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# R&D Collaboration, Competitiveness Development, and Open Innovation in R&D

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**Abstract:** The competitiveness of the agro-industrial sector depends not only on its specific performance but also on the character and degree of the innovation performance, vital to added value development and differentiation in the biobased value-chain. This work intends to show, how through research and development (R&D), collaboration is possible to improve agri-food companies' competitiveness, helping them to integrate biotechnology and offer innovative products. The method used to support the R&D collaboration model developed involves a diagnosis of biotechnological tools use, for developing appropriate solutions from food safety to food quality, improving health, and achieving new ingredients and/or food products within an agri-food Association partners survey results were integrated into the study of R&D collaboration practice. Results show that the companies (wine culture, fruticulture, and olive culture subsectors) inquired do not develop biotechnology research. They were all micro-business with a low volume of commercial billing, and only 27.3% claimed to have developed research activities in partnership with external research centres, but were not associated with higher education institutions. The barriers to the implementation of biotechnology techniques considered more relevant by respondents were access to capital and specialized human resources, which led to reinforcing the R&D collaboration strategy design.

**Keywords:** innovation; biotechnology; agri-food sector; R&D collaboration

## 1. Introduction

For the last 100 years, technological change has been a major factor in shaping agriculture [1]. Agriculture has been significantly affected by new ways to perform tasks, new products, and new procedures. These new elements of technological and institutional change are fundamental to increase production, improve quality, and introduce new products.

On forecasts of world population growth [2], there is a challenge of designing sophisticated and efficient methods to expand the production of food and renewable energy without diminishing natural resources. The establishment of sustainable agriculture that preserves the environment and provides food security is a primary factor of human development against climate change and the decrease of non-renewable energy resources. In fact, and as recently reviewed by Pelai et al. [3], the primary benefit of biotechnologies identified in the agriculture literature is food security.

With the discovery of recombinant DNA technology, the emergence of modern biotechnology in the 70s has resulted in a radical change in the technological and organizational pattern of all the sectors that directly or indirectly are connected to the "life sciences". Agriculture—and the entire production chain of agribusiness—is among these sectors that have been suffering from the discovery

of this new technology [4]. Biotechnology comprises numerous different research technologies or methods, and different sectors or fields of application [5].

Biotechnology finds application in the agricultural and food sector, mostly in five main levels [6]:

- The genetic modification of crops to increase the income of the agricultural industry;
- The genetic modification of crops to increase efficiency in the processing of nutrients and the manufacture of food;
- The application of enzymes and micro-organisms to food manufacturing processes;
- In the introduction of new features into final products;
- In analytical and diagnostic tools.

In the last few decades, biotechnology applied to agriculture has been mainly oriented towards the improvement of the income of holdings of agricultural products intended for the food sector; in the future, it is expected that higher growth is found to rise to a level of appreciation of the characteristics of the foods and the use of agricultural products in place of fossil raw materials in the production of energy and of polymers.

Especially in the EU (European Union), where public opinion is unreceptive to the use of biotechnology in the food industry, there is some controversy and some substantial barriers are expected to its expansion [6].

In recent years, the biotechnology sector in Portugal has experienced an essential and significant increase in the number of companies created, with currently more than 40 in Portugal, most of them created between 2001 and 2006 [7,8], and about half of them claim to have activity in the field of food. Specifically, in the food sector, companies aim to develop products or improve processes on a technological basis. However, start-up companies obtain most of the invoices with the provision of other services not directly related to biotechnology, while carrying out the research and development (R&D) or await the arrival of funding to start the work. On the demand side of traditional food sector companies in Portugal, there is a growing interest, but there are few partnerships in this regard. Some biotech companies in this sector established business relationships and product and process development with national food industries [6].

In recent years, European regions are experiencing industrial restructuring, provoking a shift from traditional manufacturing towards more modern and complex industries, like information, computing, and technology (ICT), biotechnology, and Big Pharma [9,10]. The need to achieve competitiveness through innovation created from incorporating knowledge and new ideas converted into economic activities will be the “front end of innovation” [11] (p. 671). This increased knowledge endowment, in turn, improves the entrepreneurial activity profitability by enabling recognition and engagement in new business opportunities [12–15].

In the highly competitive global market, the ability to innovate is a determinant for enterprises' success, which certainly depends on the qualification of the human resources but also of the establishment of strategic partnerships with higher education institutions (HEI) and R&D centres. The agri-food sector based on community and national policies and regulations should bet on the improvement of competitiveness through the promotion of technology transfer, modernization, innovation, and quality throughout the food chain. The agri-food industry, nowadays, in industrialized societies, started to renew the concept of the role of agriculture, assuming a new paradigm focusing on the sustainable use of natural resources, the creation of public goods, equity in access to quality foods, increasingly in delivering compelling value to society [16]. Traditions and cultural values, for example, assume a decisive role in the resource potential for the generation of value, if appropriately used by entrepreneurs. According to this model, knowledge, and development in agriculture also become a more complex and systemic concept breaking with the model of linear relations between stakeholders [17,18]. In this sense, the business has become increasingly sensitive to the opportunities for innovation, not only related to changes in technology but also related to the strategy, marketing, organization, and management [18]. Generally, the adoption of agricultural biotech innovation imposes

relationship-specific investments that exacerbate hold-up costs between biotech producers and farmers and research centres that facilitate the biotech innovation internalization. Many new actors now have a decisive role in the mechanisms of adoption of innovation [18]. This discussion might occur due to the research indicators, such as patents and technological innovation, which only count partially to measure the process properly [19] since the analyses must be restricted to patent-intensive sectors. The growth of firms is intensively related to knowledge and innovative basis and to the ability to combine different types of knowledge (for example when mixing science and technology-driven innovations with innovations based on learning through doing, using, and interacting), despite the limitation beside a particular point of investment [19,20]. Also, there is some discussion in the literature around the interaction of public policy and strategic R&D decision-making by business managers. Firms do act, and react, within a political environment and in the case of biotechnology, a highly politicized environment, but there is a range of perspectives offered which might promote the incorporation of these concerns [21].

