U.Porto Journal of Engineering, 8:5 (2022) 86-105
ISSN 2183-6493
DOI: 10.24840/2183-6493_008.005_0009

Received: 26 May, 2022
Accepted: 15 September, 2022
Published: 26 September, 2022

EcoSmile: Chemical Product Design of a Mouthwash for Periodontal Disease Treatment using Quercitrin extracted from Kiwi Branches

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Abstract

EcoSmile is an innovative Portuguese product of quercitrin, an antioxidant extracted from kiwi branches residues with the objective of promoting circular economy. Since periodontal disease currently affects 20 to 50% of the world's population, there is a need for an efficient product to treat this condition. This antioxidant can be used as an active ingredient of this mouthwash as it has anti-inflammatory characteristics and repairs gingival tissues.

The extraction and manufacturing processes were studied and scaled to an industrial level. The plant would be installed in Felgueiras, and a team of 14 workers was considered. An economic assessment was made, finding that an investment of €2,550,000 would be necessary. The project is economically viable and capable of generating a financial surplus.

Author Keywords. Chemical Product Design. Mouthwash. Kiwi Residues. Quercitrin. Periodontal Disease.

Type: Research Article
Open Access Peer Reviewed

1. Introduction

Worldwide, large amounts of agricultural waste are generated, such as stems, leaves, roots, and flowers. It is estimated that more than 20% of vegetable and fruit production is wasted annually. In the case of the kiwi, 1,000,000 tons of waste is generated annually worldwide. Most of these residues come from its pruning. Currently, these kiwi branches are not used and are usually burned. This has a negative impact, namely on the carbon footprint (Chamorro et al. 2022). It is known that these residues are rich in bioactive principles, mainly phenolic compounds. Thus, it would be advantageous to create new products from these compounds, as it would not only meet the population's needs but also take advantage of this waste by creating a circular economy (Chamorro et al. 2022).

Additionally, according to the World Health Organization (2022), nearly half of the adults worldwide suffer from oral diseases, with severe periodontitis affecting up to 10% of the world population, leading to tooth decay and loss. Applying this statistic to the Portuguese population means that over 1,000,000 people could suffer from these conditions.

Treatments for periodontal disease depend on its severity. Usually, the more advanced the stage of the disease, the greater the need for mechanical treatment or surgery. Dentists treat many cases by scaling and polishing the teeth and giving advice on daily oral hygiene. In order to avoid more severe treatments, such as surgery, it is fundamental to maintain good oral hygiene and use products that not only treat but also prevent periodontal disease. This is where including appropriate products, such as toothpaste and mouthwash, can be fundamental (Williams 1990).

Solutions with 0.0005% to 5% in weight of at least one antioxidant could help heal wounds in the mouth, such as those caused by a periodontitis infection (Zielinski, Moon, and Allen 2013).

Hence, a mouthwash using antioxidant and anti-inflammatory compounds extracted from these agricultural residues could benefit people suffering from periodontal disease whilst reusing pruning residues from kiwi crops.

EcoSmile is an innovative mouthwash that differentiates itself from the others because it is a Portuguese product with sustainable production and contributes to a circular economy. This study intends to analyse the different stages in designing a chemical product, a mouthwash for periodontal disease treatment. After characterising the raw material through a review of the current literature, the paper will follow the sequence Needs, Ideas, Selection and Manufacture.

2. Raw Material

2.1. Production and waste generation

Hayward growing areas have been the major focus of kiwi production since the 1980's when it started in Entre-Douro e Minho (83%) and Beira Litoral of Portugal (17%).

Market	Oct-Dec	Jan-Feb	Mar-May
National (%)	45	40	50
Exports (%)	55	60	50
Total (%)	100	100	100

Table 1: Distribution of the Portuguese kiwifruit production through the year 2017 (Antunes et al. 2018)

Kiwi is a promising crop for these regions due to its good climatic adaptability and market needs, either increasing domestic consumption or exporting (Antunes et al. 2018). Table 1 shows that exports are higher than national consumption with a slight percentage difference.

Year	2014	2015	2016	2017
Surface (ha)	2 255	2 305	2 380	2 650
Production (t)	18 150	28 331	21 075	35 411

Table 2: Evolution of kiwifruit area and production (INE 2018)

Regarding kiwi production, Table 2 compares production data for consecutive years from 2014 to 2017. There was a notable growth in production from 2014 to 2015 and 2016 to 2017 (INE 2018). According to FAO Statistical Corporate Database data, in 2020, kiwi production in Portugal reached 45,820 t, so there has been a considerable increase since 2017. No data was found for the present year of 2022; however, an increase in this value is expected, considering the trend in recent years (FAOSTAT 2022).

The kiwi species of most significant interest are *Actinidia deliciosa*, *Actinidia chinensis* and *Actinidia arguta* (Antunes et al. 2018). This paper will focus on the characteristics and data about *Actinidia deliciosa* (also known as Hawyard kiwi) and *A. arguta*. In the short term, the

Actinidia Deliciosa species will certainly be the most relevant since it is the most predominant kiwifruit species in Portugal, where the raw material will be obtained (Antunes et al. 2018). The *Actinidia Arguta* variety has been rising in the Portuguese market due to its unique organoleptic characteristics, and it is expected that its production will increase considerably in the next few years (Dep. Técnico Frutas Douro ao Minho S.A. 2014).

