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Anti-photoaging Cream using a *Quercus Suber* Extract

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Abstract

This work aims at developing a new chemical product, which involves all the product design stages, starting from the evaluation of market needs, generation of ideas, selection of the selected idea and finally, the decision of the manufacturing process. During this analysis, it was decided to use the ellagic acid extracted from cork powder, a cork industry waste, to create our final product: an anti-photoaging cream free of parabens and fragrances. This decision results from the protective role of ellagic acid against UV-B-induced oxidative stress, reducing wrinkles and sun inflammation consequences. A rough economic feasibility analysis was carried out based on an industrial showcase, in which it was calculated the Net Present Value of 1.6 M€, so the project was considered viable. It was also determined the Internal Return Rate - value of 85 %, and the Payback Time was set at 3.3 years.

Author Keywords. Cream. Anti-photoaging. Quercus Suber. Cork Oak.

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1. Introduction

This work aims at developing a product from Cork Oak, *Quercus Suber*. The Portuguese cork industry is well established and internationally recognized, representing an important driving force of the national industry. The objective of the product to be developed is to increase value in this industry. So, the first step was to make a review of the compounds that can be extracted from various parts of the Cork Oak. Initially, a primary compounds search was conducted to quantify the amount of these compounds on the feedstock-specific part. From the tree bark and cork, it was chosen suberin, ellagic acid, friedelin and ferulic acid. From leaves, gallic acid was selected (Lavado, Ladero, and Cava 2021). Finally, from the acorn, oleic acid was identified (Akcan et al. 2017). These compounds are present in considerable amounts in the feedstock, which is something to consider when it comes to market supply evaluation once it must be assured a reasonable quantity of product to satisfy the market needs.

Based on the active principles, the product design steps were taken, starting with the assessment of market needs, generation of ideas to meet those needs, selection of the preferred idea using a matrix that ranks the several ideas and enables to select one, and finally, the decision of the manufacturing process for the product selected.

Finally, the economic evaluation of the product was carried out, as well as the business plan and calculated all the costs and the profits obtained from the commercialization of the product.

2. Raw Material

The purpose of this work was the development of an innovative product from compounds present in *Quercus Suber*. This feedstock was selected based on the knowledge of how well-established and internationally recognized the Portuguese cork industry is.

Cork is generally composed of: suberin (~40.8 %), lignin (~23.8 %), polysaccharides (~20.6 %), and extractives (~14.7 %). However, it is to highlight that this composition depends on the geographic and genetic origin, tree dimension and age, among many others (Silva et al. 2005).

Portugal is responsible for 32 % of the world's *Quercus Suber* cultivation. Besides that, *Quercus Suber* corresponds to 23 % of the total forest in the national territory.

The cork oak is mainly explored to produce cork. Its annual world production is 340 thousand tonnes. Portugal has a large contribution, representing 55 % of the total world production (Amorim Cork Composites, n.d.), so it is easily perceptible the impact of the cork industry.

The cork industry is mainly focused on producing cork stoppers, both natural and agglomerated. In the process of production of natural cork stoppers, ca. 60 % of the initial raw material is discarded; however, it is not wasted since it can be used in other applications, e.g., cork powder can be used as a source of energy (Gil and Marques 2013). The idea of reusing cork powder served as the first approach to select this feedstock, as well as the availability of the other leftover components from the tree, such as leaves and acorns, which also showed some potential, corresponding to an annual production of 185 thousand tonnes (Sottomayor 2015). After some research and the choice of the bioactive compound, it was decided to develop a product from the reuse of cork powder.

3. Chemical Product Design of Raw Material

3.1. Needs & Ideas

The first step in the chemical product design process involves the identification of consumer needs in order to create a product that can fill the gaps in the market. Table 1 shows the main fatty acids extracted from cork and acorn.

Compound	mg/kg dry material	source	Reference
Ellagic acid	527 – 2 031	Cork (*Q. suber* L.)	Santos et al. (2010)
	527	Industrial Cork Powder	Santos et al. (2013)
Gallic Acid	30 – 241	Cork (*Q. suber* L.)	Santos et al. (2010)
	263	Industrial Cork Powder	Santos et al. (2013)
Ferulic Acid	14	Industrial Cork Powder	Santos et al. (2013)
Oleic Acid	57 400	Acorn	Charef et al. (2008)

Table 1: Main fatty acids extracted from cork and acorn

Table 2 lists the identified market needs of each compound (in Table 1) that could potentially be satisfied by its properties.

