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Article

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Article

Productivity and Economic Analysis of a New Intensive Collector in the Portuguese Market with Implication of Open Innovation Perspective

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Abstract: Bee venom is a sub-product of the beekeeping activity, and has a wide field of applications in several pivotal markets. Nevertheless, its collection is not an activity disseminated among Portuguese beekeepers, as its production is marginal. There are limited empirical studies on the production and the technical aspects involved in this type of activity. Our study, therefore, contributes to narrowing this knowledge gap, by analyzing and comparing the productivity and profitability of two bee venom collection techniques. The first involves equipment available on the market, and the second involves a new device developed from the aim of the present work. Concerning market knowledge, a questionnaire was given to a sample of beekeepers, to understand and characterize the market's needs and the level of information about bee venom. Because of the growing market interest in this product, a new collector is proposed, based on a set of intensive frame collectors strategically placed inside the beehives. The improvements obtained were increased production, either in terms of quantity or quality, obtaining a positive profitability. To evaluate the productivity of the proposed equipment, a comparison was performed, in an apiary, between existing state-of-the-art equipment and the proposed intensive collector. In a second stage, the profitability of the new proposed equipment was analyzed, using a comparative method between incomes and costs associated with both solutions. The results obtained showed that the new intensive collector enables a profitable collection of bee venom in Portugal, despite its higher initial investment.

Keywords: natural resources; bee venom production; productivity analysis; profitability analysis; product development

1. Introduction

Beekeeping is an activity directly linked to agriculture, since about 45% of world food production depends on pollinators, with a significant impact on national economies. Besides the pollination, this activity has the purpose of exploring various products of interest and commercial value, namely bee venom or apitoxin [1]. Since the poison is produced by honey bees, and as it is composed of several proteins, such as amino acids, lipids, organic acids, and enzymes [2], several applications arise. Because of this richness, apitoxin has been extensively studied and sought over the years, especially after its therapeutic characteristics when used responsibly have been proven. (When used incorrectly it can lead to allergic reactions of different intensities [3,4]). In fact, the target product of this study is

used in the pharmaceutical industry, in the treatment of several diseases [4,5], such as cancer [2,6,7], HIV, multiple sclerosis, arthritis, bursitis, tendonitis, dissolution of scar tissue, herpes zoster, joint diseases and rheumatoid arthritis, Lyme disease, and osteoarthritis [8]. Another field of application is the cosmetics market [9–11].

Although bee venom has several important applications in Portugal, it is almost a non-existent market. The main reason is due to internal policies that did not establish legislation, or take the necessary measures for its development on beekeeping activity over the years [1]. Beekeeping is an ancient activity from which it is possible to collect various products, such as honey, pollen, propolis, royal jelly, and bee venom, but in Portugal, the only product that is significantly explored is honey [1,12,13]. This problem is not exclusive to Portugal; the European Parliament published a technical report [14], asking for a European Parliament Resolution, due to, among other reasons, the lack of data available about this subject, both in terms of quantity and quality.

Based on the above, it can be seen the importance and interest of bee venom's collection, implying the need for an increasing production with more beekeepers dedicated to this practice [15]. This situation represents a challenge/opportunity to promote bee venom collection and develop more productive collector devices, with evidence that a profitable activity can be archived.

With this study, we seek to set up new processes by which new technologies can be adopted by a group of corporations or companies, and how they can be used to create new products or processes. The purpose is to increase the knowledge among all stakeholders and dynamically analyze the economic impacts of adopting new tools for bee venom production under an open innovation perspective [16].

To measure the level of information concerning bee venom among beekeepers, a questionnaire was drawn up and supplied for answering. With these data it was intended to also evaluate the market interest and potential growth. In relation to the collection of bee venom, specific equipment is used, composed of a glass plate overlaid with metal filaments, which are fed by a power unit combined with an electrical pulse system [17]. There are several different pieces of equipment on the market that are used both inside and outside the beehives [18].

For exterior collectors [19,20], which are placed outside the beehive, the number of bees exposed to the collector is greatly reduced, since it only affects the bees that enter and leave the hive, causing the production of small quantities of bee venom. To extract 1g of venom, 10 hives would be required, an hour per day, adequately placed [21]. Another drawback is the fact that the bee venom is exposed to weather conditions and other contaminants, and, when it is raining, this type of equipment cannot be used [22,23].

Collectors placed inside the beehive are used at the base of the nest [19], or as a cover of the beehive [24]. This type of device can collect more than the outside collectors, since it is able to be in contact with a greater number of bees, while maintaining their normal activity. However, the collectors placed in the base are subject to contamination with the waste of the bees. On the other hand, the cover ones, although with a lower risk of contamination, have the limitation that the collector area is restricted by the down face size, because it works as a cover at the top of the beehive [24].

To respond to the identified problems, the present work studies the design of an intensive collector that will take the form of a set of frames, as the usual honey enclosures, to be placed strategically inside the beehive.