As it is known, industrialisation generates waste from the kiwifruit themselves, such as flowers, branches, leaves, and seeds, among others, which can be harnessed for their bioactive compounds, such as polyphenols. In 2019, kiwi cultivation occupied 270 000 ha of world surface area, of which 43 000 ha corresponds to Europe (15% of the world distribution). As expected, this high production rate is associated with its waste. The kiwi is a vine plant that must grow on a support structure and must be pruned regularly. Pruning allows control of the size and also increases the production yield. Winter is the best time of the year for pruning the branches, and this is when most of the waste is generated in the form of stems and leaves (Carroll, n.d.). Statistical data shows that 20% of vegetable and fruit production is wasted, and in the kiwi case, this percentage translates into 1,000,000 tons of annual global residues (Chamorro et al. 2022). In the specific case of Portugal, considering the 20% referring to kiwi branch waste, in 2017, an estimate of 2.67 tons/ha was obtained, which translates into a significant amount and with potential for development of other applications.

2.2. Characterisation

Most agricultural residues are leaves and branches from the kiwi plant. To develop a chemical product, the composition of these raw materials must be evaluated.

The leaves and stems have been claimed to have a similar composition; therefore, it was assumed that the compositions found in the literature were valid for both stems and leaves of kiwi plants (Chamorro et al. 2022). The values found, combined with the bioactivity of the chemical compounds, are shown in Table 3.

Compound	Quantity	Function
Quercitrin, rutin, proantocyanidin B and C, quinic acid, myricitrin, and triterpene acid-O-hexoside	149.52 mg/g (Pinto, Delerue-Matos, and Rodrigues 2020)	Bioactive phenolic compounds: antioxidants and anti-inflammatory
Neochlorogenic acid, Chlorogenic acid, Cryptochlorogenic acid, p-Coumaroylquinic acid	Total phenolic acids: 230.17 mg/g (Pinto, Delerue-Matos, and Rodrigues 2020)	Phenolic acids: antioxidants and anti-inflammatory
Holocellulose, α-cellulose, Lignin	73.50% 38.30% 25.30% (Luzi et al. 2017)	Cellulosic compounds with antimicrobial properties for packaging applications, when combined with an antioxidant
Metals (zinc, copper, …)	Zinc: 969.13 μg/g; Copper: 201.75 μg/g (Ravipati et al. 2012)	
Sugars (Sucrose and starch, myo-inositol, planteose)	Sucrose and starch (150–300 mg/g), with planteose being 45 to 65% of total sugar (Klages et al. 2004)	

Table 3: Quantity and function of bioactive compounds present in kiwi plant leaves and stems

As shown in Table 3, kiwi plant stem and leaves have a relevant number of polyphenolic compounds. Rutin, quercitrin, quinic acid and triterpenic compounds are among the polyphenols found in the leaves of kiwi plants. These compounds have antioxidant activity, as they can capture and react with free radicals and nitric oxide (NO) radicals, and they can prevent lipid peroxidation. Several sources in the literature have studied eco-friendly extraction methods of these compounds from pomaces or ground leaves, such as an extraction with boiling water followed by a reverse-phase chromatography for purification (Henriques et al. 2017), an aqueous two-phase system (ATPS) (Velho et al. 2020) or using a macroporous adsorption resin treatment (Wu et al. 2018). There are also reports of traces of metals (the most relevant being zinc and copper (Ravipati et al. 2012)) as well as sugars (sucrose and starch, myo-inositol and the most abundant planteose (Klages et al. 2004)) in leaves of *A. arguta,* demonstrating the richness of these plant leaves. Furthermore, several phenolic compounds – phenolic acids, flavonols, flavanols and procyanidins – have been found and quantified. These compounds have been studied for their antioxidant and anti-inflammatory activities, as previously stated. A phenolic compound, 3,5-Dihydroxy-2-(Methoxycarbonylmethyl)phenyl-3,4-dihydroxyben-zoate, has been extracted by SPE from *A. chinensis* leaves, expressing genotype-resistance against a fungus, and could act as a precursor to a compound with fungicidal activity (Wurms and Cooney 2006), showing that kiwi plant leaves are a source of various chemical compounds.

Kiwi plant branches could also be used as precursors for extracting cellulose nanocrystals. For this reason, the high cellulose content found in this raw material is used. This extraction was optimised, using a 0.7% wt/v solution of sodium chlorite two times before performing a hydrolysis step. As reported, nanocellulose shows an antimicrobial activity when combined with an antioxidant such as rutin, also present in kiwi plants (Luzi et al. 2017). Kiwi stems are sources of moisture, ash, crude lipid and proteins, and some flavonoids. The flavonoids are (+)-catechin and (-)-epicatechin and have been studied as promotors for bone marrow cell proliferation (Pinto, Delerue-Matos, and Rodrigues 2020; Takano et al. 2004).

In the final product, the mouthwash, the compound used will be the polyphenol quercitrin. This will be explained in more detail throughout the paper.

3. Chemical Product Design (CPD)

3.1. Needs & Ideas

3.1.1.Needs

The first step in determining the needs is identifying the main type of users that would benefit from a product based on kiwi branches (Cussler and Moggridge 2011). Afterward, a rigorous study of the market was performed by the authors of this study. The needs are presented in Table 4 and classified into three categories: essential, desirable, and useful.

Essential needs	Desirable needs	Useful needs
Safe to use	Sustainable	National sourced raw material
Easy to use	No patent infringement	Pleasing flavour

Table 4: Needs of the product

First, it was decided that the product would be marketed primarily in Portugal, and utilised residues from kiwi plants, also from Portugal. Furthermore, it was decided that the product would be marketed in a B2C form (business to consumer). It was important that all the ideas envisioned were easy and safe to use by the buyer and did not infringe patents.

Finally, various articles and studies show that sustainability is an emerging concern for customers in the 21st century. Thus, entrepreneurship should be carried out in the most sustainable way possible (Filser et al. 2019).

Moreover, since the 2010 economic crisis, Portuguese consumers have been choosing national products over imported ones, and this trend was reinforced by the COVID-19 pandemic (DN/Lusa 2020). The product developed meets this need by taking advantage of residues from national agriculture and contributes to a more circular economy.