Compound	Need
Ellagic acid	Photodamage prevention
	Natural ingredients products
Gallic Acid	Control cholesterol levels
	Extend products' shelf life
	Reduce microbial load from toys
Oleic Acid	Lip hydration and repair
	Production of healthier dairy drinks
	Hair hydration and repair from chemical treatment
Suberin	Replace fossil-based components with renewables
	Replace plastic bottles

Table 2: Some needs identified for the compound extracted from cork

After a brainstorming session, a total of thirty product ideas arose. For the next step, it was necessary to narrow down the number of ideas by removing duplicates and eliminating the impossible or less feasible ones. In this step, the less innovative ideas were also discarded. In the end, the number of ideas was reduced to only five. These five ideas and the corresponding market needs are described below.

3.1.1. Bio-polyester fabric

Polyester is the most widely used fiber in the world. It is typically made from a non-renewable resource, and it uses an energy-intensive process. Besides that, it is usually non-biodegradable and sheds microplastic fibers when it is washed (Truscott 2020). Suberin, more precisely, suberin depolymerization mixtures, has shown potential as a renewable resource to produce bio-polyester since it is a naturally occurring aromatic-aliphatic crosslinked polyester. Furthermore, suberin also has hydrophobic properties, conferring water-resistant properties to the materials produced from it (Sousa et al. 2011). The idea is to produce bio-polyester fabrics to substitute synthetic polyesters in water-resistant jackets.

3.1.2. Anti-photoaging face cream

U.V. radiation is responsible for 90 % of visible skin aging (Ainbinder and Touitou 2010). Ellagic acid has photoprotective properties, which include alleviating skin wrinkle formation and inflammatory responses induced by exposure to UV-B radiation (Bae et al. 2010). Baek et al. (2016) reported that ellagic acid might be used as a natural resource for manufacturing anti-photoaging cosmetics. In that work, different concentrations of ellagic acid (0, 5, 12 or 30 µmol/L) were used to assess the skin anti-photoaging properties of this compound in human dermal fibroblasts; the best performance was obtained at a concentration of 30 µmol/L. It is an effective anti-wrinkle agent, whether it is applied to the skin before or after UV-B exposure. This bioactive compound can also be used to treat hyperpigmentation, giving the skin a bright look. There is great demand for cosmetics that can produce these results on the skin without any harmful side effects (Carriço, Ribeiro, and Marto 2018). Since ellagic acid is a natural and safe compound, it could be used to fill this gap in the market. With these market needs and properties in mind, the idea of creating an anti-photoaging face cream came about.

3.1.3. Lip balm

Lip dryness is a well-known problem. Especially in cold weather, it is very common to have chapped lips, so it is important to have options to protect and repair the lips. Oleic acid can be helpful in lip hydration and repair since it has both an emollient and hydrating character.

An herbal lip balm was proposed from these ingredients, aiming to attract a wider consumer base. The current focus on health and wellness has shifted the market towards natural or organic formulas, especially because a large amount of lip balms is accidentally eaten.

3.1.4. Suberin films for water packaging

Globally, more than a million plastic bottles are sold every single minute. It takes at least 450 years for a plastic bottle to degrade, and, in the U.S., only 30 % of these bottles are recycled. Suberin has hydrophobic properties that could make it a substitute for plastic (Parker 2019). Suberin also presents antimicrobial properties. The product idea consists of the use of natural materials extracted from plants to create water packaging comprising suberin films, with low environmental impact, to reduce plastic waste (Wilson 2019).

3.1.5. Food conservative gel

Households are responsible for the largest portion of food waste. U.S. households produce about 76 billion pounds of food waste per year. In terms of total mass, fresh fruits account for 19 % of losses at the consumer level. It is known that when fruit is cut, it starts to oxidize really quickly. Since ferulic acid has antioxidant activity, it could be used to prevent the degradation of food (FoodPrint 2018). Regarding this market need, it was proposed to develop a food gel or edible film that would prevent food oxidation and allow it to be preserved for longer periods. As previously mentioned, this would be especially useful for fruits or vegetables that are not consumed immediately and end up degrading due to oxidizing agents (Ou and Kwok 2004).