The achievements obtained are a larger collection area and a cleaner substance. Consequently, the potential of obtaining a higher yield from this activity is augmented, due to the increase of production and quality (cleanliness) of the collected product.

The paper is organized as follows. Section 2 presents the Portuguese market and in particular the situation regarding bee venom. Section 3 formulates the methodologies used to collect data the market under scrutiny, the necessary information data to characterize the productivity of the two collectors, both placed inside the beehive, in order to perceive the yields that can be generated with each of them. Section 4 presents the results obtained from a questionnaire applied to the beekeeper

community, and from the experimental tests made on both collectors. In Section 5 the productivity and profitability analysis is presented, and, the results obtained from the different collectors are discussed in Section 6. To end, Section 7 presents the final conclusions, and future actions, to improve market penetration of the proposed equipment.

2. Portuguese Market Case

The beekeeping sector, in Portugal, is mostly made up of small beekeepers and is directly related to agriculture. The agents of this sector use it, mainly, as a complement of income of the farms, or for self-consumption. It is an activity that is responsible for pollination of agricultural crops, contributing to a significant increase in the yield of farms and, also, for the preservation of biodiversity [1,12,13]. There are more products that can be explored in beekeeping in addition to honey, such as pollen, propolis, royal jelly, and bee venom. Due to the fact that the beekeeping labor force is not specialized, with few resources, scarce management practice, and little technical knowledge in the area, it is an underdeveloped activity [1,15].

All beekeeping products, except honey, are unknown to the common consumer, due to the lack of available information about them, and due to the lack of strategies for dissemination and commercialization by the entities regulating this sector. In 2015 there were around 11,000 registered beekeepers in Portugal, who had approximately 33,000 apiaries and 626,000 hives, as presented in Table 1 [1].

Table 1. Generic Characterization of Beekeeping Activity in Portugal.

	2013	2015	Variation (no. and Percentage)	
no. of beekeepers	16,774	10,698	−6,076	−36%
no. of apiaries	40,176	33,876	−6,300	−19%
no. of hives	566,793	626,399	59,606	10%
Apiaries/beekeeper	2	3		
Hives/beekeeper	34	59		

Concerning bee venom, there is no national legislation for its production or marketing, unlike honey. The market is almost non-existent, although consumers would be industries [2,4,9,10] that use molecules present in this substance for the treatment of various diseases, or for cosmetic purposes. The market value of this product was more than 23,000 Euros/kg in 2009 [1], but the collectors present in the Portuguese market have a very low yield and the index of contamination is quite high. The main reason is the fact that external equipment is the main device used for this collection [23]. The inside collector types are not used in Portugal, because those devices are manufactured with materials that do not meet the minimum legal Portuguese requirements, for products related to human consumption.

3. Methodology

To validate the interest in the proposed equipment, three main pieces of information need to be collected, and will be addressed in the Methodology Section. First, a characterization of potential users and its dimension is addressed. Secondly, the design of an intensive bee venom collector is implemented and tested, with the purpose of validating the increase of productivity and quality, relatively to actual state-of-the-art equipment available on the market. Thirdly, the financial outcome of the new collector is analyzed, in order to evaluate its potential interest for beekeepers.

3.1. Source of Data

To determine if there are Portuguese beekeepers interested in this type of exploration, a preliminary questionnaire (see Appendix A), was elaborated for a confidence interval of 99% and

a sample error of 10%, obtaining a sample of 164 beekeepers to be interviewed. Since it is a national analysis, the sample was stratified using the expression (1):

$$n = \frac{N \cdot Z^2 \cdot p \cdot (1 - p)}{Z^2 \cdot p \cdot (1 - p) + e^2 \cdot (N - 1)} \tag{1}$$

where n is the calculated sample, N the total population, Z the standardized normal variable associated with the confidence interval, p the true event probability and e the sampling error.

According to the sample of beekeepers in Portugal mentioned in Table 1, it is necessary to gather data on how they are distributed geographically along the country. The only reliable information found concerns “The National Beekeeping Program 2017–2019”, responsibility of the Portuguese Government, and, as can be seen in Table 2, the majority of them are in the north and center of the country. This situation is mainly due to its relationship with agriculture, since those regions are the main areas of crops related to the pollination process [1]. To take a representative sample from the questionnaire, we need to know how many beekeepers are needed by region, so results were merged, and are also presented in Table 2.

Table 2. Absolute Value of the Sample for a 99% confidence Interval and a sampling error of 10%.

Region	Absolute Value	% of Region	Absolute Sample Value
North	3,657	34%	56
Center	3,549	33%	54
Lisbon and Tagus Valley	910	9%	15
Alentejo	1,214	11%	18
Algarve	837	8%	13
Autonomous Region of Madeira	346	3%	5
Autonomous Region of Azores	185	2%	3
		Total	164

The design of the new proposed bee venom collector implements several novel features in comparison with state-of-the-art equipment [25]. The main novelty is the placement of the collector in a vertical position, taking in consideration that the viscosity of the bee venom will prevent it sliding down the glass. Consequently, the new collector will have electrical filaments in both sides of the glass, immediately duplicating the contact area. A power control unit, battery powered, will generate the electrical pulses and control the current flow to keep the bees healthy (Figure 1). Power control parameterization has been the subject of several studies [17,26,27]. In terms of voltage, frequency and current limit, the proposed equipment considered the optimal values from the work of Maulana et al. [28].