The chosen product, a mouthwash, should have a pleasing aroma or flavour to be appealing to customers. Furthermore, it is perceived that a blue or green mouthwash will be mint-flavoured and leave a pleasant freshness in the mouth.

3.1.2. Ideas

Considering the mentioned needs, ten product ideas were found, based on the active principles studied, which were repeatedly eliminated and impossible to implement. These ideas were sorted into categories according to their application area (Table S1 in the Supporting Information). The six most relevant ones are presented below (Table 5), and a brief characterisation of them can be found in Section 3.1.2 of the Supporting Information.

Product	Used active ingredient
Bioplastic for food packaging (Luzi et al. 2017; Narasagoudr et al. 2020)	Cellulose nanocrystals + Rutin
Kraft paper (Gençer 2015)	Cellulose
Spray with anti-allergenic action	Quercitrin
Facial serum	Quinic acid + Quercitrin
Toothpaste / Mouthwash (Gómez-Florit, Monjo, and Ramis 2014)	Quercitrin

Table 5: Most relevant product ideas and active principles from kiwi branches are used in their formulation

3.2. Selection

The group made a matrix analysis of seven comparative parameters, represented in Table 6, using a scale from 1 to 10 (with 1 and 10 being the worst and the best option, respectively). In addition, a weighting factor (WF) from 0 to 1 was made to the parameters. The way these WF have been assigned is explained after the table.

Parameter	WF[1]	Product Ideas					
		Bioplastic	**Kraft paper**	**Anti-allergenic spray**	**Facial serum**	**Toothpaste**	**Mouthwash**
Needs are verified	0.20	6	1	6	4	8	8
Innovation	0.10	7	2	5	5	7	7
Active ingredient quantity	0.20	6	7	7	4	7	7
Ease of Use	0.10	6	8	6	8	7	9
Cost	0.10	4	3	5	1	5	5
Ease of Regulation	0.15	7	7	2	1	4	4
Scientific knowledge	0.15	7	8	6	2	5	5
TOTAL	**1.00**	**6.20**	**5.15**	**5.40**	**3.45**	**6.25**	**6.45**

Table 6: Matrix analysis of the Product Ideas. (1WF: Weighting Factor. Total score was calculated by a weighted average of the different parameters)

The low scores some products obtained can be explained by some parameters.

It was expected that the weighting factors with greater relevance should be the verification of needs and the quantity of active ingredients obtainable from the available raw material since the main purpose of a product is that it fulfills the requirements for which it is intended and for this to happen it is necessary to have the required quantity of active ingredient.

Then, it was considered that it is important to have some scientific knowledge in the area, as this guarantees the product's efficacy. And also, the ease of regulation, since this is the only way the product can be commercialized and monetarily, is a point with a lot of importance.

Finally, it was considered that innovation, ease of use and cost have some weight in the choice of the final product, as these are factors consumers take into high consideration when purchasing products.

Kraft paper scored low on the cost parameter, as this product would be quite difficult to implement in Portuguese paper industries. This is because these companies are mostly formatted to produce paper from eucalyptus, which implies specific manufacturing processes for this raw material. Thus, in these industries, it would not be feasible to produce paper from kiwi branches.

Regarding the health-based ideas (facial serum and allergenic spray), the testing would be a long and complex process as the individual's response to the product would not be immediate. Additionally, the response is not the same in all individuals. Therefore, these ideas performed badly on the ease of regulation parameter.

Finally, the two high-scoring ideas are toothpaste and mouthwash. Between these two, the authors considered that the mouthwash would be easier to conceive and also easier for the consumer to use in the treatment of periodontal disease.

Thus, using Table 6, it is possible to conclude that the worst product option would be the facial serum and the best (and consequently the chosen product) is mouthwash for the treatment of periodontal disease.

4. Manufacture

4.1. Product specifications

EcoSmile is a mouthwash that can reduce the action of periodontal disease on the gums. Periodontal disease negatively affects the quality of life of those affected, and there is evidence that the more severe the disease, the greater the impact on quality of life. Thus, the bacteria accumulated in the subgingival biofilm inflames the tissue and can destroy tooth support (do Nascimento Júnior et al. 2021).

In this sense, the active ingredient used (quercitrin), extracted from the branches and leaves of kiwi fruit, has shown great promise when it comes to the protection and recovery of gingival tissues. In more detail, quercitrin increases the rate of collagen growth, promotes tissue healing and repair, decreases Reactive Oxygen Species (ROS) (Schieber and Chandel 2014) levels, and promotes antibacterial activity. Quercitrin also reduces the rate of bacterial growth (Gómez-Florit, Monjo, and Ramis 2014). Regarding the amount of active ingredient used, its percentage in a 250 mL package is 2% or about 5 mL of the total amount. This percentage is in the range recommended by the patents (Ibsen, Glace, and Pacropis 1998; Zielinski, Moon, and Allen 2013). To make it more appealing to the public, it is crucial to advertise that it is natural-based and results in the use of kiwi waste. In addition, in the cosmetics area, the absence of parabens in the composition of the product stands out. This is because these compounds, previously used as preservatives due to their broad antimicrobial spectrum against fungi and bacteria, caused allergic reactions in the cosmetic application area, erythemas and edemas. In addition, the appearance of cancer would also be noticed in some cases (Hoppe and Pais 2017).

Due to the composition of *EcoSmile*, this product should not be easily accessible to children due to the risk of ingestion (caused by the ethanol content of the mouthwash) and should be stored at room temperature.

4.2. Process flowchart

Figure 1 and Figure 2 show the flowchart of the *EcoSmile* mouthwash production process. In particular, Figure 1 shows the process of quercitrin extraction from kiwi leaves and branches, while Figure 2 describes the actual process of making and bottling the mouthwash. In addition, a water purification system is used to remove any water contaminants present in the final product.