3.2. Ideas evaluation

With the goal of selecting a winner idea from the initial pool, five evaluation criteria were defined, on which we graded each product idea with a number ranging from 1 to 10. Table 3 shows the grades attributed to each of the five product ideas on each of the evaluation criteria, as well as its final grade.

	Evaluation Criteria					
	Scientific maturity	**Vol. of targeted market**	**Eco-friendlines s**	**Ease of approval**	**Innovation**	
Weight on final grade	**30 %**	**20 %**	**10 %**	**25 %**	**15 %**	**Final grade**
Bio-polyester fabric	6	7	6	9	7	7.1
Anti-photoaging cream	9	5	5	7	4	6.6
Food gel	6	7	7	5	8	6.4
Lip balm	10	6	5	7	1	6.6
Water bottles	3	9	10	6	8	6.4

Table 3: Evaluation of the ideas

After completing the evaluation of the ten product ideas, the ones that received the highest scores were the bio-polyester fabric, the anti-photoaging cream and the lip balm, as can be seen in Table 3.

3.3. Selection

Since it received the highest score out of all the product ideas, the first choice was to produce a bio-polyester fabric using suberin. However, there was no information available regarding how much of this component would be needed to produce the fabric; therefore, this first option was discarded.

The next options were the lip balm and the anti-photoaging cream. For these, enough information about the extraction and production processes was available. However, to determine if these product ideas would, in fact, be feasible, some calculations were needed. These included determining how much of the needed raw material was available, how much of the relevant bioactive component could be extracted, how much of this bioactive component would be needed to produce one unit of each product, and finally, how many units of each product would be possible to produce in a year. Table 4 shows the results of these calculations. We should highlight that the amount of bioactive component by unit in the case of the face cream was defined according to the concentration used by Baek et al. (2016), which reported the skin anti-photoaging properties of ellagic acid. The yearly production was calculated assuming all the raw material available would be used, which, of course, it is not the most realistic scenario. However, this analysis clearly shows that both the lip balm and the anti-photoaging cream were feasible product ideas regarding raw material availability.

Product	Face cream	Lip balm
Presentation	50 mL	4.2 g
Bioactive component	Ellagic acid	Oleic acid
Amount of bioactive component by unit of product	453 µg (Baek et al. 2016)	456 mg (Vinodkumar, Chandrahar, and Pradip 2019)
Raw Material	Cork Powder	Acorns
Amount Produced (tons/year)	27 215 (Gil and Marques 2013)	185 827 (Sottomayor 2015)
Maximum extracted (tons/year)	223 (Batista et al. 2015)	10 670 (Charef et al. 2008)
Thousand million units produced by year	490	23

Table 4: Values calculated to determine the feasibility of each product idea

Although it was possible to move on with any of the two product ideas, in the end, the decision made was to continue with the idea of producing an anti-photoaging cream, as this one seemed more interesting for the product development team as consumers. It was also a more innovative idea, as there aren't many cosmetics that contain ellagic acid and those that do are not specifically marketed as anti-photoaging cosmetics.

3.4. Manufacture

3.4.1.Product specifications

The selected idea will be analyzed as a commercial brand: *Sobreiro*. *Sobreiro* will be presented to the market in a 50 ml tube containing an anti-photoaging cream formulated with cork powder extract that contains ellagic acid. Ellagic acid has an important protective role against UV-B-induced oxidative stress, reducing visible wrinkles and fine lines and improving the skin's condition. It also works as a brightening agent in hyperpigmented skin. This face cream is specially formulated to be applied every morning and night, leaving the skin softer, firm and reducing sun inflammation effects. It is a paraben-free and fragrance-free formulation. The main characteristic essential in this product is its capacity to reduce both wrinkles and sun inflammation effects.

Nowadays, due to the increased concern over parabens' negative effects on human health, as well as the possible irritating effects of some substances present in moisturizers as brightening agents, like hydroquinone, it is widely desirable to create a formulation free of parabens with ellagic acid as an alternative to hydroquinone. It was considered to be useful in the creation of a product that is quickly absorbed by the skin without leaving an oily appearance. All the ingredients of the final product are described in Table 5.