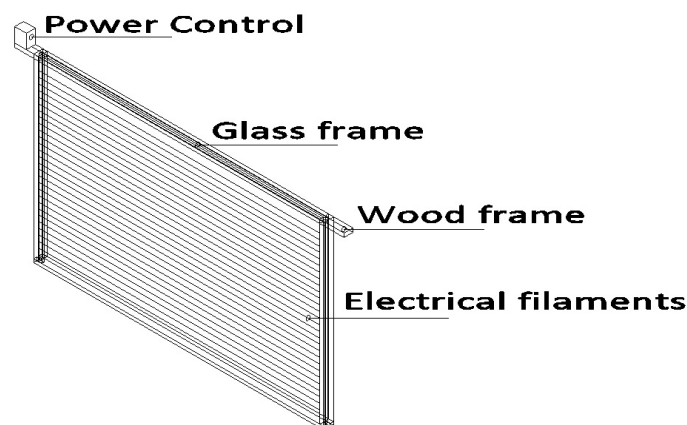


Figure 1. Individual Frame with Two Contact Sides.

On a second stage, 10 frames with glass plates are placed inside the hive (Figure 2) in a box similar to honey frames collector boxes.

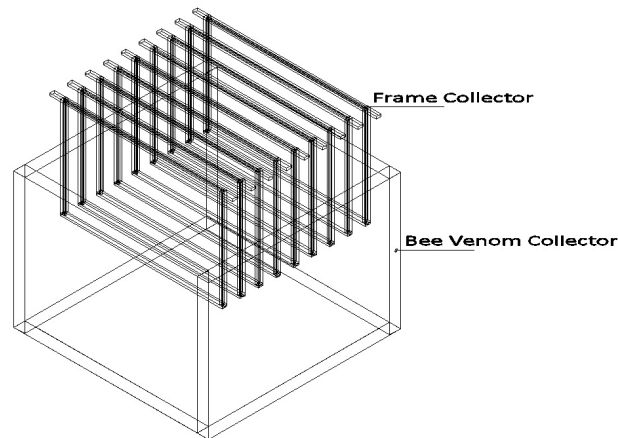


Figure 2. Collector with 10 Internal Frames.

Finally, the collector is placed inside, on the top of the beehive, to collect venom from a larger number of bees, and preventing the product from being contaminated by outside agents. The clipboard and the cover of the hive are placed over it, as shown in Figure 3.

To build this prototype, an investment of 593 Euros was made. The collector has 10 frames with a unitary contact area of $24\text{ cm} \times 33\text{ cm}$ by side, providing a contact area of 792 cm^2 , which means that each frame provides 1584 cm^2 in both sides, and the global collector $15,840\text{ cm}^2$. Filaments are separated by a distance of 3.5 mm , being powered by two AA batteries. To compare the results obtained with this collector, a state-of-the-art collector was acquired from Multi-Sweet (Group) Co. Limited, at cost of 263 Euros. The collector has measurements of $33\text{ cm} \times 33\text{ cm}$, providing a total contact area of 1089 cm^2 and filaments are separated by a distance of 3.5 mm , being powered by a lithium battery. This collector was used in a similar hive to the one used with the new collector. In this way, we tried to provide similar conditions of operation to both collectors, in order to analyze properly the results obtained. The equipment was tested during the spring (May and June), in the morning, at 8AM, for a 1 h period daily. Every three days, a three-day stop was made, to lower stress in the beehives, since the venom was collected for a total of 16 days per month.

The productivity analysis was made by comparing the quantity obtained in each collector, and a qualitative analysis regarded the quality of bee venom. The data used for the financial analysis were the market prices of bee venom and the usual costs among beekeepers: labor, tools, wear, and cleaning products. Concerning the investment by collectors, the state of the art was bought on the international market and the new one was the sum of components bought plus the labor costs involved.

