# 3. DEVELOPMENT AND COMMERCIALISATION OF AN INVENTION IN THE FIELD OF ACTIVE PACKAGING

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Wojciech Kozak

Department of Industrial Products and Packaging Quality
Poznań University of Economics and Business
wojciech.kozak@ue.poznan.pl

**Abstract**

The aim of the work is to present the case study of commercialisation process by using the example of an invention (active packaging) developed at a university (PUEB) and intended for employment in the packaging industry to preserve the quality of goods and prolong its shelf-life. The stages from basic research, further development of the solution, through the process of fundraising, obtaining intellectual property protection, prototyping and attempts at proper commercialisation including its final results are presented.

**Keywords:** commercialisation, technology transfer, active packaging, oxygen scavenger.

## Introduction

The quality of products is a guarantee of customer satisfaction (Defeo, 2016). Taking into account the product life cycle and the specifics of the sales process, it should be remembered that not only the quality created at the production stage is important, but also maintaining this quality in all further stages of the product life cycle (Pyzdek & Keller, 2012). This is especially important in the case of food products, which, by their nature, are particularly susceptible to external factors and the quality changes caused by them, unfortunately, for the worse. This leads to losses amounting to millions or even billions of dollars a year, and in addition, they are nothing more than the food waste that we grapple with all over the world (Wadman, 2015). Therefore, apart from quality management at the production stage, it is extremely important to introduce solutions that allow the maximum maintenance of the original product quality as unchanged as possible (Taormina & Hardin, 2021). In the case of food products, this is achieved by appropriate

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development and carrying out of the production process and, which is crucial, by appropriate packaging of the produced food (Galanakis, 2019).

Packaging of food products is based on the selection of suitable packaging materials and optimal packaging technology for a given product (Grumezescu & Holban, 2018). The main aim of the packaging materials is to adequately protect the product from the outside world—in the case of food, this is ensured by materials with high barrier properties. Barrier properties determine the speed or the possibility of chemical, physical and biological factors penetrating the inside of the package. Examples include, among others: water vapor, oxygen, UV light and microorganisms (Singh, Wani, & Langowski, 2017). When it comes to packaging technologies, the best results are achieved by modified atmosphere packaging (MAP) (Lee, 2021). In this case, the air originally contained in the package is replaced with a gas or a mixture of gases optimally selected from the point of view of maintaining the quality of the product. The most commonly used gases are nitrogen, carbon dioxide and (less often) argon.

It turns out, however, that in the case of products that are particularly sensitive to external factors, as well as due to the physical and biochemical processes taking place in them, even the aforementioned modern packaging methods turn out to be insufficient. The solution to this problem may be the so-called 'active packaging' (Arvanitoyannis, 2012), an example of which is the invention presented in this case study, developed by research workers of one of Poland's universities (PUEB).

## 3.1. Basics of commercialisation and technology transfer

As in the case of any invention, and, in particular, one covered by patent protection, the aim of the inventor or owner should be to transfer new technology to the market or, in other words, to commercialise it, which will contribute to the dissemination of the new technology, its implementation in practice and will provide financial benefits to inventors or organizations and institutions they work for. There are many definitions of commercialisation and technology transfer in the literature. Commercialisation may also include activities aimed at creating a business model of a given technology, shaping the process of its sale, production, sharing, sale or use so that it brings profit or constitutes a specific capital, and may also aim at obtaining added value of a given technology (Jordan, 2014). It can also be treated simply as all activities aimed at transforming knowledge into inventions, technologies, innovative products and organizational solutions serving this process (Liou, 2011).

Knowledge itself or even a specific invention is worthless until we find practical application for them, and what is most important from an economic point of view, until we find people willing to buy them. The latter is particularly difficult due to the multitude of ideas and new inventions emerging all over the world and the price pressure associated with the desire to minimize costs and maximize profits. Only truly innovative, unique and at the same time, cheap technologies are able to break into the market and be successful. There are several different commercialisation strategies that are applicable. The most common are the sale of property rights, licensing, join venture or strategic alliance, implementation on your own, creation of spin-out or spin-off companies (Rafinejad, 2007; Butler & Gibson, 2011, Trzmielak, 2013).

