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Design Process and Economic Evaluation of an Innovative Healing Plaster in Gel made from *Eucalyptus Globulus* Essential Oil

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Abstract

The main goal of this work was to design a new product containing an active ingredient of the *Eucalyptus Globulus* tree - its essential oil. This work was divided into four steps: analysis of the raw material, chemical product design (needs, ideas, and product selection), manufacture, and economic analysis. After investigating the potential of all the ideas, the product selected was a plaster in gel, named *Eucatrigel*, with triple action: it protects the wound, accelerates the healing (due to the essential oil addition), and waterproofs the region. In the manufacturing step, it was defined the mass percentage of the essential oil in the gel as 0.5 %. The formula of the gel was based on a patent (US8563604B2) owned by Bausch Health Companies. A business case was set for the economic evaluation of this product; in this case, considering an initial investment of 681 k€, the expected payback period is four years, and the internal rate of return is 35 %.

Author Keywords. Eucalyptus Globulus. Essential Oil. Gel. Healing Acceleration. Economic Evaluation.

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1. Introduction

Eucalyptus is a genus that comprises mostly tall trees but also some shrubs. The genus belongs to the *Myrtaceae* family, and there are an estimated 660 different species of *Eucalyptus*. The earliest records of this species are in Australia, Tasmania, and some neighboring islands. However, currently, several *Eucalyptus* species can be found around the world due to how easily it adapts to new environments and conditions[1]. The good adaptability, high growth rate, and wood quality of the eucalyptus trees are good characteristics that ensure their use for commercial purposes in Portugal (Fabres 2011), mainly in the Aveiro region, where their

[1]*Encyclopaedia Britannica Online*, s.v. "Eucalyptus," last modified November 26, 2020, https://www.britannica.com/plant/Eucalyptus.

application in the paper and pulp industry is found. The eucalyptus trees are used commercially in several industrial fields, with their application varying depending on which part of the eucalyptus tree is being utilized.

The objective of this work is to propose a valuable product made from a raw material extracted from the eucalyptus tree, as well as to describe a possible process to produce it. In addition, assumptions were made in order to evaluate the viability of the proposed product financially if it were to be produced by a company in Portugal.

Firstly, the chosen raw material was studied, as well as its properties and composition. Then, the product design was carried out, in which the chemical product design was defined, the manufacturing process proposed, and the economic evaluation conducted. The chemical product design includes the identification of the market needs, the brainstorming of ideas, and the selection of the best idea.

It is important to note that the proposed product would have to go through thorough testing and approval procedures prior to any investment in production or commercialization.

2. Raw Material

According to the Portuguese Ministry of Agriculture, as of 2019, *Eucalyptus* represents approximately 26 % of the continental forest in Portugal (844,000 hectares) (Agricultura e Mar 2019). It is also known that the most widespread species in Portugal is the *Eucalyptus Globulus* (Fabres 2011). Therefore, this work will mainly focus on the properties of *Eucalyptus Globulus* and its benefits. It is also going to be the species from which the extraction of the active ingredient will be performed.

The applications of the *Eucalyptus* are very diverse and range from the paper and pulp industry to the pharmaceutical and cosmetic industry (Vieira 2018; Ferreirinha 1961).

The bark has in its constitution gallotannins and some phenolic compounds (for example, ellagic acid) (Vázquez et al. 2012). *Eucalyptus'* wood is extremely resistant to decay and rot, which makes it a good option for the construction sector and the manufacture of furniture (Miller 2019; Lazzari 2020). The leaves obtained from this species are covered with oil glands filled with essential oil, for which the extraction efficiency is usually varying from 0.8 to 2.7 % (Bachheti 2015).

2.1. Essential oil

In 2010, 12 tonnes of essential oil were produced in Portugal (Figueiredo et al. 2015). The essential oil is a colorless liquid with a fresh scent that contains more than 40 known components. Some of the most notable and abundant are 1,8-Cineole (better known as Eucalyptol), α-Pinene, α-Terpineol, and *p*-Cymene (Nile and Keum 2018).

Eucalyptol, $C_{10}H_{18}O$, is the main component found in the essential oil (approximately 60 %) (Bachheti 2015). This substance has anti-inflammatory, antioxidant, antimicrobial, and mucolytic properties (Juergens et al. 2017). Therefore, it is an important compound for the pharmaceutical industry.