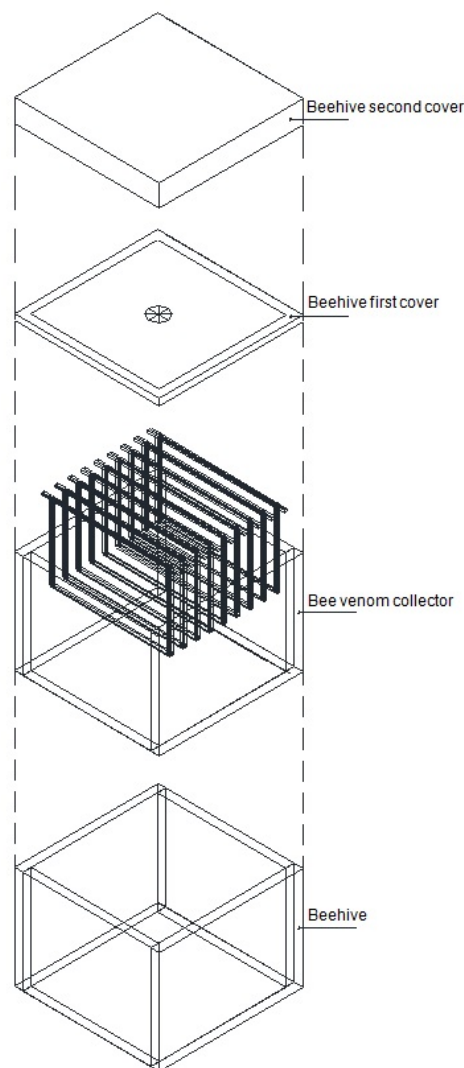


Figure 3. Intensive Collector Application.

3.2. Data Analysis

The questionnaire regarding beekeeper characterization was provided in Portuguese, from 2 November 2018 to 17 February 2019, in all social network groups of beekeepers and in all beekeeper associations in Portugal, including the islands (25 associations and the National Federation of Beekeepers of Portugal). Although only 164 would be necessary to satisfy the sample value for a 99% confidence interval and a sampling error of 10% (Table 2), all valid answers were considered in the present work.

Accordingly, with the questionnaire, the data was organized to highlight the weight (as a percentage) of the different classes of beekeepers, number of hives and their information and interest on bee venom. The trustworthiness of the data on beekeepers was controlled by comparing their self-classification with the number of hives reported. The experiment with both collectors consisted of the daily collection of bee venom, adequate packing, and sending to a certificated laboratory to measure the quantity and control the quality. This information was registered systematically to enable the discussion of results. To evaluate the financial interest of the new collector, a Comparative Income Statement (CIS), traditionally known as trading and profit and loss, was performed. Compared with other similar approaches, e.g., the Pyramid Method, mostly based on trend analysis CIS, allows the study and obtaining of a global scenario of the overall profitability of the business, observing its

periodic performance evaluation. The main disadvantages are the fact that it ignores inflationary impacts and has high dependability on financial information, which in the present case has a minor effect. Therefore, a comparison was made between several variables applied to both collectors used in the experiment: investments, operational costs, incomes, profits, and cash flows inherent to each solution. The operational cost included tools and utensils for fast wear, cleaning, hygiene, and comfort, and labor and amortizations. After gathering these data, some analyses were made: Net Present Value (NPV), the difference between the present value of cash inflows and the present value of cash outflows over a period of time; Internal Rate of Return (IRR), metric used to estimate the profitability of potential investments, a discount rate that makes the net present value of all cash flows from a particular project equal to zero; and the Payback Period, which refers to the amount of time it takes to recover the cost of an investment.

4. Experimental Results

4.1. Beekeeper Characterization

A total of 207 valid answers were collected from all the channels used for the questionnaire dissemination, validating the statistical assumption. Despite its global validity, since question 1.2 (see Appendix A) addressed the region of activity of the beekeeper, the sampling methodology was also validated by region, where the obtained results are presented in Table 3 and in Figure 4.

Table 3. Percentages by Region of collected answers.

Region	Predicted Answers	Collected Answers	Obtained Confidence Level	Obtained Error
North	34%	22%	95%	10%
Center	33%	34%	99%	10%
Lisbon and Tagus Valley	9%	9%	99%	10%
Alentejo	11%	27%	99%	6%
Algarve	8%	5%	95%	10%
Autonomous Region of Madeira	3%	1%	90%	10%
Autonomous Region of Azores	2%	2%	99%	10%

As can be verified by the analysis of Table 3, the total expected answers were obtained to satisfy the assumed statistical values; when scrutinized by region, some differences can be found. The error of the sampling of the population was achieved, and even decreased for *Alentejo* region. Regarding the confidence interval, due to the lack of expected answers in some regions, some values decreased, while remaining within the usual and acceptable values in the context of our work.

Considering all valid answers obtained, the first interpretation is the fact that the type of beekeeping practiced, by the universe of obtained answers, is mostly a hobby activity (Table 4).

To understand the reason that leads to 70% of beekeepers performing it as a hobby activity, their size was evaluated as an indicator of their individual production. The question under scrutiny was the number of hives a producer has. Obtained results show that most of them have very few hives (72% have less than 101 hives), as shown in Table 4. It was also questioned if beekeepers collected bee venom, to which only 3% answered affirmatively, as shown in Table 4. From here, the first observation points to bee venom production not being an activity considered among beekeepers.

Also, Table 4 shows that 97% of those surveyed did not collect bee venom; this value is too high, so it was pertinent to pursuit the motivations that led them not to do so. From the proposed questionnaire it was verified that 44% do not know the processes to perform this type of activity, or even do not know what bee venom is. With the bee venom market at a very embryonic stage in Portugal, beekeepers were asked about their interest in exploiting it, to which 65% answered affirmatively as shown in Table 4. As there are several segments of beekeepers, as shown in Table 4, we identified which segments would be most interested in collecting bee venom. Once there is a significant interest

in bee venom collection detected through the questionnaire, and considering the market size evaluated, an intensive collector prototype was developed. The purpose of such development and investment was to test if it was possible to collect bee venom in a more economical way and, consequently, with a higher yield. In order to validate the results obtained from the production of the new intensive collector, a comparison was made with a state-of-the-art collector, placed as cover inside the beehive.