The commercialisation process begins with determining the market potential, and thus, first of all, determining the advantages and possible limitations of a given solution, idea or technology. This is done with reference to existing, similar or alternative solutions available on the market. The size of the market is then determined, the necessary expenditures related to the development and potential introduction to the market, production costs, possible distribution channels, and existing market niches that could be filled by the solution intended for commercialisation (Szopa, 2015) are investigated.

Very often, the authors of a given idea are not able to make such an assessment on their own. Thus, additional people or entities specialized in the aforementioned activities are involved in the commercialisation process. Most often, innovation brokers or technology transfer centres are used for help (Mian, Klofsten, & Lamine, 2021). Regardless of this, the commercialisation process and the related technology transfer are accompanied by activities that allow the environment to be effectively and widely acquainted with the offered technological solution.

The first of these is the presentation of an idea or solution, e.g. at scientific conferences, symposia, as part of published works. As it happens in science, ideas are usually not fully crystallized, new ones appear, and therefore the solution is constantly developing, and at the same time, as many applications as possible are sought for it, which will increase market opportunities.

When the research is more advanced, the first prototypes are created and presented to the public (of course, provided that the intellectual property has been secured in advance). At the same time, literature research, patent analyzes and technological audits are carried out in order to be sure that so far there has not been any similar solution to the one on which the efforts are being focused upon (Gibert, Bobadilla, Gastaldi, Le Boulaire, & Lelebina, 2018). This guarantees originality and real innovation.

In the later period, when the invention takes almost its final shape, market research is carried out, and potential marketing strategies are developed. Finally, when an investor is found, production is being prepared. The culmination of the commercialisation process is launching the product on the market and selling it (Touhill, Touhill, & O’Riordan, 2008).

Various concepts, approaches and models of commercialisation can be found in the literature. Regardless of that, in each of them, commercialisation is a process of successive stages, from the idea, through its development, to the proper commercialisation (e.g. sale or licensing). One of the frequently used measures of product development and readiness for commercialisation is the technology readiness level (TRL) (Schramm, 2018). TRL method was originally developed by NASA during 1970s and was used to support technology maturity assessments and compare the maturity level of different technologies. TRL describes increasing technological maturity levels as a concept progress from an initial idea to a fully tested and proven device. Readiness levels are presented on conventional scale ranging from 1 to 9.

In this case, a given technology is assigned one of the nine levels, with the lowest, TRL 1 being the commencement of research, and the highest TRL 9 being the situation when the technology is ready for implementation. As a result TRL is a very useful tool for assessing the technology development process. TRL allows determining the level of development of a given technology, identifying missing elements (e.g. analyzes) and taking further steps (e.g. modifications, improvements) to make it fully ready for commercialisation.

Current TRL model bases on definitions presented by John Mankins, the former Director of the Advanced Concepts Office at NASA Headquarters (Mankins, 1995). Particular TRLs are shown and described in Figure 3.1.

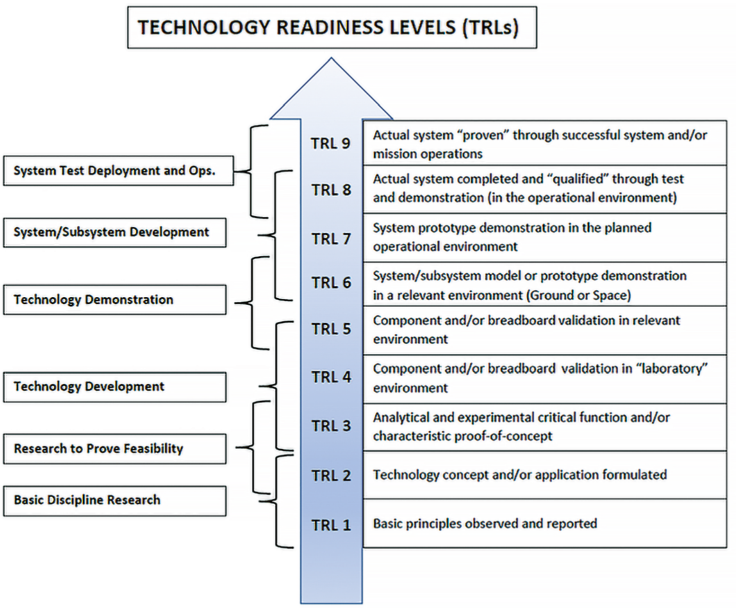


**Figure 3.1. Overview of Technology Readiness Level scale**

Source: (Mankins, 2009).