α-Pinene, $C_{10}H_{16}$, is the second most abundant compound found in the essential oil (around 20 %) (Bachheti 2015). This chemical substance has antibacterial, antifungal, and anti-inflammatory attributes (Kim et al. 2015). This compound may also be used in the pharmaceutical industry and in the manufacture of products against fungus.

α-Terpineol, $C_{10}H_{18}O$, can be found in concentrations of around 1 % (Bachheti 2015). It can act as an antioxidant, anti-inflammatory, antiproliferative and antimicrobial. It is also massively

used in the cosmetic industry due to its sensory properties (Sales, Felipe, and Bicas 2020). This compound, therefore, adds value to the pharmaceutical and cosmetic industry.

p-Cymene, $C_{10}H_{14}$, is present in a concentration of around 1 % (Bachheti 2015). Studies have shown that *p*-Cymene has antioxidant, analgesic, and anti-inflammatory properties. It is also known to leave a mild pleasant odor when applied to a certain material (Quintans et al. 2013), being used in the pharmaceutical industry.

3. Chemical Product Design (CPD)

The process of choosing the product that would be manufactured, the plaster in gel that accelerates wound healing, was divided into three steps: determination of needs, elaboration of ideas, and selection of ideas.

3.1. Needs & Ideas

Considering *Eucalyptus* essential oil characteristics, 20 market needs were identified by the authors and divided into six categories: personal hygiene, well-being, health, pests' control, fuel, and food industry. From these 20 needs, 26 ideas were originated; these ideas are listed in Table 1.

Category	Ideas
Personal hygiene	Drinkable elixir; chewing gum; mouthwash; toothpaste; shampoo; dry shampoo
Well-being	Refreshing spray; anti-aging facial cream; acne treatment cream
Health	Antifungal insoles; automatic air freshener; ointment; tape with gelatinous layer; plaster in gel; antifungal foot cream; medicine to control blood sugar; Alzheimer medicine (acts as a cholinesterase inhibitor); encapsulated essential oil; laundry detergent
Pests' control	Natural pesticide; natural insect repellent; ant-gel
Fuel	Biodiesel
Food industry	Natural food preservative; beverage + natural food preservative; post-workout drink

Table 1: The 26 ideas emerged after brainstorming from the identified 20 needs, which could use Eucalyptus essential oil

3.2. Selection

The pre-selection was performed considering factors such as the product's capability of being a company's flagship and the presence of similar products in the market. Afterward, a matrix analysis was built (Table 2) to choose three ideas from the nine pre-selected. The ideas were evaluated by classifying them on a scale of 0 to 10 regarding seven criteria with different levels of importance, according to the authors' knowledge, production cost (25 %), innovation (20 %), easiness of production (20 %), easiness of use (10 %), market acceptance (10 %), market strength (10 %) and the safety of use (5 %), a description of each criterion available in the Supplementary Information.

It can be seen in Table 2 that the three products with the highest total scores were the plaster in gel, the drinkable elixir, and the antifungal insoles.

A further investigation was then carried out to select one idea out of these three. It consisted of a more in-depth market research and a viability study based on the amount of raw material (*Eucalyptus* leaves) necessary for the manufacturing process. This process is described in the Supplementary Information.

Criterion	Market acceptance	Market strength	Innovation	Easiness of production	Production cost	Safety of use	Easiness of use	Total
Weight	**0.1**	**0.1**	**0.2**	**0.2**	**0.25**	**0.05**	**0.1**	**1**
Drinkable elixir	5.9	7.2	9	6.2	5.2	10	10	7.15
Automatic air freshener	7.8	5.4	2.5	5	4	10	7	5.02
Antifungal insoles	7.6	4.4	7	4.2	4.9	10	10	6.17
Beverage + natural food preservative	5.8	3.7	3.7	6.6	6.5	10	10	6.14
Natural food preservative	4.6	3.5	2.3	7.8	7	10	5.5	5.63
Ointment	8.6	4	2.5	4.7	3.8	7.75	10	5.04
Tape with gelatinous layer	8.4	5	3.5	2.1	2.9	7.75	10	4.57
Plaster in gel	6.2	8	9	6	5.4	8	10	7.17
Natural pesticide	4.4	3.7	5	7.8	5.5	7	9	6.00

Table 2: Matrix analysis for the 9 pre-selected ideas

Firstly, the amount of *Eucalyptus* leaves necessary for the estimated annual production was calculated for the three products. The effectiveness of the essential oil extraction process was 1.21 % (Bachheti 2015).