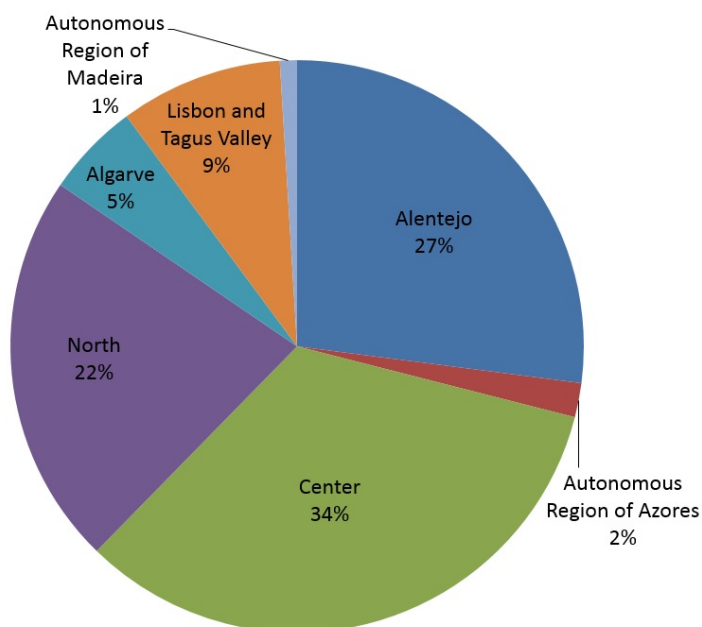


Figure 4. Percentages by Region of collected answers.

Table 4. Data collected from the applied questionnaire.

Variable	Category	Frequency	Percentage
Type of bee practiced	Hobby	145	70%
	Professional	62	30%
Size of bee venom production	1–10 beehives	60	29%
	11–25 beehives	33	16%
	26–50 beehives	25	12%
	51–100 beehives	31	15%
	101–200 beehives	23	11%
	201–500 beehives	24	12%
	More than 500 beehives	11	5%
Collection of bee venom	Yes	7	3%
	No	200	97%
Reasons for not collecting bee venom	You do not know the techniques to do it	82	40%
	it is a complicated process	18	9%
	I’m not interested in this practice	37	18%
	It requires a lot of time	27	13%
	Collectors in the market have very high prices	32	16%
	Do not know what apitoxin is	7	4%
Interest in collecting bee venom	Yes	134	65%
	No	73	35%
Interest in collecting bee venom in different segments of beekeepers	1–10 beehives	37	27%
	11–25 beehives	22	16%
	26–50 beehives	19	14%
	51–100 beehives	18	13%
	101–200 beehives	17	12%
	201–500 beehives	16	12%
	More than 500 beehives	8	6%

4.2. State-of-the-Art Bee Venom Collector

After a month using the equipment in the field, as described above, always in the same beehive, 272 mg of bee venom was collected. Every day, the bee venom was dried, and removed from the glass plates, with the help of an appropriate spatula to remove it, always using the necessary protective equipment to avoid contamination and direct contact with the skin (Figure 5a).

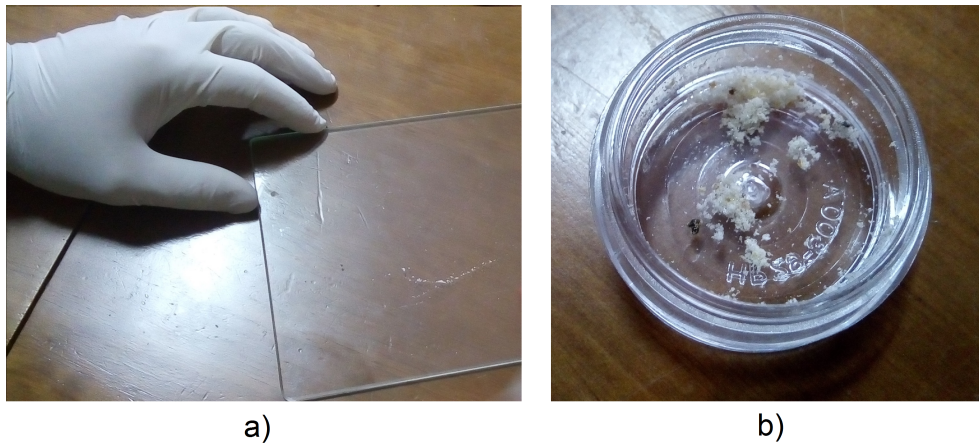


Figure 5. (a) Bee Venom Removal (b) Bee Venom Collected (intermediate container).

