COMMODITY SCIENCE IN RESEARCH AND PRACTICE

INNOVATIONS IN PRODUCT DEVELOPMENT AND PACKAGING

EDITED BY AGNIESZKA CHOLEWA-WÓJCIK & AGNIESZKA KAWECKA

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Contents

Innovation is the specific instrument of entrepreneurship

Peter Drucker

Undertaking innovative activity through launching new products on the market is a key factor in competitive economic environment. The packaging sector belongs to industries that show highly dynamic development and high diversity in product innovativeness. This is connected mainly with increased product functionality, ergonomics of economic and ecological values but also with changing get-up of the packaging (packaging reflects trends, determines novelty of product offer, identifies the brand). Thus, the modern packaging has to fit to all aspects of sustainable development, i.e. social, economic and environmental dimensions.

Increasing customer's requirements and needs for products in innovative packaging are a key factor shaping the packaging market sector. Dynamic development in the packaging sector induces permanent looking for new packaging solutions to gain competitive edge on the market. This induces the desire for staying ahead of customer's expectations and providing them with new additional benefits became the warrant of the innovativeness of market offer.

The monograph entitled **"Innovations in product development and packaging"** is a part of "Commodity Science in Research and Practice" series. Its objective is to present commodity science achievements related to the packaging industry and innovations in product development.

The monograph contains 17 chapters written by the Authors from European commodity science centres.

In individual chapters the Authors deal with widely understood innovation and packaging issues.

The monograph has been published to present the packaging topics and problems related to creation of the innovation in product development. This monograph may be a compendium of knowledge for practitioners and theorists of economic sphere as well as economics students.

Agnieszka Cholewa-Wójcik
Agnieszka Kawecka

THE MODERN TREND IN ROMANIAN HOTEL RESERVATION – AN EVOLUTION TOWARDS ONLINE BOOKING

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Introduction

Tourism products are constantly changing and are increasingly characterized by innovation. With the development of Internet, tourists began to change their behavior, moving away from traditional services. Their wish to use technology in their interest is obvious, given that in the 23 years since the first website appeared (Stanescu 2012), development has increased exponentially.

Differences between traditional tourism and e-tourism are numerous. The traditional system of promoting and selling tourism products loses more ground because of the main features: it often gives the impression of lack of transparency and lack of control by the client because the meeting ground and decision-making ground always belong to the agent.

Also, the limited number of offers and the waiting time until receiving the confirmation constitute other features. All of these bother the traveler who is nowadays more accustomed to seeking information by himself and trust the opinion of others tourists more than those of specialists.

Emergence of websites and their development have made the distances not be an obstacle anymore. Reservation systems and search engines became easier to use and now any person who wants to travel can become his own agent.

The benefits are of course, for all parties involved. Speaking only about accommodation, both hotels and tourists have advantages because hotels can make their offer known to the world, and tourists have easy access to a wide variety of offers. These changes have caused the appearance of websites dedicated to the tourists: reservation sites such as Booking.com, Expedia.com, reviews sites such as Tripadvisor.com and websites which help hotels improve their online ratings (http://www.trustyou.com/). All of these have contributed to a widening of the tourist market.

It can be said that innovation in the accommodation segment had a great impact on the entire tourism business. In a field which is present in humans' lives for over 2000 years, the changes that came about in less than 20 years forced everyone involved to adapt. The tradition in travel services started to be rewritten and companies with little experience in the market such as Expedia -15 years, Booking.com -18 years, Tripadvisor.com - 14 years in comparison to travel agencies like Thomas Cook - founded in 1841 (http://www.thomascook.com/thomas-cook-history/) are the ones who influence the market most.

But innovation in this area is not a result of intense research in tourism. It coincides with innovation in the field of websites and it can be said that tourism is one of the areas which took the best advantage from technology. The tools that can be added to customize the presentation of a hotel are often adaptations of tools already in existence. For example, the location on the map is a very common tool on web pages but a search engine for hotels by their location is a tool adapted to the tourism industry (Sigala & Marinidis 2009).