For the antifungal insoles, it was estimated that the essential oil would represent roughly 3 % of its mass composition, according to the minimal inhibitory concentration (MIC) and minimal fungicidal concentration (MFC) studies for different dermatophyte species (Nardoni et al. 2015). If an insole has 100 g, 248 g of leaves would be necessary to manufacture one insole.

- The drinkable elixir was considered to require 0.2 mg of essential oil for each unitary dose of 25 mL of elixir. As a result, it was estimated that 0.8 g of leaves would be required to obtain a bundle of 50 unitary doses.
- It was estimated that the plaster in gel would have a mass composition of 0.5 % of essential oil. So, a tube of 50 g of gel would require 20.7 g of leaves to be produced.

Hence, both a tube of gel and a bundle of elixir would require less raw material than one insole.

Furthermore, it identified two main problems in the production of the insole: how to guarantee an adequate release of the essential oil solution onto the surface of the foot and how to guarantee sufficient durability to the antifungal properties of the insole. Due to these challenges, the selection was narrowed to the plaster in gel and the drinkable elixir.

Secondly, a market investigation regarding the drinkable elixir was conducted. Drinking the elixir was considered "disgusting" and unhygienic because it was believed that this action would entail swallowing the dirt and bacteria that the elixir is expected to remove from the mouth. Thus, the plaster in gel was the product selected to be manufactured.

4. Manufacture

After the selection of the product, research was conducted in order to choose a standard formula for the gel. A patent from the United States (US8563604B2) that details the composition of a gel for wound healing and scar reduction was used as a guideline (Palefsky and Wilson 2014). Based on the options given for the production of the patented gel and the function of each substance in the gel itself, the components selected for the gel composition were: cyclopentasiloxane, phenyltrimethicone dispersion of polysilicone-11, polydimethylsiloxane, polymethylsilsequioxane powder, and *Eucalyptus* essential oil.

Each compound is responsible for a determined characteristic of the product:

- Cyclic siloxane (cyclopentasiloxane) is a volatile compound that gives fluidity and a smooth texture which provides an easy application of a thin film over the wound (Palefsky and Wilson 2014). The suggested concentration is 58.5 % w/w.
- The components that promote a barrier over the surface of the wound are called the occlusive ones. They are made of non-volatile hydrophobic materials that provide a flexible, biocompatible moisture block that is attached to the skin with emollient, non-irritating, and non-toxic features. The occlusive gel is a dispersion of polysilicone-11 in phenyltrimethicone and the silicone occlusive fluid is the polydimethylsiloxane (Palefsky and Wilson 2014). The suggested concentrations are 33.5 and 5.0 % w/w, respectively.
- The silicon resin powder (polymethylsilsequioxane) allows the formation of a dry and smooth feel film after the evaporation of the cyclic siloxane compound (Palefsky and Wilson 2014). The suggested concentration is 2.5 % w/w.
- The *Eucalyptus* essential oil accelerates the healing of the wound. The suggested concentration is 0.5 % w/w.

After establishing the suggested proportion of these components, the diagram flowsheet was made according to the same patent considering the product would be commercialized as a gel in tubes of 50 g. All the steps are represented in Figure 1, followed by their description.