In Portugal, as in Europe, the vast majority of enterprises are small and medium-sized (SME). The dimension of business has difficulty with the technological shift since they have not the ability to invest and create the industrial conditions of R&D to offer the added value products that consumers need and desire [22–26]. This framework is also reflected in the RIS3 (Research and Innovation Strategies for Smart Specialization) plan for the Centro region considering the relevance and diversity of its unique natural products, universally recognized in national and international markets. Also, in this plan, biotechnology appears to be a determinant tool for technological and economic innovation based on its character, sustainable nature, and technological excellence. Nevertheless, there is a low index for knowledge and technology transfer from R&D centres to companies, and a weak capacity for the industry to incorporate biotechnological innovation. This new cooperative challenge is of utmost relevance at the regional level to facilitate active collaborations between industry and research in the field of bioeconomy and to add value to natural products [27–30].

This is of utmost relevance for agro-industry due to its natural and regional products, that need to have market-products with add value to guarantee market and economic growth. Furthermore, small firms (characteristic in the agri-food sector) seldom innovate in isolation but, instead, rely heavily on external partners for information and other inputs. In fact, as an alternative to industry collaboration (a situation challenging in the agri-food sector since small firms perceive larger firms as competitors), small firms often partner with universities and R&D centres that provide them access to new knowledge and technology necessary for innovation, as well as the necessary mechanisms to integrate knowledge successfully [31,32]. In this context, the ability to enhance R&D activities supporting innovation in small agribusiness depends strongly on the partnership with local/proximity R&D centres [33] to obtain information and other inputs that are key determinants of innovation in small firms [34–38].

The HEI and the firm's relationship, in the R&D perspective, was deeply studied. The geographical proximity from firm to university and the academic research quality are also recognized as determinants for the relationship between university and businesses and their collaborative research and licensing [39]. On the other hand, businesses that are small-sized and/or in an isolated location have more difficulties in choosing a public R&D partner. Several authors suggested that the success of the partnership to be established between universities and firms rely mainly on the sector activity, size, and degree of research absorption capacity [40–44]. However, geographical proximity and the way that the agreements between the institutions are established and patents registered are crucial for relationship success [45]. There is no unique way of how HEI and business establish a fruitful relationship, but the trust of the relationship between the parts is what lead to the success of the knowledge transfer for other authors [46–48]. The different ways that this relationship may take place can be guided by two guidelines [45]: the establishment of partnerships and the experiences of innovation development within the regional smart specialization priorities. To promote national and regional development and diminish the differences in growth within the countries, engaged and developed smart specialization strategies to enhance the differentiation, economic development based on the

endogenous and national/regional assets, and therefore regions and countries could have a more sustainable economic and social development. This path was the origin of many European countries developing their strategies and regional organization, namely in the Centro Region of Portugal where a regional specialization strategy was designed (RIS3).

Agriculture still is an activity that maintains great importance in Portugal and in particular, in the region of AAPIM (Farmers association for mountain fruit integrated production, Guarda, Portugal) associates operate, Centro region of the country, but it is developed, above all, as a complement to other principal activities. The most relevant agricultural productions are vegetables, vines, olive groves (these two products representing the vast majority of the permanent crops of the territory), cereal (rye, wheat, and maize), chestnut, and some fruit-growing species (apple and pear). At the level of livestock farming, the ovine and bovine production stands out. The agricultural holdings are mostly of small dimensions (between 1 and 5 ha), and the total number of farms represent approximately 21% of the total farmland in the Centro Region of Portugal [49], a region that is the third-largest contributor to the Portuguese agriculture gross domestic product (GDP). This situation led to our geographical focus of the research.

Given the above, it seems that the introduction of innovation in the agriculture system is crucial. Because of this, we want to identify what is happening in the agricultural SMEs that have already demonstrated a sensitivity to the importance of innovation and implemented some type of technology. So, we contacted AAPIM (Farmers association for mountain fruit integrated production, Guarda, Portugal) with these main goals in mind:

- To estimate the economic scope and size of AAPIM's associates;
- To assess the characteristics and status of AAPIM's associate's innovation degree;
- To estimate the innovative behaviour and performance of AAPIM's associates;
- To identify business perceptions of barriers to collaborative R&D and opportunities.

With these research objectives, it was possible to propose a better science and technology (S&T) policy for AAPIM's associates within an R&D collaboration process, expressed in this paper. Therefore, we present the main results of the research made and its impact on the R&D activity developed in the Polytechnic Institute of Guarda, as an example of how HEI may contribute to the knowledge transfer needed for the small agribusinesses of the region.