When we refer to a hotel website the following question arises: what tools should it contain to meet user requirements? Well, besides the classic presentation, it is advisable to include a booking engine. Thus customers can book directly on the hotel website and are encouraged to make the decision at the time of payment. The ones who take the advantage most of this situation are the hotel chains; the individual hotels do not exploit this opportunity to its full potential. This is also reflected by the income source - which is still represented by small travel agencies for smaller accommodation units (Schmidt, Cantallops & Pizzutti dos Santos 2008). Providing website customers with a booking engine brings another benefit besides increasing the number of reservations: automatic credit card verification. This way the hotel does not lose money from accepting credit cards that are subsequently proven to be false (Carr 2010).

The novelty in the tourism industry is that innovation has enabled the tourist to have an active role: in traditional tourism, the traveler is just a client and his interaction with that unit is limited only to the period of residence. Nowadays the tourist is an extension of his experience, being able to share it with anyone. Moreover, he can provide evidence to support his opinions, such as images or videos.

Those who publish their reviews on specialized websites or hotel website have several reasons, such as a desire to help, the desire to be noted as experts or to even to obtain benefits from the hotel (Tian 2013). A study about 398 Danish and Norwegian tourists returning from vacation proved that the highest percentage - 40% were motivated in writing reviews by the desire to help other tourists (Munar & Jacobsen 2014).

The power of reviews is known both by tourists and hoteliers. What is important is that 81% of tourists consider reviews to be important, 46% post such comments and 49% say they do not consider a hotel if it has no reviews (http://www.villamarketers.com/community/vacation_rental _marketing_reviews /). The fact that these comments can redraw the trajectory of a unit is highlighted by a study done in China in 2008 on a national website of opinions: ctrip.com. It included over 3625 reviews and 248 hotels. It has shown that positive opinions about hotel may increase the level of reservations: a 10% improvement in the reviews lead to an increase of 4.4% in sales (Ye, Law & Gu 2009).

Taking into account all these aspects, we consider innovation in tourism important for everyone. It helps all the parts which are involved and promises transparency increasingly higher.

TripAdvisor and Booking.com - Leaders of the new tourism trend

According to their website, www.booking.com was established in 1996 and it now has 115 offices in 50 countries worldwide. Wanting to attract as many customers as possible, the website has its content translated in over 40 languages and it offers over 434,738 accommodation units in 200 countries. It also offers its users free booking applications for smart phones available on both IOS and Android operating systems.

Customers who use this booking site have the following benefits: increased security for online transactions, the absence of a booking fee and the lowest price offers. Since many tourists decide on their purchases based on the comments listed here, it is very important for the company to be sure that the comments are all real. Because of this, a review can be posted online only by users that had a reservation made and stayed at least one night at that hotel.

The benefits are not just for tourists. Hotels and other partner agencies have the opportunity to benefit from this collaboration. Booking.com enables anyone who owns a website to become an affiliate partner, being paid on commission.

According to the website tripadvisor.com, it is the largest travel site and registered in 2013 a monthly average of 260 million unique visitors and over 150 million reviews posted. TripAdvisor is not a booking site but it helps travelers plan for a successful holiday and it helps hotels reach a wider audience.

The company's reputation has grown so much that accommodation units display TripAdvisor certificates at their reception office. Depending on the criteria which a unit meets, it is given one of the following certificates:

Certificate of Excellence – businesses must maintain an overall rating of four or higher, out of a possible five, as reviewed by travelers on TripAdvisor. Additional criteria include the volume of reviews received within the last 12 months (http://www.tripadvisor.com/PressCenter-i5199-c1-Press_Releases.html)

Travelers' Choice awards are the highest honor TripAdvisor can bestow. Travelers' Choice award winners are selected annually based on feedback from millions of TripAdvisor members (http://help.tripadvisor.com/articles/200613977-What-is-Travelers-Choice-)

In addition to these certificates which can be obtained in accordance with ratings, Tripadvisor offers other free elements that can be posted on the hotel's website:

- Rated on TripAdvisor Badges
- Review Snippet Widget
- "Bravo!" Badges
- What's Nearby? Widgets
- Write-A-Review Widgets
- TripAdvisor App for Facebook Pages
- GreenLeader Widgets (http://help.tripadvisor.com/articles/200615417)
- Award Badges
- Logo Button Widget
- Linking Widgets
- Rave Review Widgets

Thus, Booking.com and TripAdvisor.com are an integral component of the current trend of bookings and travel planning, being preferred by tourists from around the world over traditional travel agents. Hotels collaborate with them, taking advantage of the opportunities that may arise on such public platforms and post on their website or at their reception office certificates as proof of this partnership.

Material and methods

Starting from the fact that more and more tourists are planning their holidays on the internet and strongly considering the views of other users, we wanted to find out how do the hotels from Bucharest fare in regards to this topic. We have considered a quantitative and descriptive study about 148 hotels from Bucharest which were presented on Booking.com at the date of the research, with the comfort level between 2 and 5 stars. We also have included in our research the presence of the accommodation units on TriapAdvisor and the utility of their websites.

The hypotheses from which we started are the following:

(P1): A unit of accommodation which posted its offer on a booking site has its own website.

(P2): The hotel websites have their own booking system.

(P3): On Booking.com the rates are lower than those posted on the hotel website.

(P4): The hotel ratings from Booking.com do not differ from the ones on Tripadvisor.

For each of the four research hypotheses we considered several secondary objectives:

- To investigate the booking website we took into consideration the rate room, the total number of reviews and the final score;
- For each hotel website we considered the rate room, the possibility of making a reservation and the possibility to close the deal on the reservation on the website.
- To research TripAdvisor site we considered the number of comments and total score results.

The study was carried out between 02 March 2014 and 15 March 2014, making simulations of reservations for the night of 4-5 April 2014. The prices were compared in euro, and the rooms compared in this study were the same type of room.

Results

The hotels from Bucharest included in this research that collaborate with Booking.com are structured in regards to their comfort level in accordance with Fig.1.

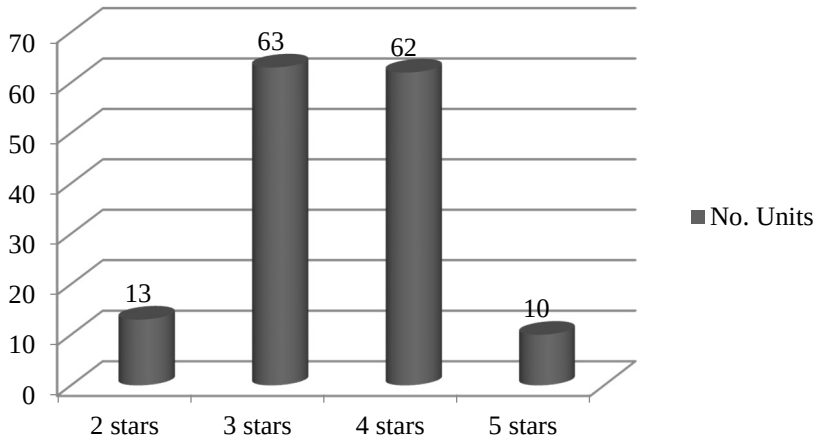

Figure 1. The hotels structure according to the level of comfort

Source: Developed by authors based on the research in March 2014

The most accommodation units are 3-stars hotels, followed by 4 stars. The number of 5 stars hotels is quite high - 7% and is largely due to the entry of chain hotels on the Romanian market through franchise or management contracts.

The research of the four hypotheses revealed the following results:

- Regarding the first hypothesis (p1), the research showed that all 148 Hotels on Booking.com at the time of the study had their own site.
- The results of the second hypothesis (p2) showed that not all hotel websites from Bucharest have a reservation system available, this situation being shown in fig. 2. The most notable results are met at 3 stars and 5 stars units.