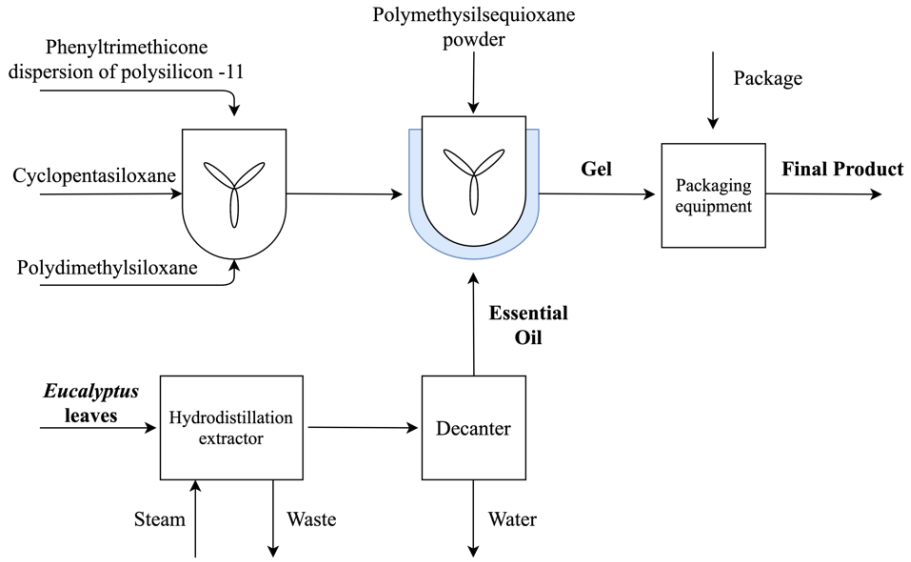

Figure 1: Process flow diagram for the production of the gel

Although more recent techniques could be used to extract the essential oil, which have advantages over traditional hydrodistillation, the use of the hydrodistillation technique was preferred because it is a more well-known and robust method (Radivojac et al. 2021). It consists of using water or steam as an extraction fluid that allows the removal of the oil from the leaves (Aramrueang, Asavasanti, and Khanunthong 2019). These leaves can come from the region of Aveiro since it is the area with the most concentration of *Eucalyptus* trees in Portugal, and a partnership can be formed with the pulp and paper industry of the area in order to utilize their waste, which is the unused leaves of this industry.

After the extraction, the spent leaf (waste) can be used as fertilizer, as a fuel for the boiler of the hydrodistiller, or it can be used to produce charcoal (Coppen and Hone 1992). The equipment that will be used in this step operates in batch mode (50 minutes), it has a capacity of 500 L, and it can produce 1.51 kg of essential oil per batch. The final product of this procedure is the mixture of essential oil and water, which is easily separated in a decanter.

The mixture of the ingredients is done in parallel with the oil extraction in 2 different steps. The first one includes the mixture of the base components (cyclopentasiloxane, phenyltrimethicone dispersion of polysilicone-11, and polydimethylsiloxane), which are responsible for the matrix that will receive the active ingredient, and it is made with a continuous stirring. Then, the dispersant (polymethylsilsequioxane) is added, and it is heated slowly up to 50 °C using a jacked mixer. While the heating is in progress, the *Eucalyptus* essential oil is added to the mixture. After the incorporation of all ingredients, the mixture is stirred at 50 °C until it becomes homogeneous and subsequently, it is cooled to room temperature (Palefsky and Wilson 2014).

Next, the mixture is ready to be introduced into the filling tube machine, after which it is ready to be packed.

5. Economic Analyses

The final step of this work consisted in performing an economic analysis to evaluate the profitability of the product. It is important to highlight that all the values considered for the analysis were estimated after research on the matter, and therefore this analysis is merely preliminary. The water and energy expenses were not considered in the economic analysis because its goal was to provide only an initial estimate of the investment needed for the manufacture of the plaster in gel.

An investment of 681 k€ in equipment and infrastructures was considered to be necessary to develop the production unit. The financing was 700 k€, being totally based on bank credit. It is expected that all credit will be refunded in seven years with an interest rate of 20 %. The credit has a grace period of two years, meaning that for two years, only the interest rate will be paid.

It was necessary to take into consideration the costs, the expected profits, the annual incomes, and the accumulations to do the economic evaluation.

The production unit would be located in Maia, with an estimated rent price of 1,400 € (average market price for 2021) due to the region being easily accessed by roads (A3, A4, A28 and A41), trains, and planes as well as its relative proximity to the region of Aveiro (from where the *Eucalyptus* leaves would be obtained). Also, Maia region is known for the presence of industrial and commercial activity.

The water would be provided by the local supplier of water, the SMAS - *Serviços Municipalizados de Água E Saneamento*. This company would also treat all wastewater produced. Additionally, the energy supplier would be EDP - *Energia de Portugal*.

The pulp and paper industry found in Aveiro uses only the tree's trunk as a feedstock, the leaves being considered a residue. Therefore, the raw material used to extract the essential oil could be easily obtained through a mutually beneficial partnership. Additionally, it would only be necessary to hire a freight company to take the leaves from Aveiro to Maia, with the manpower required for this operation being provided by the freight company.

In Table 3, it is described the costs of some equipment and machinery, and, in Table 4, it is detailed the costs of every raw material.