After being collected and placed in an intermediate container, the substance was packaged in an opaque container, and placed in a dry environment away from sunlight, until measured and controlled in quality by a certificated laboratory (Figure 5b).

4.3. Intensive Bee Venom Collector

The new device developed and described in Section 3.2 was subject to the exact same testing conditions, with a prototype being assembled to perform the field experiments, representing an investment of 593 Euros. The collector has 10 frames with a unitary contact area of 24 cm × 33 cm by side, providing a contact area of 792 cm², which means that each frame provides 1,584 cm² in both sides, and the global collector 15,840 cm². Filaments are also separated by a distance of 3.5 mm, being powered by two AA batteries. The same procedure was used with the intensive collector, but with a different positioning regarding the beehive. The collector was placed over the hive and it was covered (Figure 3). In the same period of time, 4,266 mg of bee venom was collected. Figure 6 shows the extraction of one frame from the beehive.



Figure 6. Equipment Application in Real Environment.

As previously, the bee venom was dried, and removed from the glass plates. It was observed that the bee venom collected had fewer contaminating particles, and it was spread for all over the glass plates. After the substance was collected it was packaged in a clean opaque container for further weight measurement and quality control.

5. Productivity and Profitability Analysis

In the present section, some analyses are performed to determine the project’s feasibility.

5.1. Data Preparation and Productivity Analysis

Our starting point was to compare the conditions and results obtained with the two collectors under study, as can be seen in Table 5.

Table 5. Conditions and Results Obtained.

Items	State-of-the-Art Collector	Intensive Collector	Difference
Production			
Area (cm ²)	1089	15,840	14,751
Production (mg)	272	4266	3994
Price of collectors (Euros)	263	593	330
Productivity (mg/cm ²)	0.24977	0.26932	0.01955
Annual production (mg)	3264	51,192	47,928
Working operating times			
Operating minutes/collector	3	30	27
Operating minutes/month	48	480	432
Operating days/month	0.11	1.07	0.96
Amortizations (constant quotas)			
Year of lifespan	8	8	
Yearly amortization	32.88	74.13	41.25

It is important to note that the price of the intensive collector is based on the amount spent to make a prototype, which means that under large production scales it is possible to lower its price. Under a qualitative perspective, it was noted that the bee venom collected with the intensive collector had less contamination all along the experiments period, which means that can achieve better market prices. Accordingly to these data, it can be verified that the increase in production is similar to the increase in collecting area, with some advantage for the increase in production (15.68 times) times more production versus 14.55 times more collecting area). This means the productivity is higher with the intensive collector, as presented in Table 5.

The increase in production also represented a strong increase in absolute quantity, and the major achievement is the fact that the increase in the amount of investment needed to achieve these results is much lower comparatively—only 2.26 times—which is a much lower increase in comparison to the one of production.

To analyze the profitability, the results obtained were extrapolated for an annual period, as presented in Table 5.

Because the state-of-the-art collector has only one piece to be operated, while with the intensive collector has 10 pieces or more (10 collecting frames and the beehive first cover, which is the collector in the first solution), the working operating times are higher in the new collector. This consequence is as presented in Table 5, were 16 collecting days per month are considered.

The amortizations of both collectors are presented also in Table 5.

To analyze the viability of both collectors, the general assumptions in the context of Portuguese beekeeping activity are presented in Table 6, considering also that the monetary unit is the Euro. The usual parameters to perform quantitative analyses were considered, namely inflation (2%), the

purchase price of bee venom (23 €/g), the number of working hours (7.5 h), the human resources cost (34 €/day), among several other indicators.

Table 6. General Assumptions.

General Assumptions	
Constant annual Inflation (%)	2
Price of Bee Venom (Euros/g)	23
Working hours/day	7.5
Labor daily cost (Euros)	34
Taxes on Labor Costs	24.75%
Taxes on Profits	25%
Interest rate of risk-free assets—Rf	1%
Market risk premium—(Rm-Rf) or p ^o	1.33%

5.2. Profitability Analysis

Starting with the state-of-the-art collector analysis in Table 7, sales, costs, and profitability are presented with the help of the information presented previously.

Table 7. State-of-the-art Collector.

Years	Year 1	Year 2	Year 3	Year 4	Year 5
Rate of change of prices		2.00%	2.00%	2.00%	2.00%
Sales (Euros)					
Quantities Sold (g)	3.264	3.264	3.264	3.264	3.264
Unit Price (Euros)	23.00	23.46	23.93	24.41	24.90
Total sales	75	77	78	80	81
Costs (Euros)					
Tools and utensils for fast wear	3	3	4	4	4
Cleaning, hygiene and comfort	6	6	6	7	7
Labor	65	67	68	69	70
Costs (except amortizations)	74	76	77	80	81
Amortizations	33	33	33	33	33
Total costs	107	109	110	113	114
EBITDA ¹	1	1	0	0	0
EBIT (Earnings Before Interest and Taxes)	−32	−32	−33	−33	−33
Tax over the period's income	0	0	0	0	0
Net Income for The Period	−32	−32	−33	−33	−33
Operating Cash Flow	1	1	0	0	0
Fixed Assets' Investments	263				
Free Cash Flow	−262	1	0	0	0
Accumulated Cash Flow	−262	−261	−261	−261	−261

¹ Income before depreciation.

