OXYGEN SCAVENGER DEVELOPMENT AS EVIDENCED BY PATTERNS IN RELEVANT PATENTING ACTIVITY

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Abstract
Recent observations show a growing interest in active and intelligent packaging. One of the noteworthy types of active packaging that has attracted considerable interest, also in scholarly literature, is oxygen scavenger packaging. Its literature coverage, in turn, has attracted the attention of tradesmen and other entrepreneurs. The sales of such packaging have risen in lockstep with increases in the number of patents granted.
The article explores information on patents on oxygen absorbers used in food packaging. The relevant patents were found in the Lens and Thomas Reuters patent databases. The study timeframe is 1970 to 2015. Patent publications have been additionally correlated with the number of articles published in scientific journals. Such publications were found in the ScienceDirect database.
Factors determining the number of oxygen absorber patent filings have been identified by means of LMDI decomposition analysis developed by Fujii.

Keywords
Active packaging, oxygen scavengers, polymer-based scavengers, iron-based scavengers, patents.

JEL Classification
O31, O34

Introduction
The packaging industry has seen rapid growth for a number of years now. In 2016, the packaging sector reached the worth of €698 billion. A further increase in worth to EUR 860 billion is expected by 2020. Poland too has reported a dramatic rise of the packaging sector, gradually closing the gap between its packaging material consumption and that of Western Europe. Such consumption is projected to rise to €298 per person by 2020 [Wasiak, 2017]. The mix of packaging systems that are on the rise includes intelligent and active packaging. While some such systems may not be labeled intelligent or active, their functionality is nevertheless consistent with the way that active or intelligent packaging works [Cierpiszewski, 2016].
Interest in intelligent and active packaging has long been keen all across the world. It has risen on the back of growing demand for quality food with long shelf life. The ascent was additionally driven by a newly emerged consumer preference for high quality minimally processed foods containing fewer additives that are also more durable and easier to prepare

[WPO, 2009]. A significant factor to consider in discussing packaging trends is the role that packaging plays in reducing food waste [Olsmats and Kaivo-oja 2013]. Such waste can be greatly diminished by using intelligent and active packaging. The significance of intelligent packaging for reducing food waste has been noted by Smithers Pira [2018].
Active and intelligent packaging is used widely in the USA, Japan and Australia. However, its application in Europe remains limited, due most likely to legislative barriers whose recent lifting has created opportunities for new development, as shown by consumer behavior surveys [Restuccia et al., 2010].
Some of the most common active packaging systems rely on oxygen scavengers. Many food products are highly sensitive to the presence of oxygen, which causes food to deteriorate, mainly through oxidation [Choe & Min, 2006]. This chemical reaction may significantly reduce the life of oxygen-sensitive perishables [Man, 2015]. The detrimental effect of oxygen on food is commonly delayed with the use of antioxidants whereas food browning can be slowed with synthetic preservatives [Decker, 2010].
The application of oxygen scavengers in packaging is gaining popularity as a way to eliminate unwanted oxygen content [Foltynowicz, 2018]. Absorbent materials employed to remove oxygen from packaging allow the concentration of oxygen dissolved in food or initially present in the space above the packaged product to be reduced far below the levels achieved in modified-atmosphere packages. Oxygen scavengers have the ability to lower oxygen concentrations within packages to $<0.0001\%$ provided that appropriate oxygen capturing materials and packages with high barrier properties are used [Brody et al., 2001]. Such low oxygen levels can be maintained for extended periods whose duration depend largely on the oxygen permeability of the packaging material [Ramos et al., 2015].