Equipment	Cost (€)	Reference
Hydrodistillator	21,159	Shanghai Better Industry Co.[2]
Decanter	620	Hangzhou Kuangbo Machinery Equipment Co.[3]
Mixer	804	Wenzhou Hongan Machinery Co.[4]
Automatic Tube Filling and Sealing Machine	14,762	Ruian Trustar Pharma & Packing Equipment Co.[5]

Table 3: Cost of some equipment used in production

Raw Materials	Cost (€/kg)	Reference
Cyclopentasiloxane	3.15	Hubei Star Chem Co.[6]
Polydimethylsiloxane	3.00	Shandong Dayi Chemical Co.[7]
Phenyltrimethicone dispersion of Polysilicone-11*	7.06	MakingCosmetics[8]; Hangzhou Ruijiang Chemical Co.[9]
Polymethysilsequioxane powder	6.00	Guangzhou Double Peach Fine Chemical Co.[10]
Eucalyptus Essential Oil	909.09	GranVelada[11]

* The cost of phenyltrimethicone dispersion of polysilicone-11 was estimated using the indicated references with a composition of 20% polysilicone-11 and 80% phenyltrimethicone

Table 4: Cost of the raw materials per kg

For the assumed market share, it is estimated that the sale of the products will generate approximately 850 k€. It is also expected that by 2026, that value will grow by fifteen-fold (approximately 13.3 million euros). The price of the gel was based on a market study and the current positioning of competing products. It was defined that the unitary price should be 6.50 € without VAT. This way, the price is adequate to compete in its market segment. In Figure 2 it is shown the forecast made for the economic analysis regarding the number of units sold per year, the product of units sold and the price gives the gross sales.

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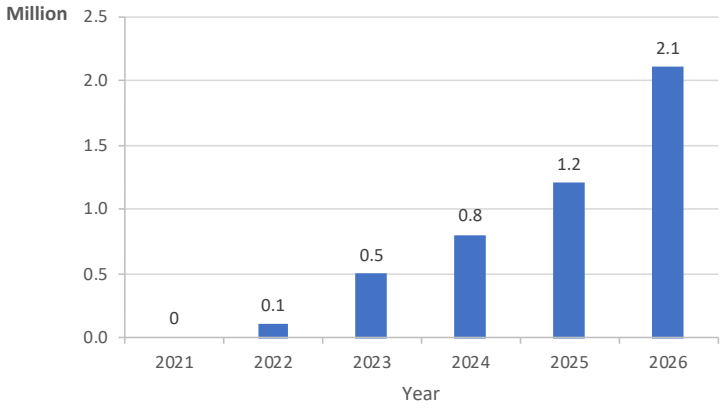

Figure 2: Annual units sold in millions

In the economic evaluation, it was also defined a gross margin for the calculation of the Cost of Goods Sold and Raw Materials Consumed (CGSRMC). This margin consists of the percentage of gross profit after considering the total net sales: the larger the gross margin, the more profitable the product is. It was estimated that the gross margin would be 90 %.

Other parameters were taken into consideration for this evaluation, such as the personnel expenses, as it is shown in Table **5** and Table **6**. Initially, it was defined the number of employees the company would have for each department, as well as their wages. Through this information, it was possible to estimate the annual expenses.

	Number of Employees	Salary (€)
Administration/ Management	1	5,000
Financial Department	3	1,500
Marketing	4	1,500
Production/ Operation	10	800
Quality	2	1,000
Maintenance	1	2,000
Supply	1	800
Research and Development	1	2,500
Production Engineer	1	2,000
Assistance	2	950
3rd Party Marketing Company	1	10,000

Table 5: Number of employees and respective salaries (paid for 14 months every year)

Expenses	2021	2022	2023	2024	2025	2026
Salaries						
Social Organs		70.0	70.0	70.0	70.0	70.0
Personnel	70.0	555.8	555.8	555.8	555.8	555.8
Charges over salaries	16.6	148.6	148.6	148.6	148.6	148.6
Insurance over work accidents and professional diseases	1.4	12.5	12.5	12.5	12.5	12.5
Social Insurance	5.9	32.1	32.1	32.1	32.1	32.1
Other expenses						
TOTAL	94.0	819.0	819.0	819.0	819.0	819.0

Table 6: Additional personnel annual expenses (k€)

To verify the profitability of this product, it is essential to study the cash flows calculated in the economic evaluation.