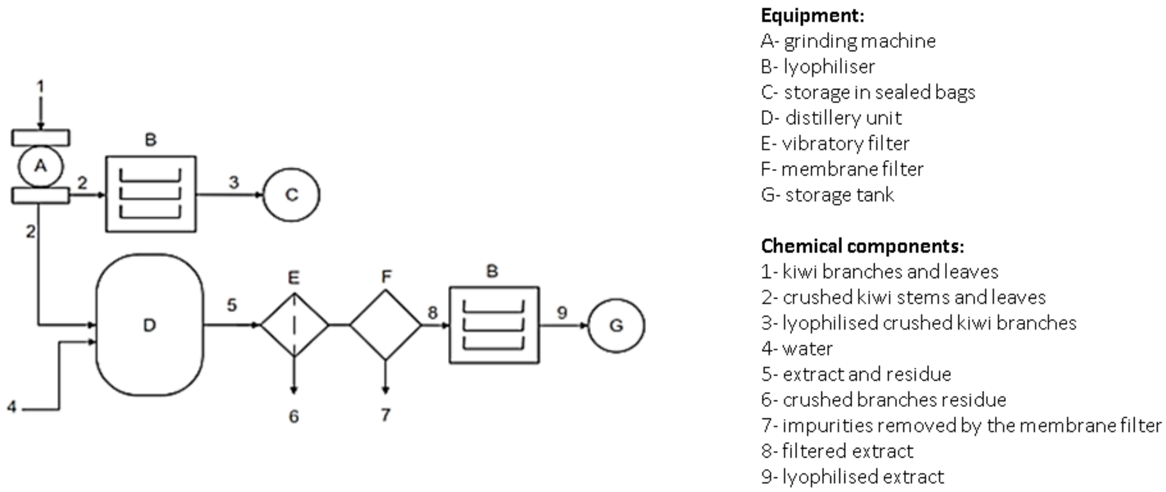

Figure 1: Extraction process flowchart

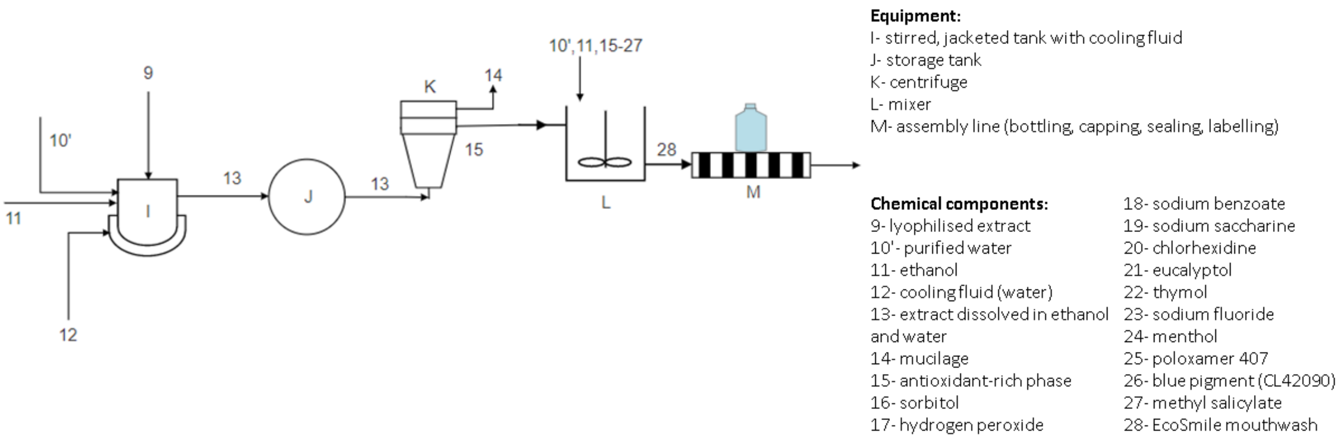

Figure 2: Extract purification and Mouthwash manufacture process flowchart

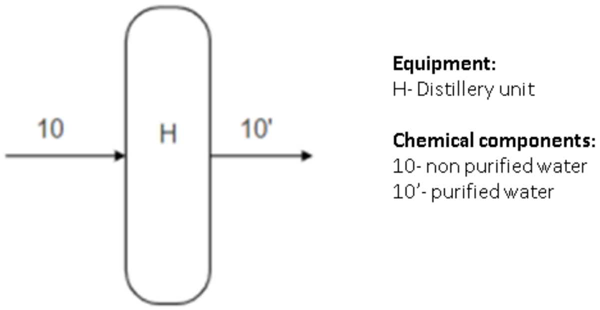

Figure 3: Water purification unit flowchart

4.3. Manufacturing process

The raw material is obtained from Portuguese producers, which boosts the local economy and makes the production process easier since transport is facilitated and there are no import costs. The kiwi branches are collected during the pruning season, arriving fresh at the company. This implies a conservation process of the branches, so they can be used throughout the year. Thus, according to the flowchart in Figure 1, the first step of the process is to shred the branches into very small fragments in a grinding machine (A) that only operates during the first trimester of the year. The material is then lyophilised (B) and stored under vacuum (C) in appropriate bags for further utilisation.

The extraction process will be carried out by hydrodistillation, using a 5 m^3 capacity hydrodistiller (D). The extract is then filtered at 8 ton/h (E, F), lyophilised (B), and stored (G). This extraction method allows for a yield of 101 to 123 mg of extract per gram of plant (Henriques et al. 2017). An average value of 112 mg/g was used in further calculations.