An inherent process accompanying commercialisation is technology transfer. Basically, it is an exchange of technological knowledge and the accompanying organizational knowledge between two entities (Hockaday, 2020). One of them is someone with this knowledge (technology donor), and the other is someone who needs this knowledge (technology buyer) (Mietzner & Schultz, 2021). Said exchange may take place between entities from different spheres of research and industrial activity. Most often, technology is transferred from the science sector to the business world. It also happens that the exchange takes place between two enterprises. Sometimes it happens that the technology provider for the industry is an individual inventor, not necessarily related to science.

When it comes to the sphere of science, the subjects of technology transfer in this case may be, inter alia, universities, research institutes, research and development centres (Audretsch, Hayter, & Link, 2015). In turn, the buyers are most often enterprises (small, medium, large), but sometimes they are also public institutions. It also happens that private persons are party to the technology transfer process.

In practice, technology transfer can take many forms. Most often it is trading in patents, licenses and broadly understood know-how. It can also be direct investments, modernization of the machine park, cooperation of companies, e.g. as part of joint-venture and mergers of companies (Hoekman & Smarzynska Javorcik, 2006). In the public domain, it may be also contracts for research and development that are commissioned by the state under government programs or other entities, e.g. companies, agencies (Marshall & Piper, 2005). In the case of scientific and research units, and, in particular, universities, technology transfer also includes publications, reports, conference reports, seminars, and classes (Link, Siegel, & Wright, 2015).

Unfortunately, commercialisation and the accompanying technology transfer is often a complicated, multi-stage, expensive and long-lasting process, which is particularly unfavourable in the conditions of high technological competition in the world (Becker & Niebuhr, 2010). On the one hand, there is a need to offer a product that is refined in every respect and tailored to the client's or investor's requirements, and on the other, there is time pressure—in the era of constant development of new technologies, products are technologically aging faster and faster.

## 3.2. Investigation methodology

Presented work bases on case study, which is one of the qualitative research methods and its main goal is to best visualize a certain case. It is an in-depth analysis of a specific phenomenon. The main purpose of this method is to best depict particular "case". It may contain a detailed analysis of the case, goals, assumptions, motives and actions (Fulford, 2012; Yin, 2009, 2012)

In this particular case an invention in packaging field developed on Poznań University of Economics and Business was analysed. The study covered the commercialization process from the idea, basic research, further development of the solution, through obtaining intellectual property protection, prototyping to attempts to implement and sell the solution. The analysis was based on the author's own experiences and the experiences of other team members who developed the invention. The aim was to define the advancement of the commercialization process. The basis for the assessment was the reference to the previously described TRL method and, as a result, indication of the technological maturity level of the presented invention.

## 3.3. Background of the invention

The first attempts to develop an oxygen absorber were made in 1998. Then, various basic studies were carried out. The resulting solution was a "by-product" of master thesis research carried out at the PUEB. It is based on copper compounds and showed satisfactory efficiency in removing oxygen from the packaging, therefore, it was decided to submit it to the patent office of the Republic of Poland as a new invention. While awaiting the decision of the patent office to grant the patent, further work was carried out to develop an equally effective, but cheaper solution. Therefore, a query of existing solutions on the packaging market was made. It turned out that most of the oxygen absorbers sold on the market are based on iron and its derivatives. However, the existing solutions were usually in the form of a sachet with a mixture of powdered iron compounds.

This form of oxygen absorber is simple to manufacture, but has a significant drawback, namely, that the sachet (mostly made of paper) containing the said active substances can be easily damaged, and its content can come into direct contact with the protected food product and be accidentally consumed with it. This, in turn, may endanger the health safety of the potential consumer.

Taking into account the above, an attempt was made to develop an oxygen absorber, the active ingredient of which would also be iron, but closed in some polymer matrix, becoming a kind of composite, which would also be a safe form of the absorber without the risk of contamination of the food protected by it. The work focused on the development of a method of obtaining iron with the highest possible oxygen absorption capacity, and then the selection of the optimal polymer matrix from the point of view of the oxygen absorber, which on the one hand, will enable oxygen penetration, and on the other hand, will constitute an effective barrier between the iron incorporated into it and packaged food product.