Accordingly to the data presented in Table 7, the profitability is marginal and does not have the capacity to recover the investment on the collector, or only in a very marginal way (2 Euros), and the cash flow reflects this consideration.

The IRR (Internal Rate of Return) is negative, where a value of −94% was obtained, in accordance with the calculated NVP, as shown in Table 8. Due to the low production of the collector under analysis, the total sales income does not cover the necessary initial investment. Basically, the sum of post-investment cash flows is less than the initial investment, and the investment loses money at the rate of the negative IRR.

Table 8. State-of-the-art Collector's Indicators (Euros).

NPV (Euros)	−211
Payback Period (Years)	-
IRR (%)	−94

The intensive collector analysis starts with Table 9, where sales, costs, and profitability are presented with the help of the information presented previously.

Table 9. Intensive Collector.

Years	Year 1	Year 2	Year 3	Year 4	Year 5
Rate of change of prices		2.00%	2.00%	2.00%	2.00%
Sales (Euros)					
Quantities Sold (g)	51.192	51.192	51.192	51.192	51.192
Unit Price (Euros)	23.00	23.46	23.93	24.41	24.90
Total sales	1177	1201	1225	1249	1274
Costs (Euros)					
Tools and utensils for fast wear	54	56	58	59	61
Cleaning, hygiene and comfort	24	25	25	26	27
Labor	635	648	661	674	688
Costs (except amortizations)	713	729	744	759	776
Amortizations	74	74	74	74	74
Total costs	787	803	818	833	850
EBITDA ¹	464	472	481	490	498
EBIT	390	398	407	416	424
Tax over the period's income	97	100	102	104	106
Net Income for The Period	293	298	305	312	318
Operating Cash Flow	367	372	379	386	392
Fixed Assets' Investments	593				
Free Cash Flow	−226	372	379	386	392
Accumulated Cash Flow	−226	146	525	911	1303

¹ Income before depreciation.

Accordingly, with these data presented in Table 9 the profitability is positive, including under a tax perspective, with a strong capacity to generate cash flow.

The NPV is positive, the payback period is very fast (less than 2 years), and the IRR is positive too. These values are presented in Table 10.

Table 10. Intensive Collector's Indicators (Euros).

NPV (Euros)	568
Payback Period (Years)	1.61
IRR (%)	163

6. Discussion

According to the results obtained from the questionnaire, it is clear that bee venom collection is marginal in Portugal and many beekeepers do not even know of its existence as a commercial product, despite its commercial value and interest in the pharmaceutical and cosmetic markets. In Table 11 we compare some data obtained from the productivity and profitability analysis made previously.

Table 11. Compared Results.

	State-of-the-Art Collector	Intensive Collector
Annual quantities (g)	3.264	51.192
Sales (5 years, Euros)	391	6126
Costs (5 years, Euros)	553	4090
Accumulated Cash Flow (Euros)	−261	1303
NPV (Euros)	−211	568
Payback Period (years)	-	1.61
IRR (%)	−94	163

As can be seen, one situation is potentially profitable—the intensive collector—and the other is not, in the Portuguese context, because, mostly, of the labor costs involved together with the low production obtained. Due to the low production of the collector under analysis, the total sales income does not cover the necessary initial investment, only the operational costs. Basically, the sum of post-investment cash flow is less than the initial investment, and the investment loses money at the rate of the negative IRR.

It is important to note that the price of the intensive collector is based on the amount spent to make a prototype, which means that under large production scales it is possible to lower its price. Under a qualitative perspective it was noted that the bee venom collected with the intensive collector had less contamination all along the experimental period, which means that can achieve better market prices.

As previously mentioned, there is a 65% interest from the beekeepers surveyed; extrapolating to the universe of beekeepers in Portugal, this interest corresponds to 6,954 beekeepers who hold around 407,159 hives. With the intensive collector it is possible to collect annually, from a beehive, 51.192 g, which corresponds to an annual commercial value of 1177 Euros/beehive. With 407,159 beehives it is possible to collect approximately 20,843 kg/year, which corresponds to a commercial value of 479,396 Euros. This extra annual income that can be withdrawn from the hive can represent an interesting increase in income for beekeepers, to add to the incomes derived from the other products, namely the honey.

Accordingly, with these considerations, we consider it is worth it to further develop/refine our first prototype, to increase the yields obtained and to design the frames in order to enable their efficient mass production. The purpose would making it possible to lower the initial investment on their purchase. As we can verify, there is a market ready to be developed.