	Ingredients	Function	Concentration
Oil phase	Almond oil	Emollient	20
	Cetyl alcohol	Co-emulsifier	1.5
	Coconut oil	Emulsifier	3
Aqueous phase	Glycerol	Humectant	2
	Xanthan gum	Thickener	0.3
	EDTA	Stabilizer	0.1
	Citric Acid	Neutralizer	0.03
	Hyaluronic acid	Moisturizing agent/humectant	0.5
	Cork extract	Anti-photoaging	0.002
	Propylene glycol	Humectant	1.38
	Water	Solvent	71

Table 5: List of ingredients and their function and concentration in the cream (Adapted from Cheng, Y. S., K. W. Lam, K. M. Ng, R. K. M. Ko, and C. Wibowo. 2009. "An integrative approach to product development-A skin-care cream". *Computers and Chemical Engineering* 33, no. 5: 1097-113. https://doi.org/10.1016/j.compchemeng.2008.10.010.)

The ingredients were chosen based on their specific action and also on their availability in the market, and cost. Each one of the present ingredients plays a specific role in the emulsion:

- Emollient: forms a protective oil film in the skin, decreasing the water loss and enhancing the penetration of the active drug (Azizzadeh et al. 2018).
- Emulsifier: acts as an interface between immiscible components, preventing the separation of liquids that usually do not mix by increasing the stability of the mixture (Helmenstine 2020).
- Humectant: provides skin hydration due to its hygroscopicity (Ujiie 2006).
- Stabilizer: maintains the activity of other ingredients, aiding emulsion stability and improving its shelf-life.
- Thickener: regulates the emulsion viscosity and improves the rheological properties (Karsheva, Georgieva, and Handjieva 2007).

3.4.2. Ellagic acid extraction process

Many bioactive components, including ellagic acid, can be extracted from cork products such as natural cork, cork powder, and black condensate. To perform the extraction, solvents such as water, methanol, dichloromethane, ethanol, and propylene glycol have been commonly used (Carriço, Ribeiro, and Marto 2018).

It was decided that the ellagic acid would be extracted from cork powder since it is the major waste generated by the cork industry (Carriço, Ribeiro, and Marto 2018). As for the extraction process, it will be carried out in a jacketed vessel equipped with a condenser and stirring paddles. To perform the extraction, the cork powder and solvent are added to the vessel, adding 20 mL of solvent for each gram of cork powder. The cork powder and solvent are then mixed at a constant temperature of 70 °C for a period of 6 hours. The solvent used will be a mixture of water and propylene glycol in the proportion of 0.4:0.6 v/v. After the extraction is complete, the cork powder is separated from the liquid by performing a filtration. Based on the literature, this procedure will yield about 8.2 mg of ellagic acid for each gram of cork powder (Batista et al. 2015). It is important to mention that the extract contains, additionally to ellagic acid, other phenolic compounds. However, as ellagic is the major constituent of the extract, and as the other compounds do not present a negative effect in the formulation, it was not necessary to separate it from the other compounds. The solvent was selected because it is compatible with the final product proposed in this work (Anti-photoaging cream using), water and propylene glycol being widely used in cosmetic products, there was also no need to remove them (Batista et al. 2015).

3.4.3. Cream manufacturing process

The production process of *Sobreiro* cream involves three fundamental steps:

1. Preparation of the oil phase
2. Preparation of the aqueous phase
3. Homogenization of the emulsion

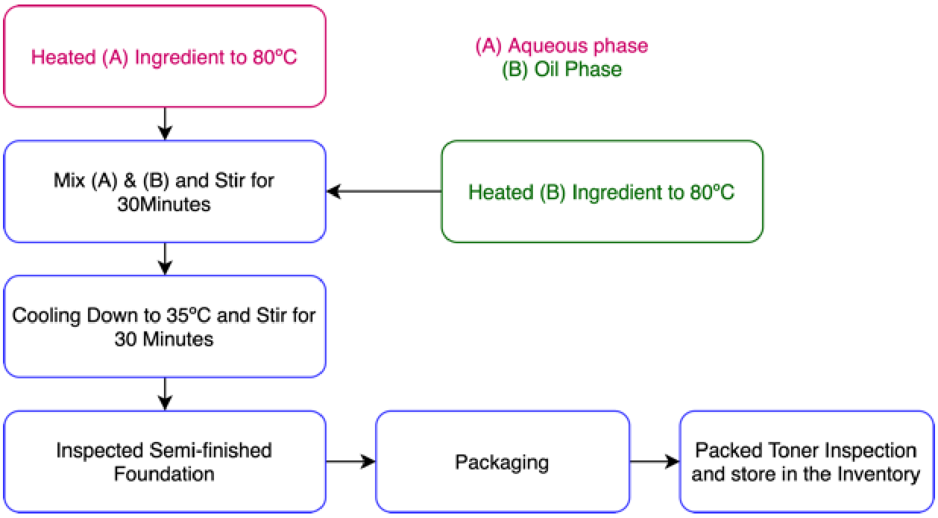

Figure 1: Process flowchart

(Adapted from Biocrown Biotechnology. n.d. "Skin care product production lines". Accessed December 2020. https://www.biocrown.com.tw/en/page/Skin-Care-Product-Production-Lines/production.html.)