After many trials and studies of absorption capacity, the most effective method of obtaining iron was selected and optimized (Foltynowicz, Kozak, & Fiedorow, 2002). Herein, silicone was chosen as the matrix due to its unique feature—oxygen permeability, which was considered once by manufacturers of contact lenses as a material ensuring oxygen access to the eyeball (Efron, Morgan, Maldonado-Codina, & Brennan, 2010). The obtained material was also checked for possible migration of iron from the polymer matrix and emission of undesirable odors. For this purpose, studies on specific migration and use of an electronic nose were carried out. These attempts were successful, the material turned out to be neutral and therefore usable in packaging.

Meanwhile, in 2007, after 8 years of patent procedure, a patent was granted for the previously described copper-based solution (Patent 193082, 2007). Following this success, the patenting of said iron-silicone composite was also considered. However, in order to gain a competitive advantage, by proposing an original solution that had no counterparts on the market, an attempt was made to develop an oxygen absorber that uses nano-iron as an active oxygen absorbing agent. At the same time, it was found that the previously used silicone matrix will also work perfectly in the newly proposed solution. Intensive research and modifications to the new solution were carried out, as well as tedious tests of its effectiveness as an oxygen absorber.

In the end, promising results were obtained. Among other benefits, we discovered that the obtained nano-iron did not require water for oxidation, which was a unique feature compared to the available iron-based oxygen absorbers. The potential oxygen absorber could therefore be used to protect the quality of dry products susceptible to oxygen. Therefore, it was concluded that this invention should be protected by a patent and its inventors should be protected as much as possible with regard to intellectual property rights. The only problem was that patent protection for inventions, and, notably, international patent protection, was a huge cost that neither the inventors nor the institution they worked for (a public university) would be able to provide. Thus, an attempt was made to obtain funds from an external source.

It turned out that under the development projects of the European Union, under the innovative economy operational program (POIG), there are funds in the form of grants for the protection and commercialisation of inventions. After reviewing the requirements, an application was prepared and submitted to the institution dealing with the distribution of the aforementioned funds in Poland (OPI). To the delight of the inventors, in 2010, the project was granted and it was possible to start the patent procedure—first at home, and later abroad.

The patent procedure was thus started, and, in the end, 3 patent applications were prepared for two methods of obtaining an active substance absorbing oxygen and one method for obtaining an appropriate oxygen absorber composite. After the filing of the patent applications, the inventions were henceforth entitled to priority rights, so it was possible to start talks with potentially interested parties in the patented solution without fear of losing intellectual property or to lose out to simple piracy.

As a natural consequence of the steps taken, attempts were made to commercialise the invention.

## 3.4. Commercialisation process

Before the official presentation, the invention was thoroughly researched and tested (e.g. for compatibility with food products susceptible to oxygen spoilage) (Kwiatkowska-Sienkiewicz, Foltynowicz, & Kozak, 2015) and then presented to the public for the first time in 2014, at a packaging conference in Melbourne, Australia (Foltynowicz & Kozak, 2104). It aroused the interest of one of the participants, as it turned out, an employee of a Danish Technological Institute. Several meetings were held at the invitation of the Danish side, during which contact was made with another eminent research centre dealing with packaging, namely, the Fraunhofer Institute. The invention was jointly tested for its properties and compared with commercially available solutions.

The results of the joint research were published in 2017 (Foltynowicz, Bardenshtein, Sägerlaub, Antvorskov, & Kozak, 2017). They showed that the solution has (in some respects) advantages over analogous products available on the market. The Danish and German sides proposed a joint application for a grant under the Horizon 2020 program. Additionally, Scandinavian and German companies from the food and packaging industry, as well as a professional consulting company specializing in EU grant applications, were invited to the consortium. Working meetings were held, and then in 2016, an application was prepared and submitted to the European Union for a project that would lead to the implementation of the described solution for production on an industrial scale.