Then, the extract is purified by ethanol precipitation, being mixed with water and ethanol in appropriate proportions and kept in a cooling tank (I) for about 15 h. Part of this solution goes into a storage tank (J) and subsequently is centrifuged (K) at a flow rate of 8 m^3/h, which allows the mucilage to be separated from the extract of interest. This stage is crucial to obtain a more concentrated extract, as the concentration of phenolic compounds in crude plant extracts is expected to be low. Henriques et al. (2017) have estimated that the purified extract should have a concentration of 36.9 µg/mg of extract.

The next phase of the process, shown in Figure 2, is the effective production of the mouthwash, where all the components (15 through 27), including the quercitrin extract, are placed in a mixing tank (L). This tank has a maximum capacity of 1 m^3. The last step consists of packaging and labeling the product in an automatic machine (M), which operates for less than one hour per day.

During the whole process, a conveyor belt is also used to transport the branches to the shredding machine, about ten wheeled buckets, six pumps, and twenty-one valves. A water distiller (H) is also used because the water utilized in the mouthwash must be pure, as it is a product with medical properties that will be used directly by people.

A more detailed description of each step of the process, with the quantities and duration of each batch, is provided in Chapter 5.3 of the Supporting Information. The values given correspond to the first quarter of production, increasing by 20% in each trimester and remaining constant during the fourth year.

5. Economic Analysis

5.1. Gantt diagram

A Gantt Chart (Table 7) is a resource used in project management. It describes the duration and the importance of activities or tasks during a specific period, thus showing the beginning and end of each project activity as a whole and any possible overlaps between different activities. A more extensive involvement is shown through a darker colour.

In this study, a Gantt Diagram was applied to the four stages of the Chemical Product Design (CPD) process: needs, ideas, selection, and manufacture.

The activities analysed were Marketing, Research & Development, Investments, Engineering, Production and Sales. These activities were tracked over four years.

Year	**1**				**2**				**3**				**4**			
Trimester	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
CPD Stage	**Needs**	**Ideas**	**Selection**	**Manufacture**												
Marketing																
Investments																
Research & Development																
Engineering																
Production																
Sales																

Table 7: Gantt Chart for *EcoSmile*

Marketing is crucial during the company's first year, as its role is crucial to establish the first contact with potential customers. Marketing will allow the company to understand the public's needs. With this information obtained through surveys, the R&D department will be able to draft product ideas to satisfy the needs mentioned. The Engineering division will play an essential role in helping determine the most viable product option, compromising innovation and demand, and then must draft the process flowchart. During the first year, after the Selection stage, the first investments are made: the R&D department needs to select the best materials, whilst the Engineering branch must purchase equipment and optimise the production process. The Sales department will work alongside the Marketing department to define the best market approach.

During the second year, production and sales to the public will begin. Investments decrease as significant expenses are made during the company's first year (purchase of equipment). Subsequently, the only purchases are those of reagents, and scheduled expenses include salaries and the terrain rent. It is assumed that the product is already ready to sell and does not require the testing and licensing phase. Production becomes crucial by the end of the second year, at the same time when sales allow the company to become self-sufficient. When sales become constant, assuming a saturated market, marketing activity can decrease.

5.2. Marketing strategy

In the stage of developing a marketing strategy, it is important to consider the market in which *EcoSmile* will be inserted. Thus, it is imperative to define a strategy capable of reaching the most significant number of people appealingly, to obtain a high sales volume and subsequently achieve success (Reis et al. 2018). The development of a strategy for this product began with market research. As mentioned before, the percentage of population with periodontal disease is still quite significant, 20% to 50% (World Health Organization 2022). Thus, creating a product that can act to decrease this population sample becomes quite convenient. It is important that the marketing strategy influences the customers to know that this need exists and that the product will be able to satisfy it.

As part of this process, the pharmaceutical representatives would promote the product (making it known and providing samples of *EcoSmile* to customers of selected pharmacies or dental clinics), choosing promising regions capable of highlighting it (Oporto, Lisbon, and South of Portugal).

Marketing should follow the development of several areas, such as technology innovation and new means of information and communication (Bolico da Silva 2018). Thus, knowing that social networks are one of the most impacting means of communication, it would be interesting to invest in this area. Therefore, information about the product would be accessible to both young people and adults since platforms like Facebook and Instagram are increasingly more diverse and accessible. However, placing ads on open TV channels would be a good idea to add even more reach. To make the whole strategy work, an estimated value of €1,000,000/year would be necessary. This amount includes expenses such as the salaries of the pharmaceutical representatives (ca. €800/month) and ads on Facebook and Instagram (ca. €50,000/month), with the intention to place one ad per day on both platforms (ca. €800/day). Finally, the ads on the TV open channels would be 30 seconds and run twice a day for five years, with the possibility of extending the contract later (ca. €15,000/month). In addition, the VAT of 23% was considered.

Furthermore, a Working Capital of €200,000 would be created to cover potential additional financing needs. However, the use of Working Capital should always be seen as an exceptional situation when one cannot follow the standard procedures to be observed in the acquisition of goods/services (IST 2019). This option could be made in cases such as late payments to be received or anticipated payments (for example, to suppliers); there is a margin to prevent these situations. In the Gantt diagram, Table 7, sales to the pharmacy begin in the first quarter of the second year and then sales to the public start at the beginning of the fourth year. Finally, the retail price of *EcoSmile* would be €8.99, which is very competitive and attractive compared to the products already on the market, which range from roughly €8 to €18.