## 2. Materials and Methods

The Centro Region of Portugal, where AAPIM and its associates are located, accounts for approximately 31% of Portugal's total area and 22% of the population living in the country. This region is characterized by presenting a low demographic density resulting from the existent asymmetry within the region where there are desertified "inland" areas, in contrast with the coastal lands, which are more populated, urbanized, and industrialized. This asymmetry is also reflected in the regional economy encompassing both low technology level industrial sectors (e.g., agri-food), and some medium and high-tech sectors such as health services, biotechnology, telecommunications, new materials, ICT, and renewable energies. The primary sector accounts for 3.8% of regional gross value added (GVA), and the regional industrial structure is mainly composed of SME (about 99% of total) [50]. Considering its specificities, the RIS3 of the Centro Region highlights eight thematic domains as determinants for regional innovation and economy: agroindustry, forestry, sea, tourism, ICT and electronics, materials, health and wellness, and biotechnology, to valorise and potentiate the main regional endogenous resources, adding value [51].

As a result, the Guarda Polytechnic Institute, as an HEI research centre, developed a knowledge transfer model to promote R&D collaboration with local firms, in particular, in the agri-food sector. This model, polytechnic to business (P2B), is embedded with the RIS3 guidelines and have defined four focus areas of intervention [45]: Lodging P2B (ideas and innovation development); IDT Services (Innovation and Development of Technological Services) -innovation services to answer business

challenges and development of strategic business partnerships; boxes of training (specific training courses to answer business needs); Policasulos (an incubator and accelerator centre). One of the first challenges assumed in P2B was the design of a specific R&D collaboration strategy with the regional firms in the agri-food sector. For that, this work was planned to understand and operationalize the concept of biotechnological tools, its influence on agriculture, the role of biotechnology and impact on innovation development, and business success and competitiveness, based on R&D alliances.

### *Data Collection*

The information was collected through a survey (Appendix A) that uses the provisional statistical definition of biotechnology adopted by the different OECD (Organization for Economic Cooperation and Development) groups and measures biotechnology activities per the list-based definition [5]. The method was chosen to provide a direct and interpreting use of data since it quantifies the aspects necessary to analyse in the research, allowing us to examine relationships between variables. For that, the research design was based on descriptive research since the study's objective involves the portraying of the characteristics of the research focus and the determination of the frequency of occurrence and the degree of the association of the variables [52]. Furthermore, descriptive research is also useful to combine with the decision maker's implicit model of how strategy and marketing system function regarding biotechnology use. AAPIM carried out the data collection, so it would be possible to have more direct contact with the business companies and collect data more comprehensively. The survey is divided into sections that address farmer's associate's business, investment, revenues, R&D expenditures, and employment, as well as their innovative activities, including innovation strategies and collaborative R&D performance, were collected. Demographic and socio-cultural information, in terms of gender, age, type of degree was also analysed.

The survey was distributed, according to the method of the sample survey, using as reference the population of AAPIM business associates ( $n = 555$ ). A convenience sample of AAPIM businesses companies associates was defined, with a confidence level of 95% and a confidence interval of 11%, ( $n = 55$ ), considering the number of associates per subsector of activity: Viticulture (267 associates) with 27 surveys distributed; Fruticulture (143 associates) with 14 surveys distributed; Oliviculture (145 associates) with 14 surveys distributed. Although the sample size was small in absolute terms, it was representative of the target population. The survey warrants the anonymous of the respondents, all the rights regarding general data protection regulation (GDPR) rules were accomplished, and all participants allowed the use of the information and data collected.

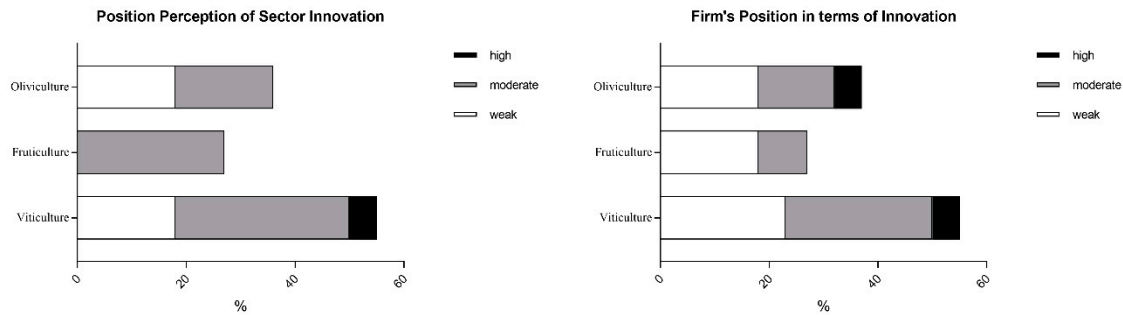
Data were coded and entered a database and were reviewed by the research group, before been submitted to descriptive statistical analysis through SPSS software.