1. Types and classification of oxygen scavengers

Oxygen scavengers are also referred to as oxygen absorbers or, less commonly, deoxidizers. An overview of oxygen scavenger types varying in terms of material composition, chemical and physical mechanisms of oxygen binding, scavenger form (sachet, labels and extruded molds, film), the speed of oxygen removal, etc., is provided in review articles by Foltynowicz [2018], Gaikwad and Lee [2017] and the reference literature cited therein.
The oxygen scavenger market was worth USD 1.8 billion in 2016 and is forecasted to reach USD 2.41 billion by 2022, with projected increases expected to proceed between 2017 and 2022 at the cumulative annual growth rate of 5.1% [Anonim, 2017]. While oxygen scavengers may be growing at a slower rate than active, intelligent and smart packaging (whose estimated cumulative annual growth rate between 2011 and 2021 has been reported and is projected to be 7.7%), their share of the packaging market is nevertheless set to reach 10%. Between 2011 and 2021, the sales of active, intelligent and smart packaging worldwide are projected to rise from USD 11.7 billion in 2011 to USD 25 billion in 2021 [Harrington, 2011].

2. Patents

The growing significance of active and intelligent packaging and its promising projections for future growth inspire interest in such systems, reflected not only in scholarly literature but also, and most significantly so, in the choices made by traders and other entrepreneurs. What counts for them is not only the way in which problems are solved but also the practical applications, development trends and legal restrictions. Some of the related dilemmas may well be resolved by examining patent information.
Patents play a vital role in today's economy. They contribute to the dissemination and effective use of patented technologies, foster innovation and help reward research efforts [Moser, 2013]. Surveys and analyses of patent registers are crucial for innovation planning

and management. They offer insights into the state of technology that results from the legal status of the patented property as well as patent scope or reach. Patent analysis also allows entrepreneurs to formulate appropriate business strategies early in the innovation cycle. Bibliographic data can be used to identify active areas of research and the organizations that operate in them [Lee at all., 2011]. The economic significance of inventions is evidenced by the fact that inventors apply for international protection in the PCT - WO or EPO system and can be demonstrated by citation analysis [Foltynowicz, 2011].

The aim of the study was to analyze the patent information available on oxygen scavengers used in food packaging. The relevant patents were found in the Lens [2017] and the Thomas Reuters patent databases. The study timeframe is 1970 to 2015. Patent publications are additionally correlated with the number of articles published in scientific journals. Such publications were found in the ScienceDirect database. A decomposition analysis was performed by the methodology presented by Fujii [Fujii, 2016].

3. Discussion of outcomes

Figure 1 shows the number of patents and the number of publications on food packaging. An analysis of the data in the graph shows clearly that interest in the new systems rose markedly around the year 2000. This is particularly true for interest expressed in scientific journal articles, of which almost 15000 annually have been published in recent years.

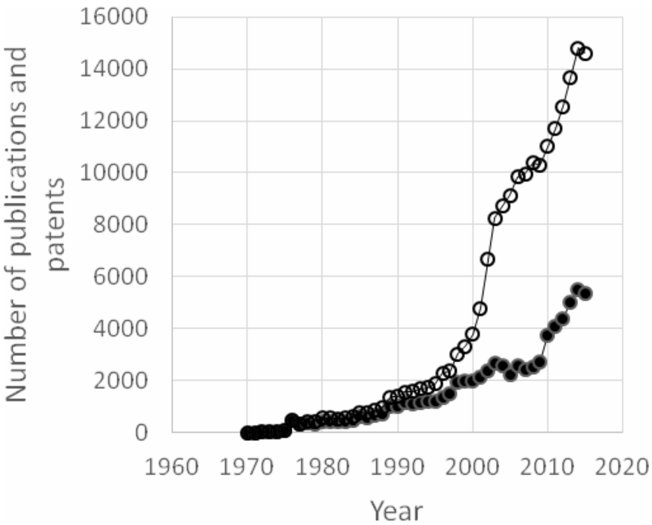
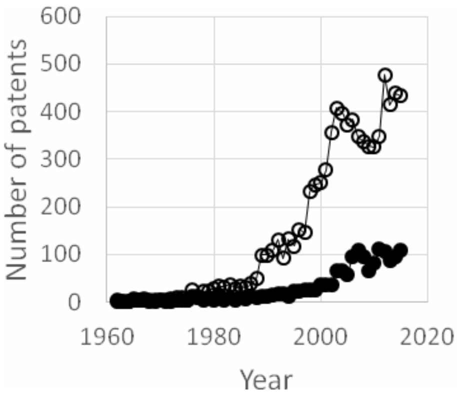