5.3. Production volume and cost

It was estimated that maximum annual production could be 1,460,000 L; however, due to the Portuguese market, it was considered that the quantity produced during the fourth year was 215,000 L. The production will start at the beginning of the project's second year with a trimestral initial output of 50,000 packages with a growth rate of 20% through the first trimester of the fourth year. Table S2 in the Supporting Information summarises the quantity and price for each 250 mL bottle of mouthwash for each component and their function (Oral Health Foundation, n.d.). The annual cost of reagents will be €1,550,000. The production facilities will be in Felgueiras, Porto, a pavilion suitable for the industry with 1,100 m^2 and a monthly rent of €2,000. Payments will begin in the third trimester of the project when the necessary equipment for production (previously described in Section 4.3. - Manufacturing process) will also be assembled. The cost of each unit is summarised in Table S3 in the Supporting Information. These values were obtained from industrial machinery providers. Considering the cost per kWh being €0.1724, the energy consumption and operation hours of each piece of equipment, it was also possible to calculate the total cost of Energy, which corresponds to €44,094 per trimester. Table S4 of the Supporting Information represents the number of employees by function and their monthly and annual salaries. Financial charges were also considered at a rate of 23.75% (Matias 2018), so the total annual cost payable to employees is €278,586. A working capital of €200,000 in the first quarter was also considered, and a fixed amount for other Services such as Brand Licensing, Accounting and Maintenance of €30,000 per trimester.

5.4. Economic feasibility

The economic viability of the project should be assessed by considering certain economic parameters, such as Cash-Flow, payback period, NET Present Value (NPV) and Internal Rate of Return (IRR). A financial study was carried out, considering the various investments and costs, as well as the income associated with the product sales. Costs related to operation, human resources, investment, financial charges, and services (marketing, brand licensing, accounting, maintenance, etc.) were considered.

Figure 4 represents the evolution of NET and PV Cash-Flows during the first four years. NET present value is a calculation applied to determine the value of a business and NET cash flow is the amount of cash generated or lost over a specific period of time.

As can be seen in the graph in Figure 4, the NPV of Cash Flows has a minimum, which corresponds to the initial investment to be made, i.e., approximately €2,550,000. This value will be obtained through bank credit.

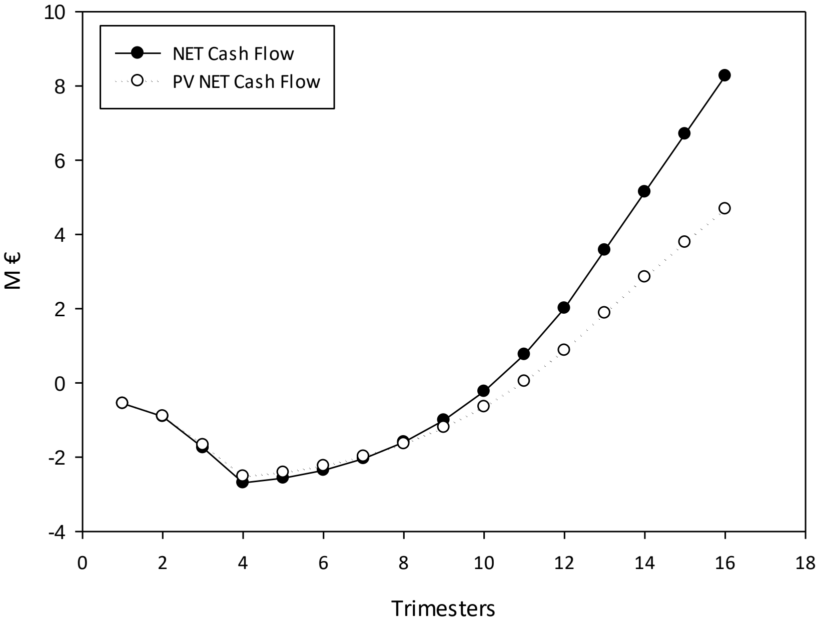

Figure 4: NET Cash Flow and PV NET Cash Flow during the first four years

Table 8 shows the values obtained for the Present Value of Cash Flows and the NPV of Cash Flows for a cost of capital of 15%. Figure 5 shows the accumulated costs and profits over the period of the first four years.

Year	1	2	3	4
NET Cash Flow (M€)	-2.69	-1.59	2.01	8.27
PV NET Cash Flow (M€)	-2.69	-1.74	0.94	4.96

Table 8: NET Cash Flow and PV NET Cash Flow in millions of euros over a period of four years