### **3. Results**

The distribution of the subsectors analyzed was: 63.4% from Viticulture, 36.4% from Oliviculture, and 27.3% from Fruticulture. The majority of the respondents were males, with a majority of respondents over 50 years old, with primary and secondary education level, and were the owners of the business companies, that, in the majority of the cases, had more than ten years of existence. The responses from all the companies inquired were very similar consequently, independently of the characteristics of the individuals or of the companies they were from, there was no observation of different perceptions and use of the biotechnology tools since no correlation was found between demographic aspects and the answers. The reliability test of Cronbach Alpha was determined in the biotechnology scales (part 2 of the survey) used and presented a "Good" (0.710) internal consistency which gives 95% confidence in the data collected. The questions on part 3 of the survey, with business implications (marketing, innovation, and strategy) that could lead allow an analysis on how the business system of the companies was integrating the biotechnology use, as described later, did not allow a reliability test since it showed no cases ( $n = 0$ ) in the majority of the questions.



Firms engaged in the AAPIM association vary significantly in size and scope and mainly have low annual revenues, independently of the activity subsector. With a revenue of just 125.000€, the majority of the business companies have a significant concern in saving production costs despite recognizing the difficulty they have in reducing labour and fix costs more. The perception of the firms was that innovation has moderate importance for their business and recognize that they have a weak positioning towards it (see Figure 1).



**Figure 1.** Innovation perception. Source: Author’s calculation from the research dataset.

The environmental concern of these businesses seems something important, in particular, from a biodiversity respect perspective. However, they do not see that biotechnology is fundamental to their business strategy despite admitting that biotechnology may answer some consumer needs (see Table 1).

**Table 1.** Perception of consumer’s biotechnology acceptance.

	Perception of Biotech Answer to Consumer Needs	Concern in Biotech Communication to Consumers	Perception of Public Biotech Acceptance	Use of Biotech Arguments to Different Products
<b>Yes</b>	50%	31.8	27.3%	22.70%
<b>No</b>	31.80%	59.1	63.6%	77.30%

Source: Author’s calculation from the research dataset.

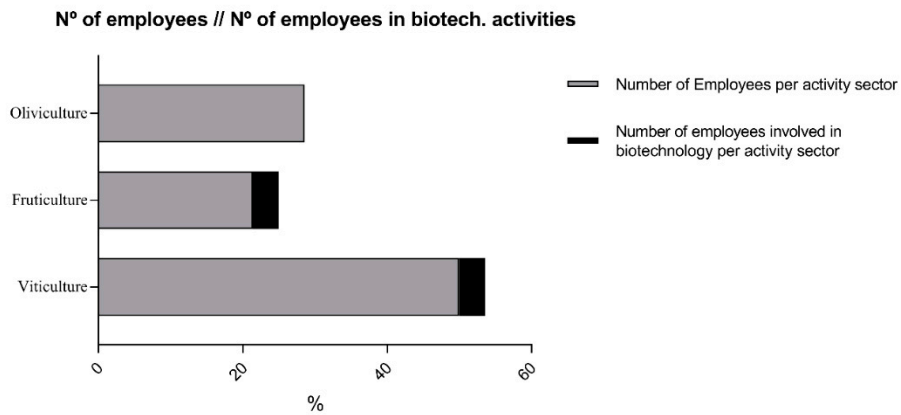
There is no communication investment of the bio characteristics of their products to the market, internal or external (they do not feel relevant to export), the reason why the majority of the firms do not recognize that patent registration as a useful tool to the competitive positioning (70% think that patent registration or other licensing is not relevant for the business). Furthermore, this is reflected in the absence of patent registration.

They devote only a small fraction of their resources to biotech-related product development or investment activities. R&D expenditures are null, as well as the involvement in Biotechnology-related activities or employees (Figure 2). Despite this, one firm has registered the participation in biotechnological research activities.

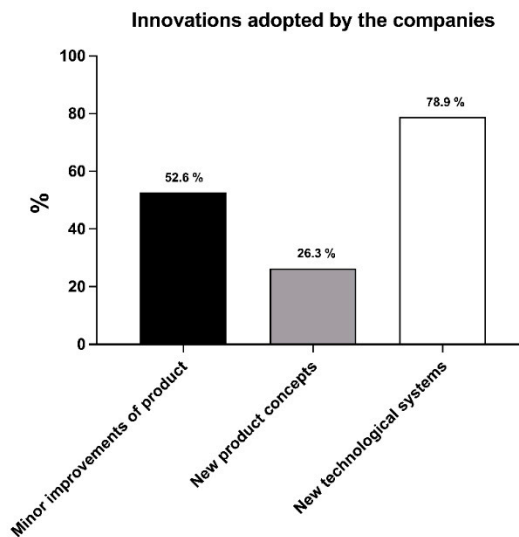
Research activities were registered for 27.3% of the firms that claimed the participation in research activities mainly in association with external R&D centres that did not belong to HEI.

In terms of product development, the viticulture sector has a higher percentage of use of biotechnology in product development than the other two sectors (viticulture—50%; oliviculture—28%; fruticulture—22%).

In most of the cases, the innovations adopted by the firms were new technological systems (Figure 3). They state no concern in launching new products (the few new products launched did not have any biotechnology implication), or new markets as they try to improve the quality of the current products produced and commercializes by them, where they recognize has already made them increase the sales volume.