In Figure 3, it is shown the values of each cash flow for every year of the business: The Present Value (PV) Cash Flow is the annual Cash Flow discounted to the year 0 (2021) and the Present

Value Accumulated Cash Flow is the sum of the PV Cash Flow until the considered year. The PV Cash Flow ($PV\ CF_j$) is calculated by Equation (1):

$$PV\ CF_j = \frac{CF_j}{(1+i)^j} \quad (1)$$

where i is the interest rate, CF_j is Cash Flow for time period j, in which j varies from 0 to 5. In the first two years, it is predicted that the company will suffer losses. However, in the following years, the company will have profits, reaching the maximum of the evaluation in 2026 with 4 966 025 €.

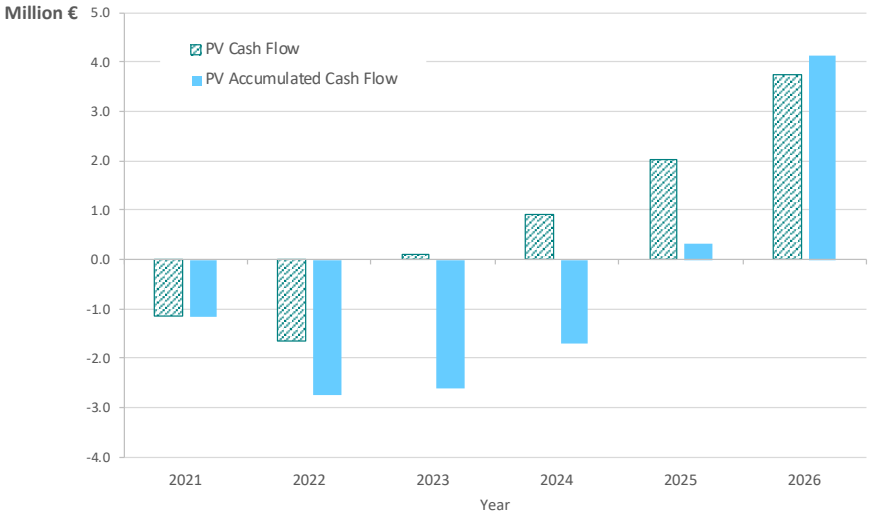

Figure 3: PV Cash Flow and PV Accumulated Cash Flow throughout the years

Through the cash flow values, it was possible to determine the Net Present Value (NPV), the Intern Rate of Rentability (IRR), and the Payback Time (PBT) of the business as shown in Table 6, calculated by Equations (2), (3) and (4), respectively.

$$NPV = \sum_{j=0}^{n} \frac{CF_j}{(1+i)^j} - \text{initial investment} \quad (2)$$

$$\sum_{j=0}^{n} \frac{CF_j}{(1+IRR)^j} - \text{initial investment} = 0 \quad (3)$$

$$\sum_{j=0}^{PBT} \frac{CF_j}{(1+i)^j} - \text{initial investment} = 0 \quad (4)$$

Where n is the total number of periods.

NPV (M€)	IRR	Payback Time
4.1	35 %	4 years

Table 7: NPV, IRR and Payback Time of this business

The NPV is positive, and so the business case made for the essential oil of *Eucalyptus* is viable. This is also seen from the value of IRR larger than the interest rate considered for this analysis (20 %). Additionally, it takes four years for the initial investment to be returned, after which there is only profit.

6. Conclusions

The product design process, based on three steps (chemical product design, manufacture, and economic analyses), provided an idea of how a new product based on a Portuguese natural raw material can be carried on into the market. The use of *Eucalyptus* as a raw material is advantageous due to its wide spreading in the Portuguese territory, which facilitates the

acquisition of the leaves. Additionally, the leaves are a waste of the pulp and paper industry, and so its usage enables partnerships and promotes new local businesses. The leaves can be used to easily extract the essential oil, and rather than only one component of the oil being important, all elements complement each other, which results in strong pharmacological features. Thus, a product that contains the *Eucalyptus* essential oil will have a wide range of features, which adds value to it.

It is important to highlight that the compositions exposed in this article are merely an initial estimation based on the mentioned patent. Therefore, laboratory tests need to be conducted in order to get a working and effective product. These tests will also allow the improvement of the formula.

Considering the assumptions made in this work, this product is viable, as can be seen from the values of the NPV (4.1 million €) and the IRR (35 %).

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Supplementary information

Chemical Product Design (CPD) - Needs & Ideas

To *Eucalyptus* essential oil were identified 20 market needs by the authors and divided into six categories: personal hygiene, well-being, health, pests' control, fuel, and food industry. After brainstorming, 26 ideas originated, which are listed in Table 1.

