	Sebiaclear active	
Brand	SVR	

Ingredient (INCI)	Function
AQUA	Vehicle
GLUCONOLACTONE	Chelating agent
CYCLOPENTASILOXANE	Emollient and solvent
PROPANEDIOL	Solvent and thickener
METHYL METHACRYLATE CROSSPOLYMER	Occlusive
NIACINAMIDE	Active ingredient for acne treatment
SODIUM HYDROXIDE	pH adjuster
AMMONIUM ACRYLOYLDIMETHYLTAURATE/ VP COPOLYMER	Thickener
HYDROXYETHYL ACRYLATE/SODIUM ACRYLOYLDIMETHYL TAURATE COPOLYMER	Thickener and emulsifier
SALICYLIC ACID	Active ingredient for acne treatment
SACCHARIDE ISOMERATE	Humectant
CITRIC ACID	Antioxidant, exfoliator and pH adjuster
DIMETHICONOL	Emollient and humectant
GLYCERYL STEARATE	Emollient and emulsifier
PEG-100 STEARATE	Emulsifier, solvent and humectant
POLYSORBATE 60	Surfactant (Emulsifying)
SODIUM CITRATE	pH adjuster and chelating agent
SORBITAN ISOSTEARATE	Surfactant (Emulsifying)
FRAGRANCE	Fragrance

APPENDIX IV: DENSITY VALUES FOR THE DIFFERENT INGREDIENTS OF BOTH FORMULATIONS

Facial cleansing gel			
Ingredient (INCI)	**Nº CAS**	**Concentration [%]**	**Density [kg/L] at 20/25 ºC**
Aqua	7732-18-5	46.3	0.997
Sodium Laureth Sulfate	9004-82-4	12	1.010
Myristic acid	544-63-8	10	0.862
Cocamidopropyl Betaine	86438-79-1	8	1.050
Glycerin	56-81-5	5	1.260
Melaleuca alternifolia leaf oil	85085-48-9	3	0.878
Ethanol	64-17-5	3	0.789
Propylene glycol	57-55-6	3	1.040
Salicylic acid	69-72-7	2	1.440
Citric acid	77-92-9	2	1.660
Sodium chloride	7647-14-5	1.5	2.160
Caprylyl glycol	1117-86-8	1	0.914
Sodium benzoate	532-32-1	1	1.500
Sodium hydroxide	1310-73-2	1	2.130
Phenoxyethanol	122-99-6	0.5	1.100
Carbomer	9003-01-4	0.5	1.200
Citrus bergamia peel oil	89957-91-5	0.2	0.877
Density of the facial cleanser [kg/L]:			1.05

Night cream			
Ingredient (INCI)	**Nº CAS**	**Concentration [%]**	**Density [kg/L] at 20/25 ºC**
Aqua	7732-18-5	61.5	0.997
Glyceryl stearate	31566-31-1	7	0.970
Glycerin	56-81-5	6	1.260
PEG-100 stearate	9004-99-3	5	0.900
Niacinamide	98-92-0	5	1.400
Melaleuca alternifolia leaf oil	85085-48-9	3	0.878
Ethanol	64-17-5	3	0.789
Propylene glycol	57-55-6	3	1.040
Salicylic acid	69-72-7	2	1.440
Zinc PCA	68107-75-5	1	N/A[1]
Dimethicone	9006-65-9	1	1.000
Phenoxyethanol	122-99-6	0.5	1.100
Sodium benzoate	532-32-1	0.5	1.500
Xanthan gum	11138-66-2	0.5	1.500
Citric acid	77-92-9	0.4	1.660
Sodium hydroxide	1310-73-2	0.4	2.130
Lavandula angustifolia oil	8000-28-0	0.2	0.882
Density of the night cream [kg/L]:			1.03

[1] N/A: Data Not Available