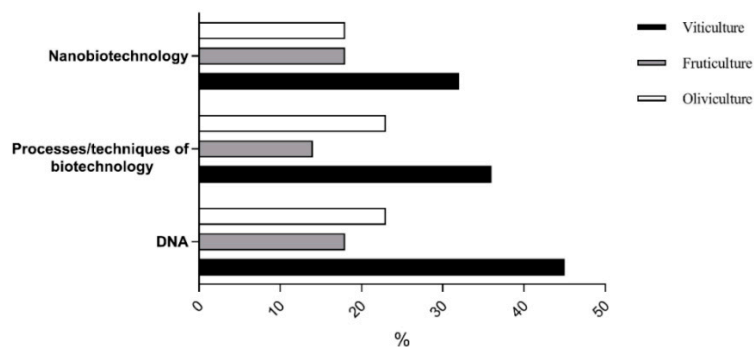


**Figure 2.** The number of employees vs the number of employees in biotechnology activities. Source: Author’s calculation from the research dataset.



**Figure 3.** Innovations adopted by the companies. Source: Author’s calculation from the research dataset.

Despite this, SMEs in the different subsectors states development of biotechnological activities and, in particular, the viticulture sector was the most active in the use of these techniques. DNA technologies were identified as the most frequent, followed by process/techniques of biotechnology and nanotechnology, mainly applied in the firm’s processes or environmental protection (see Figure 4).



**Figure 4.** Biotechnology activities developed by the business per activity sector in the last five years. Source: Author’s calculation from the research dataset.

These results are following the major concern stated by the firms, which was product quality improvement.

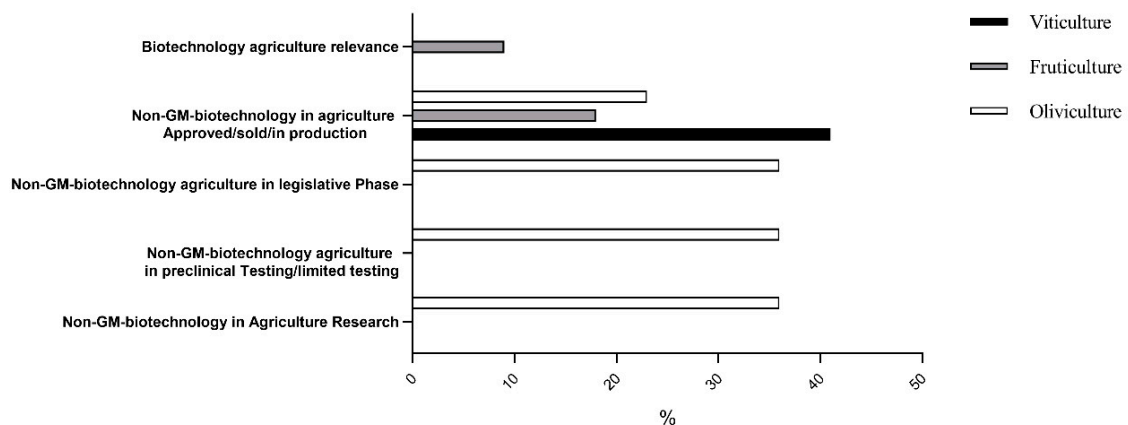
As Table 2 shows, in terms of biotechnological methods used, the majority of the firms asked to use non-GM biotechnologies.

**Table 2.** Types of biotechnological methods applied to the agri-food sector.

	Research	Preclinical Testing/ Limited Testing	Legislative Phase	Approved/Sold/ in Production	Not Relevant
GM-biotechnology agriculture: new genetically modified varieties of plants, animals, and micro-organisms	0	0	0	0	0
Non-GM-biotechnology agriculture-new varieties of plants, animals, and micro-organisms not genetically modified, biological control of pests	15%	15%	15%	33%	4%
Extraction of natural resources—energy, extraction of compounds, etc.	0	0	0	0	4%
Industrial processing—bioreactors to produce new products, biotechnology for transformation of inputs	0	0	0	0	0

Source: Author’s calculation from the research dataset.

The firms that answered positively to the use of these techniques belong mainly to the oliviculture subsector, as Figure 5 shows.



**Figure 5.** Sector usage of biotechnology techniques applied in the business companies studied. Source: Author’s calculation from the research dataset.

In general, the businesses claimed to apply some biotechnological techniques, mainly in their production process, to improve their product quality and consequently increasing sales. They intend to answer more effectively to the needs of their national/regional market but with no concern of promoting an integrated business strategy.

The data collected in terms of business and marketing strategy highlights that, for the majority of the cases, the firms that integrate biotechnological activities within their business strategies do not deal with the market/consumers in order to enhance their efforts in offering products based in biotech processes. Despite this, they stated this as essential and even considered as their main concern, which was environmental preservation. Their business actions do not include any action of improvement in this area, not by making business associations, registering patents or developing any R&D joint activity based in pure research, or allocating employees to this type of activity. Their lack of interest in exporting is another demonstration of a lack of interest in improving their production and sales. In this sense, it is clear that the financial barrier is significant. Moreover, access to capital is one of the main barriers identified by these firms to develop their biotech and innovation processes.



Considering this and based on the polytechnic to business model implemented and registered by the Polytechnic of Guarda, an analysis was carried out concerning the first five years of implementation of the co-promotion research projects, innovative services, and specialized training (see Table 3). The co-promotion projects represented a total of €3,434,341.99 and were mainly dedicated to innovation management, marketing strategy design, and network consolidation, involving 15 companies and several partners R&D centres. Of particular relevance is the consolidation of the partnership with Inovcluster, which represents the majority of agri-food companies in the Centro Region, which develop an interface role between companies and R&D centres identifying the main challenges and contributing efficiently to the development of successful co-promotion projects. The subsectors of cheese and lactic products, wine, and olive oil were the most open to innovation and mostly related to the exportation potential as well as the dimension and technological development within the production system.