Fig. no. 1. Number of publications in scientific journals and number of patents on food packaging (keywords: food, packaging; ○ – publications, ● – patents)

Source: Own research

For the sake of comparison, Figure 2 shows the number of patent applications and patents granted for active and intelligent packaging. The data reveal similar upward trends for both active and intelligent materials. It should be noted, however, that the quantities of the latter are considerably smaller in absolute terms. It also appears that the number of patent applications and patents granted for active packaging has reached its peak in recent years, while the number of patents for intelligent packaging seems to continue to climb steadily. Interest in such systems is growing and yet, in absolute numbers, it remains substantially below the number of patents on active packaging. Figure 2 does not show the numbers of articles on such systems that have appeared in trade magazines, as many of them do not refer directly to “active” or “intelligent” packaging in their keywords and instead use the chemical names of active substances, the names of microbes, etc. even where the systems they describe meet the definition of active or intelligent packaging.



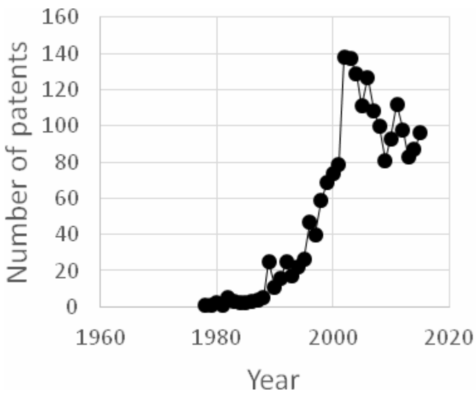


Fig. no. 2. Number of active and intelligent packaging patents (○ – active packaging, packaging patents (○ – active packaging, ● – intelligent packaging)

Source: Own research

Fig. no. 3. The number of patents on oxygen scavengers according to the Lens database.

Source: Own research

As mentioned earlier, the sales of oxygen scavengers account for ca. 10% of the total market for active, intelligent and smart packaging. However, interest in the latter, as expressed through patent applications, is clearly greater: for instance, 326 active packaging systems, 100 of which concerned oxygen scavengers, were patented in 2010 (Figure 3).

An analysis of the Thomas Reuters patent database covering the period from 1994 to 2013 showed over 3,000 patents and patent applications for oxygen scavengers. During the same period, the Lens database reported nearly 1,900 such items. The discrepancy is highly pronounced. According to the Thomas Reuters Patent Database, oxygen scavenger patenting rose until 1990 and plateaued throughout the following decade only to fall sharply in 2000. Meanwhile, a search of the Lens database shows that both patent applications and patents granted leveled off. The active packaging sector and the related research had been on the rise for decades. Such packaging first appeared in Japan, then spread to the US and finally, considerably later, made its appearance in Europe. The literature explained the lag with the absence of appropriate legislation and predicted accelerated growth in the European Union once Framework Regulation 1935 of 2004 of the European Parliament and the Council enters into force [EU, 2004]. It nevertheless appears that the data provided in Figure 3 fail to support these forecasts. No significant increase in patent publishing has been noted since the above date. Neither has there been a significant rise in the number of patents granted in the EU member states. The U.S. remained a patenting leader while China advanced to second place.