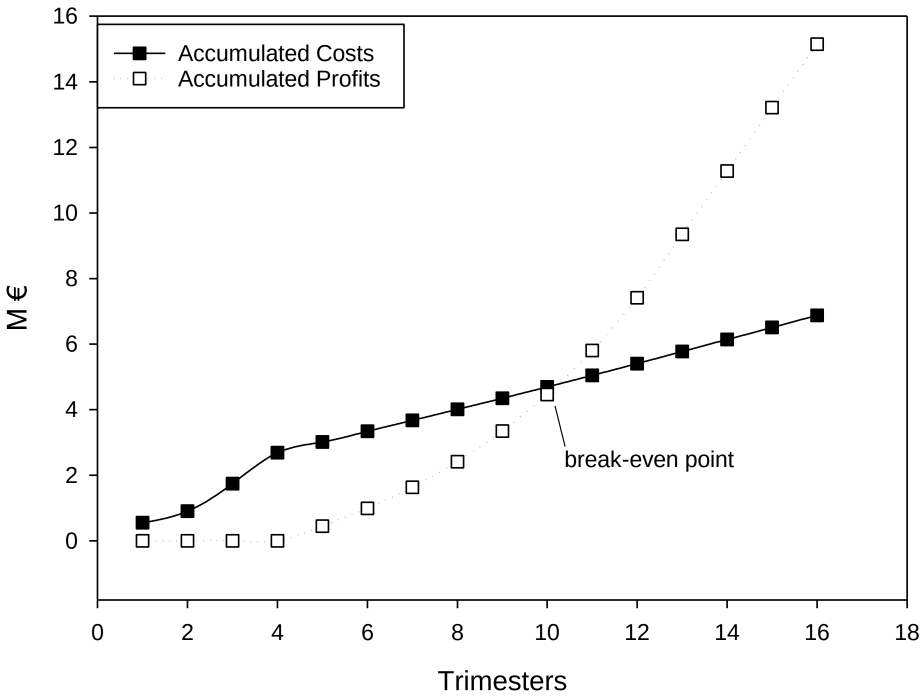

Figure 5: Accumulated costs and profits during the first four years

As can be seen from Figure 5 and Table 8, for a four-year investment analysis, the NPV is €4,960,000, which leads to the conclusion that the project is profitable. The lowest value was obtained at the end of the first year, which would be predictable, as this is a start-up year with many associated costs and no profits since production only starts in the second year. From that point onwards, as sales progress, its value increases. This investment has a payback time of just a little more than ten trimesters, i.e., 2.5 years, represented in Figure 5 as the breakeven point. This point is where accumulated costs equal accumulated profits. The IRR was also determined, obtaining a value of 66%, which is quite high and higher than 15%, allowing the project to be carried out with some financial comfort.

Since all these economic parameters lead to the same conclusion, one can guarantee that the planned investment will be successful and profitable in a relatively short period of time.

6. Conclusions

EcoSmile mouthwash is a product of natural origin for treating periodontal disease based on quercitrin extracted from kiwi branches. Quercitrin has an anti-inflammatory and antioxidant action, protecting and repairing gingival tissues. This mouthwash is a Portuguese product with sustainable production, which makes it stand out from the products already on the market with the same purpose. It was determined that an investment of €2,550,000 would be necessary and that the updated cumulative monetary balance became positive at the end of the tenth trimester of the project. The quantity produced was 215,000 L during the fourth year, which generates a Present Value NET Cash Flow of €4,960,000, considering a selling price of €8.99 per unit of mouthwash. It is possible to conclude that the project is economically viable and capable of generating a financial surplus. Therefore, it is considered that the product presents an added value of investment, as it is innovative, viable and contributes to a circular economy.

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Acknowledgments

This work was developed under the scope of the course unit of Product Engineering of the Master in Chemical Engineering at the Faculty of Engineering of the University of Porto, during the 1st semester of the 2021/2022 academic year. Professor Cláudia Gomes, Doctor Ricardo Santos, and Doctor Yaidelin Manrique, supervisors of this work, are members of the Associate Laboratory LSRE-LCM funded by national funds through LA/P/0045/2020 (ALiCE), UIDB/50020/2020 and UIDP/50020/2020 (LSRE-LCM), funded by national funds through FCT/MCTES (PIDDAC).

Supporting Information

3.1.2. Ideas

Categories	Ideas
Cosmetic	Serum
Health	Toothpaste, mouthwash, allergy spray, slimming pills, food additive
Packaging	Kraft paper Bioplastic for: Food packaging, detergent capsules, coffee capsules

Table S1: Product ideas and their respective categories

The main ideas are further described:

Facial serum

Quercitrin and quinic acid also have an antioxidant effect and can present anti-ageing properties (Tungmunnithum et al. 2018; Hano and Tungmunnithum 2020). Therefore, they could be applied in a facial serum. However, once again, there would be the problem of testing which would be a long and complex process as the answer would not be immediate.

Toothpaste / Mouthwash

Studies show that quercitrin can contribute to the recovery of cell tissues and its antibacterial activity can be a potential treatment for periodontal disease (Gómez-Florit, Monjo, and Ramis 2014). The product idea would be either a toothpaste or a mouthwash. Between these two, the mouthwash would be easier to conceive and also easier for the consumer to use in the treatment of the disease.

Spray with anti-allergenic action

Quercitrin, a precursor of quercetin, is present in kiwi branches and leaves. It has anti-allergenic properties against bronchial asthma responses and allergic rhinitis (Jafarinia et al. 2020; Chen and Ko 2021). The product could be a spray with anti-allergic action, however this idea was excluded because the symptoms are not the same for all allergies, nor does the population react in the same way to the same allergy, so the testing process would be very complicated.

Kraft paper

This product, produced from cellulose, would be advantageous, since it would represent a more sustainable way of producing paper and would allow the use of resources that otherwise might be wasted (Gençer 2015). However, this product would be quite difficult to implement in Portuguese paper industries. This is because these companies are mostly formatted to produce paper from eucalyptus, which implies specific manufacturing processes for this raw material. Thus, in these industries it would not be feasible to produce paper from kiwi branches.

Bioplastic for food packaging

The first idea consisted of creating a bioplastic with cellulose nanocrystals (Luzi et al. 2017). The cellulose has the ability to increase the mechanical strength of the bioplastic and also to make it more resistant to water. The possibility of incorporating rutin in this material was studied. The goal was to create food packaging with antimicrobial properties and with the ability to extend the shelf life of food (Narasagoudr et al. 2020).

5.3. Production volume and cost

Components

Component	Function	Quantity/bottle (%)	Price/bottle (€)
Quercitrin	Active principle	2.0 (Zielinski, Moon, and Allen 2013)	--
Water	Solvent	71.9 (Obtained by mass balance)	0.00032[1]
Ethanol	Solvent/ Antimicrobial	21.6 (Van der Weijden et al. 2015)	0.050
Sorbitol	Sweetener	2.0 (Gonçalves et al. 2001)	0.067
Hydrogen Peroxide	Bleaching agent/ Antimicrobial	1.50 (Hossainian et al. 2011)	0.021
Sodium Benzoate	Preservative	0.30	0.00065
Sodium Saccharin	Humectant /Sweetener	0.20 (Ibsen, Glace, and Pacropis 1998)	0.0024
Chlorhexidine	Antiseptic/Disinfectant	0.12 (Araújo et al. 2012)	0.0060
Eucalyptol	Antimicrobial	0.092 (Araújo et al. 2012)	0.018
Thymol	Antiseptic	0.064 (Araújo et al. 2012)	0.059
Methyl Salicylate	Antimicrobial	0.060 (Araújo et al. 2012)	0.000029
Sodium Fluoride	Antimicrobial	0.050 (Parashar 2015; Poppolo Deus and Ouanounou 2021)	0.000047
Menthol	Flavor agent	0.042 (Araújo et al. 2012)	0.038
Poloxamer 407	Surfactant	0.034 (Oral Health Foundation, n.d.)	0.00079
CL 42090	Blue colorant	0.0012 (Oral Health Foundation, n.d.)	0.00082