**Table 3.** Polytechnic to business (P2B) agri-food implementation areas of the last five years.

Lodging P2B (Ideas and Innovation Development)		
Idea/Project	Business Partner	Results
NATFARM—Product development based on thermal water	Natura Empreendimento S.A.	Co-promotion project application
Product development with natural plants	Planalto Dourado	SME 4Inova Technology and Process Award—3rd Prize
Bio packaging for cheese	Queijaria Casa Agricola dos Araís	SME 4Inova Productivity Award—1st Prize
LDT Services—innovation services to answer business challenges and development of strategic business partnerships		
Applied Research Projects		
Project	Funding Programme	Funding
S4Agro—Sustainable Solutions for Agro-industrial Sector	Portugal Structural funds—COMPETE	€1,088,688.85
Valor Jarmelo—Jarmelista territorial recovery value for the preservation of the identity and the genetic of Jarmelo indigenous race of ruminants	Portugal Structural funds—PDR2020	€307,311.4
+Agro—Promotion and enhancement of the Mountain Olive Oil	Portugal Structural funds—COMPETE	€1,081,013.35
Promotion and enhancement of the Mountain Olive Oil	Portugal Structural funds—CENTRO2020	€586,459.71
Dermo Bio	Portugal Research funds—FCT	€147,425.83
Stai.Bin—Technological system to support the promotion and evaluation of the economic, social, and environmental impact of the short circuit SmartFarmer.pt	Portugal Research funds—FCT	€149,942.85
Partnerships and Network in Agri-food Business		
Name	Type	Role
MORE—Mountains Research Collaborative Laboratory	Non-profit Private Association <a href="https://morecolab.pt/">https://morecolab.pt/</a>	Shareholder founder
Network of Higher Education Institutions for the Safeguarding of the Mediterranean Diet (RIESDM)	Agreement (to consolidate research and knowledge production within the Mediterranean Diet)	Partner
Innovative Services		
Subject	Business Client	Business agreement amount
Valorisation of Natural and Dietary Products	Biosic, Sociedade de Produtos naturais, Lda	€15,000.00
International Market Study—Olive Oil Sector	Agrocluster do Ribatejo	€17,500.00
The Olive Oil Sector in Portugal—Post-production Chain Analysis	Agrocluster do Ribatejo	€20,000.00
Strategic Analysis for the Olive Oil Sector	Inovcluster—Associação do Cluster Agro-Industrial do Centro	€21,000.00
Boxes of Training (specific training courses to answer business needs)		
Course	Area	Education Level
Management and Innovation of Endogenous Products	Business and Agri-food	Professional Higher Technical Courses (EQF and ISCED level 5 course)
Policasulos (Incubator and Accelerator Centre)		
Entrepreneur Project	Entrepreneur Team	Business Creation
FruMo (Chestnut Valuation)	Alfeu Magalhães	AgroTamanhos (Agricultural cooperative)
Royal Roe (Marketing of Trout Roe)	Débora Soares; Samuel José	Project
Pearl Culture	Cláudio Manuel Alves Ferreira	Project

Source: Author’s calculation from research dataset.

#### 4. Discussion: R&D Collaboration, and Open Innovation in R&D

Most of the firms in the sample are strategic followers, with null R&D expenditures. Despite this, they have a moderate perspective about the role of biotechnology and innovation for their business core, assuming its weak commitment in this area. Also, it was registered that they do not devote special attention to have qualified staff for product development or R&D activities. The new products introduced in the market by these firms do not result from R&D activity outputs. These findings confirm that a lack of technically qualified competences constitutes one of the most determinant constraints to innovation by small firms, and as was stated and reviewed in other works [34,53–55].

Another critical aspect resulting from data analysis is the low R&D activity of these small firms involving R&D partnerships. On the other hand, it was mentioned that this activity, when it exists, depends on external R&D centres. This aspect is of utmost importance, once European research policy highlights the effectiveness of the proximity approach of research centres from local universities to the innovation of local and small firms to improve the knowledge and technology transfer [39,56]. If this worked, this partnership would also change the non-patent registration relevance for the business scenario, since for the R&D centres its essential and a way to show their work. This situation, as Grillitsch et al. stated, is typical of non-patent-intensive sectors; therefore, it should not be used as a research/innovation indicator [19]. We also observed that, in this situation, it is beneficial to a university-enterprise relationship to improve and develop an important role in technological business success [57]. In fact, and as was registered for other industries, which have experienced a strong positive effect with the application of open innovation concept and practice, the development of technology and joint patent applications within university—enterprise partnerships increases the market value of the patent [58].