To identify the factors that influence the number of oxygen scavenger patent applications, use was made of LMDI decomposition analysis [Fujii, 2016] to examine the overall number of food packaging patents and the number of patents specifically concerned with food packaging. The indicators employed for this purpose show priority given to research oxygen scavengers (PRIORITY 1), priority given to food packaging tests (PRIORITY 2), and total patent applications (TOTAL). PRIORITY 1 is a ratio of scavenger patent applications over total patent applications for food packaging, whereas PRIORITY 1 shows patent applications for scavenger food packaging divided by total patent applications. These ratios rise where increases in the number of oxygen scavenger patent applications outpace those in the total food packaging patent applications, showing that their inventors focus on scavenger systems giving them a higher priority. The “TOTAL APPLICATIONS” indicator shows total patent applications for food packaging reflecting the overall R&D effort in the field.

The distribution analysis was made by Equation 1

$$POCH = \frac{POCH}{TOT\ FOOD\ PACK} \cdot \frac{TOT\ FOOD\ PACK}{TOTAL} \cdot TOTAL = \frac{PRIORITY\ 1}{PRIORITY\ 2} \cdot \frac{PRIORITY\ 2}{SKALA} \cdot SKALA \qquad (1)$$

where: *POCH* denotes the number of oxygen scavengers patents, *TOT FOOD PACK* denotes total food packaging patents and TOTAL denotes the total number of all patents.
To compare changes in different periods, use was made of the following ratio (Equation 2):

$$\frac{POCH^t}{POCH^{t-1}} = \frac{PRIORITY\ 1^t}{PRIORITY\ 1^{t-1}} \cdot \frac{PRIORITY\ 2^t}{PRIORITY\ 2^{t-1}} \cdot \frac{SKALA^t}{SKALA^{t-1}} \qquad (2)$$

where: t denotes a given period, and t-1 denotes the period that precedes it. After computing the logarithm of and multiplying both sides of the equation by coefficient

$$\omega^t = \frac{POCH^t - POCH^{t-1}}{\ln(POCH^t) - \ln(POCH^{t-1})}$$

the following equation was produced (Equation 3):

$$\Delta POCH^{t,\,t-1} = \omega^t \ln\left(\frac{PRIORITY\ 1^t}{PRIORITY\ 1^{t-1}}\right) + \omega^t \ln\left(\frac{PRIORITY\ 2^t}{PRIORITY\ 2^{t-1}}\right) + \ \omega^t \ln\left(\frac{SKALA^t}{SKALA^{t-1}}\right) \qquad (3)$$

The resulting relationship makes it possible to examine patenting activity for interest in the systems in question and the extent of the total food packaging research. The priority given to scavenger research is revealed by the PRIORITY 1 indicator, placed on the right side of the equation. The PRIORITY 2 indicator shows the impact of food packaging research while the final indicator reveals the impact of the extent of such research.

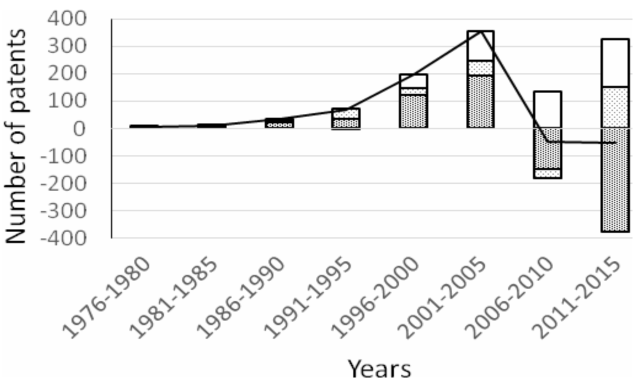


Fig. no. 4. Impact of the importance of packaging systems and total patenting activity on the number of inventions patented over five-year periods (the continuous line denotes change in the number of patents, ▩ change in the number of scavenger patents resulting from shifts in importance, ▨ change in the number of patents resulting from interest in food packaging, and ☐ shifts in the extent of patenting activity**)**

Source: Own research

As shown in Figure 4, the number of patents rose until 2005, propelled by increases in the overall patenting activity and in patenting activity related to food packaging in particular, as well as a sharp rise in interest in oxygen scavengers. However, while activity related to food packaging patents has grown continually since 2005, the share of oxygen scavenger patents declined markedly during that period.