Unfortunately, despite the very good assessments of experts, funding was not granted. Therefore, it was decided to slightly change the application form, taking into account expert comments, and apply again for the next call for applications. This time it was a haircut from obtaining financing, and as proof of the commercialisation potential of the proposed project, the project team was awarded the Seal of Excellence certificate, opening up the possibility of obtaining funds for the implementation of the project from other sources. This was also done and an attempt was made, together with a partner from the chemical industry, to obtain funds from the Polish enterprise development agency (PARP) to test the possibility of producing an invention on an industrial scale.

In 2017, the first three patents—one in Japan and two in Poland were granted (of the aforementioned POIG project) (Patent 6093713, 2017; Patent 227585, 2017; Patent 227096, 2017).

In the meantime, a unit specializing in the valuation of modern technologies intended for commercialisation was commissioned for the assessment of the solution. With the help of the PUEB Knowledge Transfer Company, cooperation was established with a company from the food industry that was interested in a solution extending the durability of its products. Joint research on the compatibility of the oxygen absorber with the edible product began. In the course of the research, the absorber was given a special form adapted to the packaging used by the food manufacturer. The test results turned out to be interesting, the absorber gave better quality protection effects than other packaging methods used so far by the company, e.g. MAP, but the cooperation ended without a favourable outcome.

One of the problems was most likely the potential costs of adapting the packaging line to the possibility of using an oxygen absorber—it would be necessary to ensure an oxygen-free atmosphere, which would be a significant investment. Another issue was that the company interested in the invention wanted to obtain the rights to produce it exclusively, while the owner of the invention, in this case a public university, was more interested in selling the license. In connection with this turn of events, further attempts were made to establish cooperation with the food industry in order to commercialise the invention, so far without a happy ending. In 2018, two further patents were granted (1 in Israel and 1 in European Union) (Patent, 227146, 2018; Patent EP2658666, 2018) and the project submitted to the Polish industrial development agency was included in the list of projects to be financed.

There was a possibility of developing the invention and transferring its production from laboratory to industrial scale. Unfortunately, the obstacle was the fact that, as it turned out later, the second participant of the project would first have to put up in advance a large own contribution (almost 1/3 of the entire project budget foreseen), which taking into account the prototype character of the invention would be too much of a risk for the company. Ultimately, the company's authorities did not agree to advance the funds and the project was unfortunately not implemented. Nevertheless, it can be stated that the invention has reached the 6th technological readiness level (TRL), and thus it has become a prototype that has been tested in conditions similar to real ones (Schramm, 2018).

In its current form, it is waiting for interest from business and funds for development. It is the limited resources that most likely limit the ability to offer potential customers a ready-to-use solution. The whole commercialisation process of the presented invention is shown in Table 3.1.

**Table 3.1. Commercialisation process of oxygen scavengers**

| No. | Time period | Development stage | Development phase | Technical readiness level (TRL) | Remarks |
|---|---|---|---|---|---|
| 1. | 1998–1999 | Idea of new type of oxygen scavenger. Initial work on an oxygen scavenger based on copper | Research | 1 BASIC PRINCIPLES OBSERVED | Works were a subject of a master thesis. Patent application has been submitted to the Patent Office of the Republic of Poland |
| 2. | 1999–2005 | Formulation and tests of composite oxygen scavenger based on iron powder built into silicone matrix | Research | 2 TECHNOLOGY CONCEPT FORMULATED | Works were a subject of PhD thesis |
| 3. | 2005–2010 | Nano-iron synthesis and formulation of composite oxygen scavenger based on it | Research | 2 TECHNOLOGY CONCEPT FORMULATED | Works were a subject of several master theses. In 2007, first patent was granted |
| 4. | 2010–2014 | Improving of the invention. Shelf life test with packed products protected by developed solution. Official presentation of the invention to the public | Development | 3 EXPERIMENTAL PROOF OF CONCEPT | Shelf test were realized in cooperation with Gdynia Maritime University. Presentation of the invention took place in Melbourne (Australia) during an international packaging conference |
| 5. | 2014–2016 | Comparative tests with commercial alternatives | Development | 4 TECHNOLOGY VALIDATED IN LAB | Tests were performed in cooperation with the Danish Technological Institute (Taastrup) and the Fraunhofer IVV Institute (Freising) |
| 6. | 2017–2018 | Performance test in real conditions with packed product. Adaptation to the requirements of a potential buyer. Efforts undertaking to obtain financing for the production of the invention on an industrial scale | Development | 5 TECHNOLOGY VALIDATED IN RELEVANT ENVIRONMENT | Cooperation with food producers. Application for Horizon 2020 and PARP grants. The first was awarded with "Seal of Excellence" certificate, and the latter was granted. In 2017 and 2018, five patents (in Japan, Poland, Israel and EU) were granted |
| 7. | 2019 | Further development and test. Presentation of the invention to potential buyers | Development | 6 TECHNOLOGY DEMONSTRATED IN RELEVANT ENVIRONMENT | A producer of packaging materials showed interest in the invention and expressed a desire to purchase it. Unfortunately, the invention was not sold on so far |
| 8. | 2019–2020 | New idea to use the presented invention as antimicrobial packaging. Initial shelf life test with food products were conducted | Research | 1 BASIC PRINCIPLES OBSERVED | Three patent applications have been submitted to the Patent Office of the Republic of Poland |
| 9. | 2021- | To be continued… | | | |