Future research could reveal how this partnership would improve business development and success analysing the enterprise R&D organizational ambidexterity and how it promotes this type of small agribusiness evolution, considering its life cycle and development model, and therefore be able to help these companies to integrate the biotechnology use and concern in their business strategies [59]. Other innovation strategies for this type of small agri-food business could be supported on the development of new business models since they lead to market growth and it is required technology development to implement it maturely [60]. In this way, they could foresee more easily the need to develop and integrate new technology and they would establish new markets within an open innovation strategy. The “new” concept of bioeconomy based on the sustainable exploitation of biological resources, has emerged as a critical strategy to meet resources use efficiency and innovative processes and products. In this sense, consumers and producers share environmental concerns, as also registered in this study. In fact, in this study, farmers assume the quality improvement of products as their focus and non-GM biotechnology tools were recognized as useful for eco-innovative product development following the actual green trend widely discussed and reviewed in previous works and reports [61,62].

Resources constraints have long been recognized as one of the factors that impact on the business performance and growth of SMEs. Small-sized SMEs limits innovation and limit access to capital investment on innovation. The findings of this study about the evidence supporting the lack of agri-food SMEs capacity and competences to access to capital to improve their production and sales based on biotechnological innovation incorporation are entirely following the significant concerns of national and European Union Policy that highlights regional networks as the bottleneck for achieving knowledge and technology dissemination as reviewed by Muscio and Ciffolilli [63].

Furthermore, researchers can be encouraged to realized open innovation in the agri-food industry by the design of new and better balanced internally and externally R&D incentive systems to encourage the researcher to take on the challenge [64]. Another point, which can contribute to the development of the agri-food industry, is the open innovation produced from other industries because most innovation is based on a recombination of existing knowledge, concepts, and technology [65]. In this sense, we also confirm that the supply chain collaboration is a determinant for the agri-food industry.

Regional inter-organizational collaborations for creation and diffusion processes have been considered more successful when reflected not only the geographical proximity but also institutional, technological, social, and organizational proximity. For this, the existing local and regional network between agri-food firms, farmers organizations, and research centres from higher education institutions was considered crucial to the future developments of this sector [66–68]. As stated by Enkel and et al. (2009) [69] a coupled process of co-creation innovation would have significant benefits for this industry, since the cooperation with external R&D entities is fundamental to overcome competitive disadvantages when this innovation collaboration is not implemented and taking into account the constraints find in external knowledge transfer.

## 5. Conclusions

This study, despite the small size of the sample, characterizes the SMEs of the agri-food sector from Centro Region of Portugal regarding innovation consistently and constitutes the first analysis ever of the regional innovation system in agri-biotechnology. Is clear that the SMEs in this study demonstrated a higher level of engagement with monitoring their marketplace, and other marketing activities, as some other, studies already highlighted [70]. Results highlight that investment acts as a constraint in the path of introducing innovation in this sector and in engaging these SMEs in a more competitive strategy supported by it. Therefore, policymakers should consider strategies that can assist agri-food sector SMEs in accessing and managing resources for innovation through regional networks involving producers, organizations, and research centres. Also, regional HEI and their research centres, assisted by the policymakers, may engage in education and research activities that support actions to help these SMEs.

Lastly, there is potential for considerably more research into innovation in SMEs in general, and in the agri-food sector, in particular, to be able to draw business strategies to introduce innovation in the SMEs management and production.

It is important to develop an action plan that can integrate the consumers and suppliers of innovation (R&D regional network) to reinforce the proximity and the development of applied projects with a real and positive impact on the economic sustainability of regional SMEs. This fact is of the utmost relevance within the agri-food sector that quickly can internalize innovation in the economic and marketing strategies considering the development of high-value products based on a sustainable biotechnological approach.

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## Appendix A Biotechnology Use Survey

With this survey, we intend to understand how companies in the agri-food sector use biotechnology in their activity and how they can integrate biotechnology into their business strategies as a competitive factor.

### Part 1—Business and Employment

1.1 How many employees your company has? \_\_\_\_\_

1.2 How many of your employees are involved in biotechnology activities? \_\_\_\_\_

1.3 How many of its employees involved in biotechnology activities develop: \_\_\_\_\_

- Research activities
- Other biotechnology activities (ex.: Production)

1.4 How much time have their employees spent developing:

- Biotechnology research activities
- Other biotechnology activities (ex.: Production)

1.5 What is the billing volume of the company?

- <125,000 €
- 125,001 to 250,000
- 2,500,001 to 5,000,000
- 5,000,001 to 10,000,000
- >10,000,001

1.6 What is the amount in research spent by the company per year? \_\_\_\_\_

**Part 2—Biotechnology**

2.1 Point out the biotechnology activities used by your company in the last 5 years:

- ADN—genomics, pharmacogenomics, genetic engineering, DNA sequencing/synthesis/amplification, gene expression profiles, etc. (Ex: genetically modified organisms, transgenic organisms, genetic improvement of species, selection of varieties)
- Cell cultures and tissue engineering—cell and tissue cultures, tissue engineering, cell fusion, vaccines/immunostimulants, embryo manipulation, micropropagation.
- Biotechnology processes/techniques—fermentation through bioreactors, bioprocesses, bioremediation, phytoremediation (Ex: bioprocesses and bioreactors, biofertilizers, biological struggle, biopesticides, bioherbicides...)
- Bioinformatics—creation of genome databases, protein sequences, modelling of complex biological processes, including biological systems.
- Nanobiotechnology—application of nano/microfabrication tools and processes in biosystems study (Ex: veterinary products, vaccines, biotechnical fight (semi-chemicals, insect growth regulators, self-acid fight)
- Another: (specify) \_\_\_\_\_

2.1.1 If you answered yes, say what kind of use it makes of biotechnology:

- Do you research on this biotechnology use?
- Do you use this biotechnology for product or process developments?
- Do you use this biotechnology in production process (including for environmental purposes)?