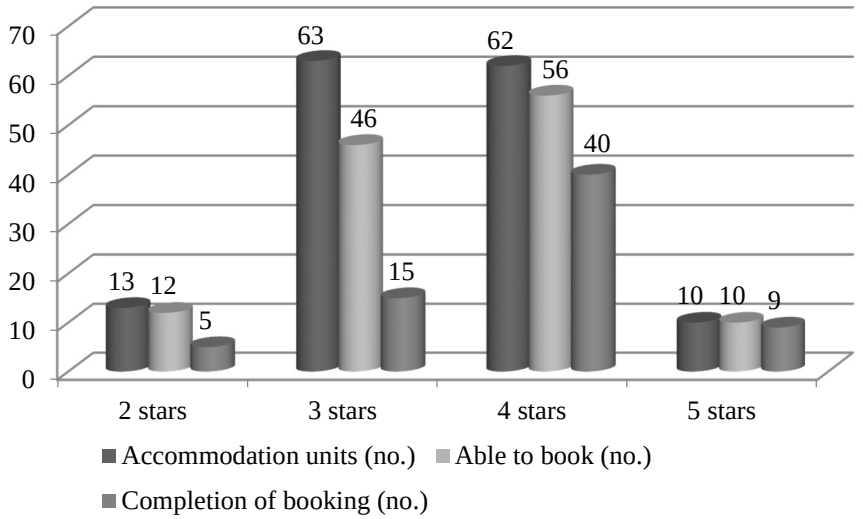

Figure 2. The reservation system of the hotels according to the level of comfort

Source: Developed by authors based on the research in March 2014

The 5 star hotels are those that have the most comprehensive website, allowing a booking in 10 cases of 10 and its finalization with confirmation in real time in 9 cases. This can be explained by the fact that they reach a targeted segment of customers who have high demands and they expect to have a wide range of services available, especially the possibility of online booking. At the opposite pole are the 3 star hotels that have a low level on both booking aspects. Only 15 of the 63 websites, about one in three, allow their costumers to book online and to pay by credit card from their website.

Presenting the results in percentages, of the total of 148 hotels, 83% have a reservation form. But only 47% allow the booking to be finalized, providing

a ferm confirmation. The remaining 17% of sites only allow reservations by phone and their prices are presented in a table, without any regards to dates.

- The third hypothesis (p3) made was that the rates on booking sites are smaller than those on the hotel websites. Not all accommodation units could be analyzed, because 21 of the sites did not have prices posted online. In this situation, the customers have to contact the hotel by e-mail or phone to find out that information. Thus only 127 units remained for comparison. The analysis of the data showed that in 33% of cases the rates from Booking.com are higher than those from the website. The situation in regards to the booking prices and according to the level of comfort is shown in fig. 3.

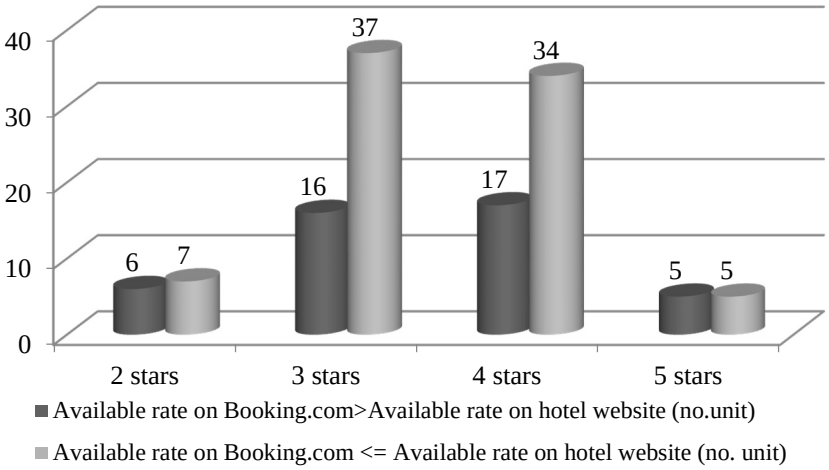

Figure 3. The rates situation according to the level of comfort

Source: Developed by authors based on the research in March 2014

The analysis showed that for each comfort category some hotels sell rooms more expensive on their website than on Booking.com. The categories that have almost the same number of units in each of the 2 possible situations are the 2 star hotels and 5 star hotels – 50% of units have higher rates on Booking.com.