Creams can be either an oil-in-water (O/W) or a water-in-oil (W/O) emulsion. Oil-in-water creams can be obtained by adding oil phase to water, while water-in-oil emulsions are prepared by adding aqueous phase into oil. From the dermatological point of view, a W/O product is favorable, but for the customers, it can be a disadvantage as W/O emulsions cause a greasy feeling in the skin. So, in order to satisfy this condition, it was decided to create an O/W product providing a moisturizing action without leaving a sticky texture (Shechter 2018).

In a cream or lotion production process, the critical stage in obtaining a stable emulsion with the right consistency is the mixing step. The main condition for obtaining a stable emulsion is to set high shear mixing between phases, resulting in a small and uniform droplet size preparation. The time required to form the emulsion usually goes between thirty minutes and one hour.

In the oil phase preparation, almond oil, coconut oil, and cetyl alcohol are put together. It is required the use of external heating in order to reach 80 °C, so the solid ingredients such as cetyl alcohol can melt. The emulsifier agent should be the last ingredient added to the oil phase.

The aqueous phase is prepared separately in a mixer by increasing the temperature of the medium until approximately 80 °C. The bioactive compounds are dispersed in this phase and the stabilizers, thickeners, humectants, and neutralizers are mixed together. The oil phase is added to the water phase, maintaining the temperature. The two phases are vigorously mixed until the product is homogeneous and with the expected texture, forming the emulsion. The product is cooled down, and the mixing process is finished. The emulsion is then sent in big bags to the packaging area of an associated company. Finally, the prepared product is ready and stored in the inventory.

It is important in the mixing stage to maintain the stirring speed below 10,000 rpm to prevent breaking down the carbon chains of the thickener. In industrial processes, it is recommended that the homogenizer is equipped with a vacuum line to remove bubbles during agitation (Azizzadeh et al. 2018; Silverson 2016).

It is to remark that no experimental work was conducted; all experimental data was obtained by literature; this work aims to describe a product design process.

4. Economic Evaluation

For the economic evaluation, a "Business to Business" (B2B) approach to the market is proposed. The cream will be sold to a cosmetics company. A company like *Benamôr* was considered in defining this scenario. The production of the cream is made by a start-up company that will work in the facilities of this partner with a rent agreement for the space. So, the market costs are not considered, and only the production costs of the new company are analyzed regarding the product viability. It t is to remark that the impact of the cork powder market value and other applications for this material was not considered in the economic analysis.

4.1. Production cost

To calculate the cost of the production, firstly, it was determined the costs of raw materials for the creams' production, which include the cork and the various components of the cream. The raw material used for the extraction will be used as part of the cream, with the exception of cork. This way, the total cost of raw material for each 50 mL cream would be about 1.89 €.

Then it was considered the costs of the equipment for both the extraction and the production of the cream, which amounts to 55 k€. This equipment was designed for the year 2025, so it is not necessary to buy new equipment in the first 5 years of production.

It was also necessary to calculate the costs associated with the required employees to maintain the company working. The wage, the number of employees, and the months that each employee will work are present in Table 6. To calculate the yearly costs with human resources, it was considered a year of 14 months, including holiday and Christmas allowances. In the first and second years, the factory will not be operating all year because the equipment's capacity allows the production of all creams in a shorter time frame, as referred to in Table 6.