The drop in the absolute number of both polymer- and iron-based oxygen scavenger patents, as shown in Figures 5, may suggest declines in interest in oxygen-scavenger-related research. However, it is also conceivable that the main oxygen-scavenger-market players increasingly choose to protect their inventions through know-how to prevent imitations of their products. Such periods of patenting inactivity have already been observed, e.g. from 1990 to 1994 [Brody et al., 2001] when only 20 packaging-related oxygen scavenger patents were granted. After such period, usually there is a flood of new solutions. Such solutions seem to be nanomaterials, which, as well as of nanotechnology application in food packaging and food safety is continuously increased [Duncan, 2011]. The most recent patents and scientific works have been discussed by Angiolillo et all. [2018] with emphasis on the use of nanotechnology for the development of new packaging materials with improved barrier and other properties with a closer look to the application of nanotechnology applied to the food packaging sector. Also in the field of oxygen scavengers such research are successfully carried out [Foltynowicz et all., 2017a] and patent protection has been already obtained for the developed solutions [Foltynowicz et all., 2011; Foltynowicz et all., 2017b].

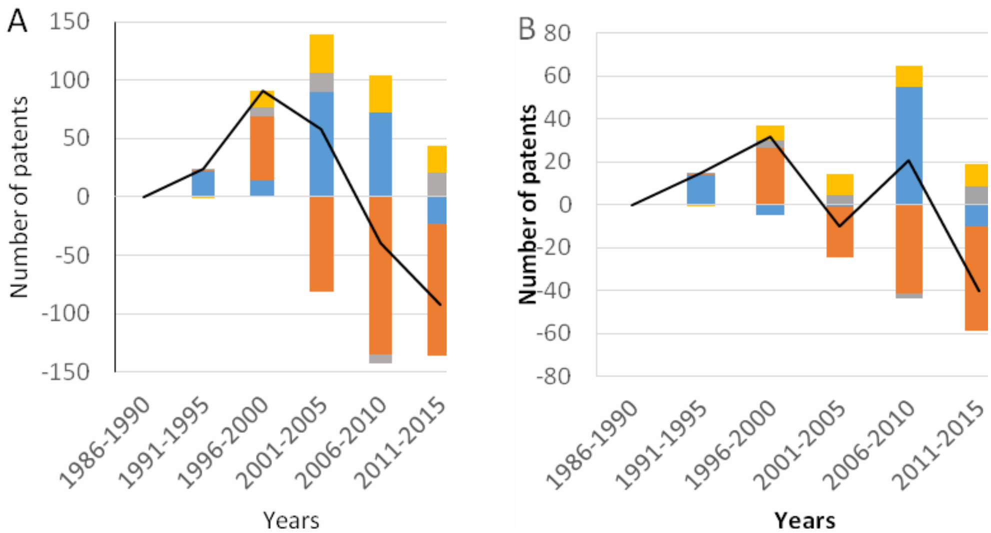


Fig. no. 5. Impact of the importance of packaging systems and total patenting activity on the number of patented polymer-based (A) and iron-based (B) scavengers *(the continuous line denotes change in the number of patents, ■ change in the number of patents related to iron- / polymer-based scavengers, ■ change in the number of scavenger patents resulting from shifts in importance, ■ change in the number of patents resulting from interest in food packaging, ■ shifts in the extent of patenting activity)*

Source: Own research

Conclusions

A study of patent trends can help explore newly-developed technologies, quickly recognize the threats that result from the research and development efforts of the competition, identify the related opportunities and set one's own organization on the most advantageous course of development. The analysis of databases concerning oxygen scavengers has shown that interest in research on such products peaked at the turn of the century. Recent declines in the related patent numbers may reveal that researchers have set their sights on other packaging systems and/or that new innovative solutions have been developed for which industrial property protection is only now being obtained, suggesting that a surge of relevant patent applications may be imminent.

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