On the 3 star and 4 star hotel websites, the situation is different; in percentage, 30% and 33% respectively, advertise higher prices on Booking.com. The average difference in higher prices on booking.com compared to the hotel website is 6.25 euro and the average difference in higher prices on hotel website and booking.com is 7.47 euro.

- The fourth hypothesis (p4) focused on the hotel ratings from the booking website and from TripAdvisor. We started from the idea that the score should be similar. However, the results removed this assumption right

away, just by analyzing the number of comments. On booking.com the average of comments was 137 and on TripAdvisor was 72.68. Regarding the number of hotels that do not have any comments, there was a single case on Booking.com and 18 cases on TripAdvisor.

In order to compare the results, we transformed the scores from the booking website, multiplying the final grade by 10, ie 9.2 grade became 92. Fig. 4 presents the situation of comments from the 2 analyzed websites.

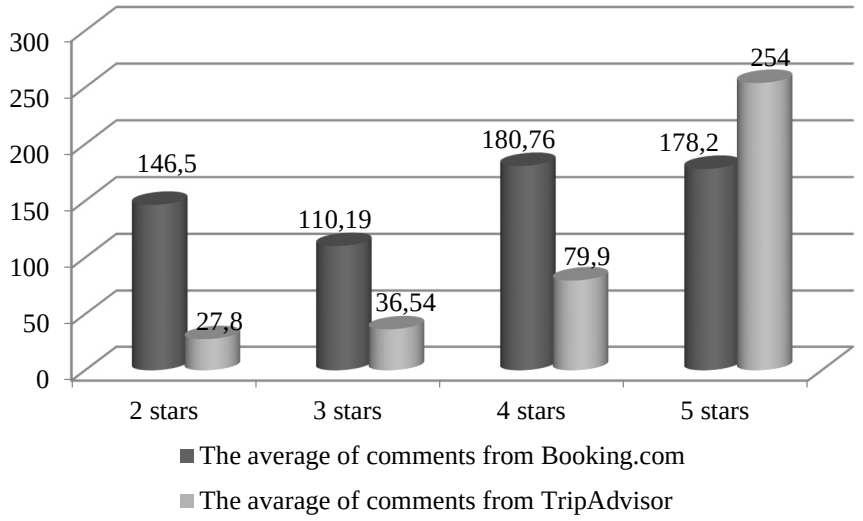

Figure 4. The hotel ratings average acording to their level of comfort

Source: Developed by authors based on the research in March 2014

It can be noticed that the comments made on TripAdvisor follow a specific trend - the average increases with the degree of comfort: the fewest comments are made for 2 star hotels and most for 5 star hotels. On the other website, the comment average does not follow a pattern, for this time the 4 star hotels have the most views, followed by the 5 star hotels. So, we can say again that the units with a higher degree of comfort - 4 and 5 star have the most attention from tourists.

Looking at the averages of the two websites, it was obvious that the only instance when TripAdvisor has more reviews is for the 5-star establishments, otherwise the situation changes and the differences are even almost 7 times lower.

There are also some differences in regards to the hotel ratings on the two websites: the ratings from Booking.com are higher, regardless of the degree of comfort provided by the accommodation units. This situation is illustrated in fig.5.