Function performed	Basic monthly salary	1st		2nd		3rd		4th		5th		6th	
		Em	Mo	Em	Mo	Em	Mo	Em	Mo	Em	Mo	Em	Mo
Administration / Direction	1 900	1	12	1	12	1	12	1	12	1	12	1	12
Financial administration	1 700	-	-	-	-	-	-	1	12	1	12	1	12
Production / Operation	700	-	-	2	1	2	2	2	12	2	12	2	12
Quality	1 700	-	-	1	1	1	2	1	12	1	12	1	12
Manutention	1 700	-	-	1	1	1	2	1	12	1	12	1	12
Provisioning	700	-	-	1	1	1	2	2	12	2	12	2	12
R&D	1 400	2	12	2	12	2	12	2	12	2	12	2	12

Table 6: Salary of each function and number of employees (Em.) and number of months worked (Mo.)

The costs of marketing and packaging will be the responsibility of the company that this product will be sold to, so they do not need to be considered here. It is, however, necessary to take into account the renting costs that are 4 080 € per year. It was also considered a working capital of 8 723 € to answer to possible contingencies. This value is more significant when the annual production has a higher increase when compared to the previous year.

4.2. Sales volume and product cost

This product will have a shelf price of 15 €, which is the typical price of the creams of the selling brand. Considering the production cost and that the company, as well as the final sellers, also need to make a profit, the selling price for the start-up company will be 3 € which means a gross margin of 33 %.

The target market will be women, mainly within the age range of 18- to 29 years old, since the main reason for premature aging is due to UV-B radiation. As the cosmetic industry is very competitive, it was assumed that the share of this cream would be 2.5 % of the skin care market for anti-aging creams. However, sales are expected to increase at a yearly rate of 2.3 % in Portugal because of the increasing demand for anti-photoaging products.

After the first year of sales, the company is expected to start exporting to Spain since the selling brand is already present in this country. This way, Spanish sales were calculated considering a smaller value than the proportion of the population between the two countries, Portugal and Spain, because the brand has less stores in Spain than in Portugal. In the following year, the cream will start to be exported to several European countries where the selling company is already present. Likewise, for Portugal, the same reasoning was followed, and sales were expected to increase by 2.3 % in the following years. Table 7 summarizes the number of creams expected to be sold each year.

Year	1st	2nd	3rd	4th	5th	6th
Portugal (thousand units)	-	58.9	60.2	61.6	63.0	64.5
Abroad (thousand units)	-	-	116.4	1 115.6	1 141.3	1 167.6

Table 7: Number of thousand units of cream tubes produced each year

Figure 2 shows the cash flow and the accumulated cash flow for the first six; in this cumulative cash flow, it is assumed that all units of cream tubes produced each year are sold. With this data, it is possible to calculate the Net Present Value (NPV) of 1.6 M€, with a Payback Time of 3.3 years and an Internal Rate of Return of 85 %.

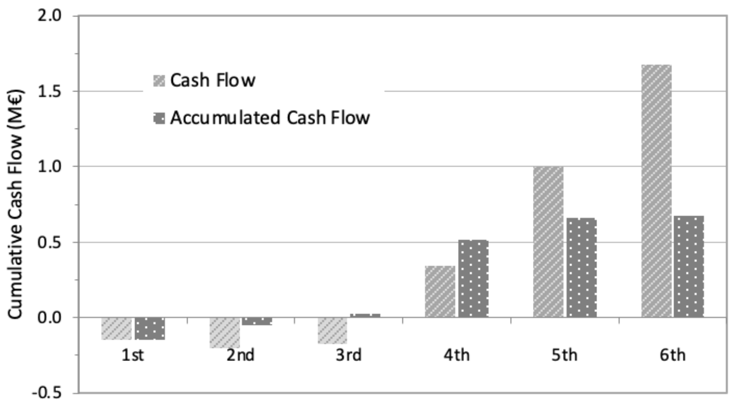

Figure 2: Cash Flow and Accumulated Cash Flow throughout the six years

5. Conclusions

This work describes a product design process of developing an anti-photo-aging cream, having *Quercus Suber* as raw material to obtain the bioactive compounds. Design stages start from evaluating market needs and generating ideas that could tackle the market gap. As a result of a deep analysis and ideas evaluation, the final product was an anti-photo-aging cream with ellagic acid in its composition. Ellagic acid is extracted from cork powder using water and propylene glycol solvent in the proportion of 0.4:0.6 v/v, which are components widely used in cosmetics. Finally, the last step consisted of performing an economic analysis. It was calculated a Net Present Value of 1.6 M€, an Internal Rate of Return of 85 %, and a Payback period of 3.3 years. It is to remark that the impact of the cork powder market value and other applications for this material there was not considered in this economic analysis.

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