Table S2: Quantity and Price of each ingredient, per bottle of *EcoSmile* mouthwash. Values of composition were calculated based on the percentages found on the references mentioned, and the solvent quantity was adjusted by mass balance. Prices were consulted on Alibaba, except where stated.

[1]Águas do Porto, 2021, "Tarifário 2021", https://www.aguasdoporto.pt/files/uploads/cms/adp/35/files/1613490200-klKJOzzEqn.pdf.

Equipment cost

Equipment	Cost (€)	Energy (kWh)
Grinding machine	11,379.55	74.4
Lyophilizer	80,182.00	11.2
Hydrodistiller	23,994.45	4.6
Vibratory Filter	2,704.13	4.4
Membrane Filter	1,113.66	60
Centrifuge (×4)	141,529.12	3,696
Cooling tank (×12)	154,686.36	52.5
Mixing tank	1,677.97	0.2
Packaging and labelling	40,091.45	2.2
Distillery Unit	1,682.06	6.5
Others (pumps, valves, etc)	12,436.84	147.8

Table S3: Cost and Electricity consumption of each equipment.
Prices were consulted on Alibaba.

Grinding machine (A)

This machine will only operate during the first trimester of each year. In the first year of production, approximately 5,162 kg of kiwi branches (1) will be treated per day, which corresponds to an operating time of about 0.52 h.

Lyophilizer (B)

All the residues coming from the grinding machine (2) are lyophilized in this equipment and then vacuum-packed (C). These will be used during the whole year.

Hydrodistiller (D)

The hydrodistiller with a capacity of 5 m^3 needs to process about 9,616 L of water (4) together with 961.5 kg of residues (2) per day, and therefore needs to make 2 cycles of 10 minutes.

Filter

All the mixture coming from the hydrodistiller, i.e., 10,577 kg per day, must be filtered in a vibrating screen (E) to remove all solids (6) at a rate of 8 ton/h, which means an operating time of 1.3 h. The mixture is then further filtered through an ultrafiltration membrane (F) to remove small particles (7) remaining in the extract.

Lyophilizer (B)

The resulting extract (8) is lyophilized and kept in a storage tank (G) before being used in the next step. This procedure allows to obtain a more concentrated extract and thus to obtain better extraction yields (between 101 and 123 mg of extract/g of plant) (Henriques et al. 2017).

Cooling tank (I)

In this equipment, 108 kg of extract (9) is mixed with 10.8 m^3 of water (10’) and 43.1 m^3 of ethanol (11). The mixture remains at a low temperature in a 20 m^3 cooling tank for 15 h, so 3 tanks are needed at this initial production stage. In order not to limit the process, the resulting extract is transferred to storage tanks (J) with a capacity of 30 m^3 and then is fed to the centrifuge according to its capacity.

Centrifuge (K)

Afterwards, it is necessary to separate the extract (15) from the mucilage (14), using a centrifuge. In the initial production stage, 53.8 m^3 of extract has to be processed per day, using 1 centrifuge for approximately 6.8 h. After this step, an extraction yield of about 36.9 μg of phenolic compounds per mg of extract is obtained (Henriques et al. 2017), which is equivalent to 3.97 kg of phenolic compounds per day in this case. This step is crucial to obtain an extract rich in phenolic compounds, as in plant crude extracts their concentration is expected to be low (Henriques et al. 2017).

Mixing tank (L)

After obtaining the desired active principle, the mouthwash production occurs. All ingredients should be mixed, forming a uniform mixture. First, 143 L of previously distilled water (10’) is added. Then 3.97 kg of quercitrin extract (15) is added. Lastly the remaining components are incorporated, 42.9 kg of ethanol (11), 3.97 kg of sorbitol (16), 2.98 L of hydrogen peroxide (17), 0.60 kg of sodium benzoate (18), 0.40 kg of sodium saccharin (19), 0.24 kg of chlorhexidine (20), 0.18 kg of eucalyptol (21), 0.13 kg of thymol (22), 0.099 kg of sodium fluoride (23), 0.08 kg of menthol (24), 0.07 kg of poloxamer 407 (25), 0.0024 kg of CL 42090 (26) and 0.12 of kg methyl salicylate (27).

Packaging and labelling (M)

The packaging and labelling of the vials are done by an automatic machine, which fills about 60 bottles of 250 mL per minute. In the initial phase, it must fill 794 bottles per day, which is equivalent to approximately 14 minutes of operation.

Quality control

The quality of the product is assessed by monitoring the flavour, appearance, odour and viscosity, checking variations in product specification (Hayes, n.d.). Two employees will be responsible for this control, testing and supervising the product resulting from each batch.

Labour costs

	N	Monthly Salary (€/month)	Total Monthly Salary (€/month)	Total Annual Salary (14 months) (€/year)
Operators	5	1,000	5,000	70,000
Supervisor	1	1,200	1,200	16,800
Cleaning	1	750	750	10,500
Quality Control	2	1,200	2,400	33,600
Sales	2	1,115	2,230	31,220
Engineers	3	1,500	4,500	63,000

Table S4: Number of employees (N) and their monthly and annual salary