Category	Ideas
Personal hygiene	Drinkable elixir; chewing gum; mouthwash; toothpaste; shampoo; dry shampoo
Well-being	Refreshing spray; anti-aging facial cream; acne treatment cream
Health	Antifungal insoles; automatic air freshener; ointment; tape with gelatinous layer; plaster in gel; antifungal foot cream; medicine to control blood sugar; alzheimer medicine (acts as a cholinesterase inhibitor); encapsulated essential oil; laundry detergent
Pests' control	Natural pesticide; natural insect repellent; ant-gel
Fuel	Biodiesel
Food industry	Natural food preservative; beverage + natural food preservative; post-workout drink

Table S.8: The 26 ideas emerged after brainstorming from the identified 20 needs, which could use Eucalyptus essential oil

Considering factors such as the product's capability of being a company's flagship and the presence of similar products in the market, nine ideas were pre-selected, and a matrix analysis was carried out (Table 2) to choose the final three ideas. The need related to these final ideas is described in Table S.9.

	Need	Idea
Personal hygiene	Nowadays, people are constantly busy and looking for ways to save some time. This scenario adds value to products that offer a simpler and faster way of doing everyday activities compared to traditional products.	Traditional elixirs are not drinkable, which can be a nuisance for people that want to maintain good oral hygiene but do not have the time or the desire to go to a restroom to do so. Thus, an elixir that contains the *Eucalyptus* essential oil would be drinkable (Hu et al. 2014) and effective (due to the essential oil's antimicrobial properties), allowing people to take care of their oral hygiene quickly and practically
Health	Foot infections are a common nuisance that can be persistent and hard to treat. They can cause great discomfort, such as burning between the toes or on the soles of the feet, and feet raw skin. The most usual culprit is a fungal pathogen, which can even colonize on intact skin (Moyer 2020; The Healthline Editorial Team 2019).	Insoles embedded with the *Eucalyptus* essential oil can prevent fungal infections due to the essential oil's antifungal properties
Health	Wounds such as shallow cuts, first and second-degree burns may not cause problems such as significant blood loss, but they can still be quite painful and uncomfortable. For certain groups such as diabetics and the elderly, these injuries can lead to serious health issues due to the longer time needed for them to heal (Harvard 2018; Villines 2019). Additionally, the elderly tends to be more susceptible to the development of pressure ulcers due to changes associated with the aging process	The *Eucalyptus* essential oil has antimicrobial properties that help wounds heal faster. Therefore, a gel that contains the essential oil and hardens once applied, forming a resistant protective layer, can act as a plaster and accelerate the healing at the same time. This would be helpful for people whose wounds take longer to heal such as diabetics or who are more susceptible to certain wounds such as pressure ulcers. Moreover, the gel would also be advantageous for people that have a normal healing speed. A traditional plaster has the disadvantage of having a fixed form, making its application in certain body parts unfitting and

	(Ferreira Chacon et al. 2010). Thus, a product that accelerates healing while protecting and waterproofing the wound would be an asset	ineffective. On the other hand, a gel that can function as a plaster is more versatile and does not present such a problem.

Table S.9: Needs related to the three final ideas

Selection Criteria

In order to choose three ideas out of the nine pre-selected ones, a matrix analysis was carried out (Table 1), in which the ideas were rated considering seven factors: easiness of production, easiness of use, innovation, market acceptance, market strength, production cost, and safety of use.

Firstly, the relevance of each criterion to a start-up, and considering the general characteristics of the nine pre-selected ideas, was analyzed to organize the criteria into different levels of importance. As a result, 4 levels were established, as it is shown below:

- Level 1: production cost.
- Level 2: innovation and easiness of production.
- Level 3: easiness of production, easiness of use, market acceptance, and market strength.
- Level 4: safety of use.

Next, in order to classify the pre-selected ideas on a scale of 0 to 10, percentages for each level of importance were defined following two general rules: all criteria of the same level ought to have the same percentage, and the difference between subsequent levels ought to be around 5 - 10 %. The final percentage distribution, as well as a brief description of each criterion, is shown below.