2.2 Does your company currently develops processes that require the use of biotechnology? Yes  No

2.3 Does your company applies the following biotechnology applications:

	Research	Pre-Clinical Testing/ Limited Testing	LEGISLATIVE Phase	Approved/Marketed/ in Production	Not Relevant
GM—biotechnological agriculture: new genetically modified varieties of plants, animals, and micro-organisms					
Non-GM—biotechnological agriculture—new varieties of plants, animals and non-genetically modified micro-organisms, biological pest control					
Extraction of natural resources—energy production, extraction of compounds, etc.					
Industrial processing—bio reactors to produce new products, biotechnologies for input transformation					

2.4 When did your company put biotech products on the market? \_\_\_\_\_

2.5 Your company currently develops products that require the use of biotechnology? Yes  No

### Part 3—Strategy and Marketing

3.1 What is your idea about the level of innovation in the sector? Weak  Moderate  High

3.2 How do you position your company in terms of innovation? Weak  Moderate  High

3.3 What kind of innovation has your company already adopted?

- Minor product improvements
- New product concepts
- New technology systems

3.4 Does your company has developed research activities? Yes  No

3.4.1 If you answered yes, please indicate which research activities you have developed:

- Developed research activities internally?
- Developed research activities in association with other companies?
- Developed research activities with external research centres?

3.4.1.1 Please indicate which research centres have carried out research:

- Research centres of higher education institutions
- Other research centres

3.5 In the last 5 years, how many products has your company has launched on the market? \_\_\_\_\_

3.6 How do you classify your company's innovation objectives? Weak  Moderate  High

3.7 What kind of innovation objectives have you achieved?

- Replace end-of-cycle products
- Improve product quality
- Extend the product range
- Access to new markets
- Increased sales volume
- Comply with legislation and standards
- Lower labour costs
- Decrease material consumption
- Decrease energy consumption
- Reduce environmental damage
- Preserving biodiversity

3.8 Do you consider biotechnology to be a central issue for your company's activity and/or strategy?  
Yes  No

3.9 Does your company knows the mechanisms of industrial property? Yes  No

3.10 How you defend ownership in the face of competition?

- Keep secret
- Knowledge is tacit
- Development and market times are relatively short
- Protects using patents

3.11 Does your company holds patents in the field of biotechnology? Yes  No

3.11.1 If so, how many patents your company holds? \_\_\_\_\_

3.12 What are the barriers you consider most relevant for the implementation of biotechnology techniques?

- Difficulty in establishing partnerships with R&D centres
- Access to capital
- Access to specialized human resources
- Access to international markets
- Difficulty in distribution and access to distribution channels
- Acceptance/perception of the public
- Legal requirements
- Patent rights and other licensing costs

3.13 Do you consider that the biotechnological issue meets the needs of consumers? Yes  No

3.14 Do you use biotechnological arguments to differentiate your products? Yes  No

3.15 Are you concerned with informing its consumers about the biotechnological characteristics of its products? Yes  No

3.16 Do you consider that introducing biotechnology into your company’s strategy is an opportunity? Yes  No  Or a risk? Yes  No

3.17 Is biotechnology part of your company’s mission and strategy? Yes  No

3.17.1 If so, how does it develop its strategy considering the biotechnology factor?

3.17.1.1 Action in the internal market:

- Supply of genetic materials from your own country.
- Biodiversity conservation agreements with national governments.
- Direct involvement in biodiversity conservation practices in the internal market.
- Contributions to conservation efforts.
- Affiliation in a conservation action group.
- training and development of conservation professionals.

3.17.1.2 Action in developed countries:

- Supply of raw materials from developing countries.
- Direct involvement in biodiversity conservation initiatives in developing countries.
- Biotechnology development agreements in developing countries.
- Joint ventures with companies in developing countries for conservation reasons.
- Establishment of research facilities in developing countries for the conservation of materials.
- Contributions to conservation efforts in developing countries.

3.17.1.3—Biodiversity conservation agreements:

- Organic extraction agreements (payment of user tax to developing countries in exchange for access to protected natural habitats).
- Biological prospecting agreements (user fee paid to developed countries, along with royalties arising from the development of consequential products).
- Sampling agreements (fee paid to developed countries in exchange for the collection of samples of plants and animals).

#### **Part 4—Respondents**

4.1 Sex: F  M

4.2 Age

- Less than 30 years
- From 30 to 39 years
- From 40 to 49 years
- From 50 to 59 years
- Over 59 years old

4.3 What position do you hold in the Company? \_\_\_\_\_



## 4.4 Academic level:

Basic Education  
 Preparatory Teaching  
 Secondary School  
 Degree  
 Master  
 PhD

## 4.5 Seniority in the Company:

<5 years  
 5 to 9 years  
 10 to 19 years  
 20 to 29 years old  
 More than 30 years

## 4.6 Economic Activity Classification (EAC): \_\_\_\_\_

## 4.7 Year of Company Constitution \_\_\_\_\_

- I allow my data to be used regarding the research purpose of the study “Biotechnology Use Survey” develop by the research team of Polytechnic Institute of Guarda and AAPIM technicians, complying with GDPR rules.

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