Source: Own work.

The experiences described in the work lead to the conclusion that companies in Poland potentially interested in a solution are not willing to invest in the development of prototypes in order to adapt it to their needs, they are more interested in an almost ready-to-use product. This is an insurmountable barrier for most public universities, as they have limited resources for development and commercialisation of inventions created under their auspices. The observations made are consistent with the observations of other researchers in this area (Trzmielak, Grzegorczyk, & Gregor, 2016).

## 3.5. New life of the invention

Regardless of what has been presented above, further attempts have been made to commercialise the invention. Recently, a light at the end of a tunnel has appeared, namely, in the course of new research conducted at the PUEB, it turned out that iron, which was the active factor of the described oxygen absorber, has very good bacteriostatic properties. Hence, the idea of creating a packaging material based on said iron that could potentially be used as so-called "anti-microbial packaging" (Barros-Velazquez, 2016). This idea has become the subject of another patent application that is awaiting the decision of the Polish patent office (Patent application P.432267, 2019).

The new solution has aroused the interest of a company operating in the field of plastics. Negotiations are, hence, underway to sell the technology for the production of an active agent that was originally designed as an active element of an oxygen absorber. Perhaps, ultimately, the original invention will be commercialised as a completely different solution in terms of its function, but will still support traditional packaging. Ultimately, this would be commercialisation by finding a new application for a non-commercialised (so-far) invention.

## Conclusions

This paper presents the use of case studies to analyse and determine the advancement of the commercialization process. In this particular case, the subject of the analysis was the process of the emergence and development of an invention in the field of packaging at one of the Polish universities. The study covered the period from the first ideas, initial tests, concept changes, modifications, further development and attempts to implement the invention in a form that takes into account and is adapted to the specific requirements of a potential buyer. In addition to the process of developing the invention, the process of obtaining intellectual property protection for it, including obtaining national and international patents, is also presented. An additional element was the presentation of financing sources for the development of the invention, as well as the method of cooperation with potentially interested industry representatives.

The analysis of the advancement stage of the invention was carried out on the basis of the TRL model commonly used for this purpose. The effect of the work is, firstly, the identification of breakthrough moments in the product development process, and then relating them to the TRL model. As a result, the technological maturity of the analysed solution was determined as TRL 6. Thus the invention was formally placed in the context of the widely understood commercialization process. The study also partially answers what else should be done to achieve full technological maturity, so as to enable the completion of the commercialization process, understood as a sale or granting a license.

The conducted case study can also be a practical guide for potential inventors and help them, first of all, to identify all elements related to planning, development, financing, as well as legal protection of new technical solutions. It will also allow to avoid problems and stumbles that the authors of the presented invention had to deal with. They did not have similar studies at their disposal and in many moments they based their decisions on intuition, which was burdened with a considerable risk and certainly contributed to the extension of the product development process and its commercialization. An additional advantage of the analysis presented in the paper is that it takes into account the specificity of the operation of Polish universities in the field of commercialization, which is a derivative of a relatively small commercialization experience and specific principles of financing and implementing the commercialization process by universities.

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