- Production cost (25 %): it measures the costs associated with manufacturing the product. The higher the value to the cheaper the production process. This criterion has the highest weight because of its extreme importance for a start-up with limited resources.
- Innovation (20 %): it represents the product's capacity to offer something new and different to the customers. The more innovative products have higher values in this category. This criterion has the second-highest weight because being innovative is fundamental for a product coming from a start-up to attract customers' attention.
- Easiness of production (20 %): it is an estimation of how easy it is to manufacture the product. It is related to the number of processes as well as their complexity and technological maturity. The higher the score, the easiest the production process is considered to be. This criterion has the second-highest weight because more complex processes are more complicated and challenging to implement, and that can be critical for a start-up with limited resources.
- Easiness of use (10 %): it is a measure of how easy it is for the consumer to use the product. The higher the value, the simplest the product’s use is considered to be. This criterion has the third-highest weight because products that are complicated to use can drive potential customers away.
- Market acceptance (10 %): it is an estimated measure of how easily the market would accept the product in question. The higher the value, the bigger it is considered to be the consumers' acceptance. This criterion has the third-highest weight because public rejection is a challenging problem for a start-up that does not have many resources.
- Market strength (10 %): it is an estimation of the product's strength, that is, its ability to compete in the market. While market acceptance is measured from the point of view of

the consumer, the market strength is estimated from the point of view of the manufacturer. The higher the score, the bigger it is considered to be the product's strength. This criterion has the third-highest weight because when a new product is put on the market, it needs to be able to compete in it to be successful.

- Safety of use (5 %): it is an estimation of the product's safety regarding human health. However, for the natural pesticide, it is regarding the environmental impact associated with the use of the product. The higher the score, the safer the product is. This criterion has the lowest weight because all the ideas were believed to be relatively safe.

Criterion	Market acceptance	Market strength	Innovation	Easiness of production	Production cost	Safety of use	Easiness of use	Total
Weight	**0.1**	**0.1**	**0.2**	**0.2**	**0.25**	**0.05**	**0.1**	**1**
Drinkable elixir	5.9	7.2	9	6.2	5.2	10	10	7.15
Automatic air freshener	7.8	5.4	2.5	5	4	10	7	5.02
Antifungal insoles	7.6	4.4	7	4.2	4.9	10	10	6.17
Beverage + natural food preservative	5.8	3.7	3.7	6.6	6.5	10	10	6.14
Natural food preservative	4.6	3.5	2.3	7.8	7	10	5.5	5.63
Ointment	8.6	4	2.5	4.7	3.8	7.75	10	5.04
Tape with gelatinous layer	8.4	5	3.5	2.1	2.9	7.75	10	4.57
Plaster in gel	6.2	8	9	6	5.4	8	10	7.17
Natural pesticide	4.4	3.7	5	7.8	5.5	7	9	6.00

Table S.10: Matrix analysis for the 9 pre-selected ideas

The highest weights were given to the criteria that, according to the authors' knowledge, consider more relevant to a start-up company, namely production cost, easiness of production, and innovation of the product. It can be seen in Table 2 that the three products with the highest total scores were the plaster in gel, the drinkable elixir, and the antifungal insoles.

The amount of raw material (*Eucalyptus* leaves) was considered necessary for the manufacturing process to select a final idea. It was considered an extraction yield of 1.21 % (Bachheti 2015).

248 g of leaves should be necessary for each 100 g of the insole for the antifungal insoles. The drinkable elixir (25mL) requires 0.2 mg of essential oil; a bundle of 100 unitary doses should be necessary 1.6 g of leaves. It is estimated that the plaster in gel has a mass composition of 0.5 % of essential oil. So, a tube of 50 g of gel would require 20.7 g of leaves.

Hence, both a tube of gel and a bundle of elixir would require less raw material than one insole. The drinkable elixir should be considered "disgusting" and unhygienic because it was believed that this action would entail swallowing the dirt and bacteria that the elixir is expected to remove from the mouth. Thus, the plaster in gel was the product selected to be manufactured.

A market investigation was conducted with a small group of people to determine which product would be manufactured, in which the following questions were asked:

- Do you think using the drinkable elixir would be hygienic?
- Would you use the drinkable elixir instead of toothpaste?
- Would you use the plaster in gel for small cuts, minor burns, etc.?
- Do you think the plaster in gel would be more practical to use than the traditional plaster?

- Which product do you think would be more useful for all ages?

The drinkable elixir was considered unhygienic by most people interviewed due to the belief that using it would entail swallowing the dirt and the bacteria that the elixir is expected to remove from the mouth. Furthermore, they were not interested in using the drinkable elixir instead of toothpaste. On the other hand, the plaster in gel was considered an excellent product for small injuries. At the end of this study, it was concluded that the plaster in gel would be more attractive to the general public.