7. Conclusions

The purpose of this work was related to the market of bee venom in Portugal, its expression and the productivity and profitability analysis of a new intensive bee venom collector. After analyzing the data available, it was realized that bee venom is a very important substance and has great value in the global pharmaceutical and cosmetic markets. However, in Portugal the bee venom sector is quite not explored, although there is interest in Portuguese beekeepers pursuing to this practice, according to data obtained in the questionnaire, which corresponds to 65% of the answers. Since there is a significant interest in bee venom collection and considering the market size evaluated, an intensive collector prototype was developed. The purpose of such development and investment was to test if it was possible to collect bee venom in a more economical way in the Portuguese context.

To validate the results obtained from the production of a new intensive collector, a comparison was made with a state-of-the-art collector, placed as cover inside the beehive. Through the experimental test, it could be verified that, effectively, bee venom was cleaner, and productivity is higher with the new collector. Although the cost of the equipment is higher too, it is possible to achieve return on investment in a short time, and get a better income in the beekeeping activity, which amount will depend on size and operation efficiency.

The results obtained showed also that the state-of-the-art collector was not profitable in the Portuguese context, because of the conjunction of lower production with high labor costs, meaning a difficult situation among advanced economies, where labor costs are usually higher. That is why we think intensive equipment is important in the context of advanced economies with higher labor costs. On the other hand, the economic risks are usually lower when we deal with relevant quantities, and the opposite when they are marginal, as is the case of the state-of-the-art collector.

Due to the lack of knowledge among beekeepers, the need for commercial and technical workshops to disseminate the activity to potential users should also be considered as future work. It is emphasized that the proposed product is not protected by intellectual property, which means that any association or trader is free to develop the mass production and marketing of the product.

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Appendix A. Questionnaire—Technology in Beekeeping

Dear Sir / Madam,

We thank you for 7 min of your willingness time to answer to a simple questionnaire related to beekeeping activity, and your opinion on a new technology under study.

The answers will be completely anonymous and your collaboration is essential, to contribute on the development of a technology that can best satisfy this sector of activity.

1. General data

1.1. Are you a beekeeper?

Yes	<input type="checkbox"/>
No	<input type="checkbox"/>

(Finish questionnaire)

1.2. In what region are you located?

North	<input type="checkbox"/>
Center	<input type="checkbox"/>
Lisbon and Tagus Valley	<input type="checkbox"/>
Alentejo	<input type="checkbox"/>
Algarve	<input type="checkbox"/>
Autonomous Region of the Azores	<input type="checkbox"/>

1.3. What kind of beekeeping do you practice?

Hobby	<input type="checkbox"/>
Professional	<input type="checkbox"/>

1.4. How many hives do you have?

Between 1 and 10	
Between 11 and 25	
Between 26 and 50	
Between 51 and 100	
Between 101 and 200	
Between 201 and 500	
More than 500	

1.5. What products do you get from your beekeeping activity?

Honey	
Pollen	
Propolis	
Beeswax	
Bee venom	
Royal jelly	

2. Bee venom

Bee venom is the poison produced by bees, increasingly used in the treatment of various diseases, such as cancer, AIDS, Parkinson’s, multiple sclerosis, among others. Bee venom is composed of several substances capable of damaging the viruses responsible for causing the diseases mentioned. It gives its importance in the current market.

Although it is a substance that is not often produced or marketed in the Portuguese market, it is the one that has the highest market value in relation to all other products that can be obtained from bee farms.

2.1. Do you collect bee venom on your farm?

Yes		(Go to 3.)
No		

2.1.1. Why?

You do not know the techniques to do it		(Finish questionnaire)
It’s a complicated process		
I’m not interested in this practice		
It requires a lot of time		
Collectors in the market have very high prices		
Do not know what bee venom is		

2.2. Would you be interested in exploring the bee venom market?

Yes	
No	(Finish questionnaire)

3. Bee Venom Collectors

Collector A	Collector B
Image 1	Image 2

3.1. Are you familiar with the collectors that appear in the image?

Yes	<input type="checkbox"/>
No	<input type="checkbox"/>

3.2. Do you use this equipment to collect bee venom?

Yes	<input type="checkbox"/>
No	<input type="checkbox"/>

3.3. Do you use other equipment to collect bee venom?

Yes	<input type="checkbox"/>
No	<input type="checkbox"/>

3.4. How many milligrams of bee venom do you usually get per hive on your farm?

<100 mg	<input type="checkbox"/>
100 mg	<input type="checkbox"/>
>100 mg	<input type="checkbox"/>
I do not collect bee venom	<input type="checkbox"/>

4. New Technology in Study

Equipment for the collection of bee venom is under study that, compared to the current equipment, has a yield approximately 5 times higher.

We now ask for your opinion on the purchase of this equipment.

4.1. Would you be willing to buy this higher-yielding equipment to collect bee venom?

Yes	<input type="checkbox"/>
No	<input type="checkbox"/>

(Finish questionnaire)

4.2. What price would you be willing to pay for this equipment?

	Would buy	Weights Buy	Would not buy
Less than 400 euros	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Between 400 and 500 euros	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Between 501 and 600 euros	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
More than 600 euros	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Thanks for your collaboration!

If you would like more information on this topic, please leave us your contact.

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