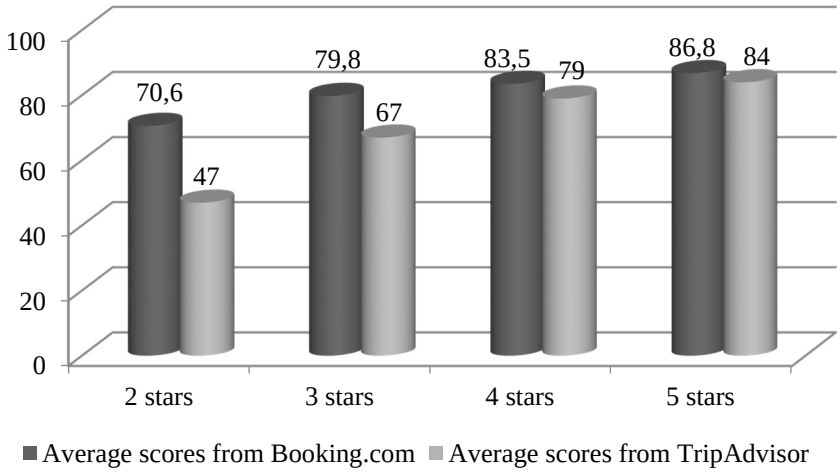

Figure 5. The average ratings of the hotels according to the level of comfort

Source: Developed by authors based on the research in March 2014

The biggest variance of ratings is registered in the case of the 2 star hotels. From a maximum of 100 points, the rating average on Booking.com was 70.6 and on TripAdvisor 47. In the situation of the others levels of comfort this trend continues, which means that those who write comments on the review website are more demanding than the users of the booking website and have higher expectations from accommodation units.

The analysis of the four hypotheses proved that the hotels from Bucharest take advantage of the opportunities given by Internet. Even though almost half of the tourists prefer informing themselves from the review websites, in the case of the Bucharest hotels included in this research, the ratings are not the same on different websites, with notable differences being recorded at times. Therefore, a new problem arises: the confidence generated by the information posted on the internet.

Advantages and limitations of research

Advantages of the research converge from the fact that the analysis was done in the online environment, so we were able to evaluate 148 hotels in a short time (about 13 h and 30 min), taking advantage of the non-stop availability of the websites.

Research limitations come from the fact that not all units from Bucharest were included, but only those present on the Booking.com website. Also, the

fact that not all the accommodation units from TripAdvisor had enough reviews limited the research results, forcing us to reduce the number of hotels included in the analysis of the reviews and ratings levels.

Considering that online bookings and the reviews posted on specialized websites are subjects for research with many research papers investigating this area, such a study done in an Eastern European capital is welcome. Based on the results of this study, the research can be continued at a country level and the results can be compared with those from another European country similar to Romania-e.g. Poland.

Conclusions

From this research conducted on 148 hotels from Bucharest with the level of comfort between 2 and 5 stars the following results can be noted:

- All the hotels included in the study have their own websites;
- In 83% of cases, the hotel websites have a reservation form. The rest of 17% allow only for phone booking;
- 47% of units have a modern booking system on the website which allows payment by credit card and provides a real-time confirmation;
- 33% of the hotels have higher rates posted on Booking.com than the ones posted on their website and in this situation the difference is 6.25 euro. In the cases where the rates are higher on the hotel website, the difference is 7.47 euro;
- Regarding the comments made on Booking.com and TripAdvisor, there are significant differences from website to website. The average of the comments made on the booking website is 137 and the average of the comments from the reviews website is 72.68;
- The ratings are also different. Whatever the level of comfort, the ratings on Booking.com are higher than the ones on TripAdvisor and the biggest difference is in the case of 2 star hotels.

This research shows that the presence in the online environment is important for the units included in this study. Even though one out of 2 tourists is interested in reading the opinion of others about a hotel, the research results show that the comments' accuracy can't be taken for granted since there are significant differences from website to website. The result is slightly predictable because of the subjective aspect of these reviews which can eventually affect the final score of a hotel.

Thus, the evolution in the tourism industry caused by the developments in IT is spectacular managing to transform this sector in less than 20 years. Even if the lack of transparency in regards to tourism has decreased and the internet now allows the tourist to get an accurate impression of a destination ahead of time, we cannot say that there is a perfect overlap between what a tourist desires and what he may purchase, as of yet. But the first steps in this

direction have already been taken and the results are now available to everyone who has a mobile device with internet connection.

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PRODUCT INNOVATION MANAGEMENT VIA PATENT LANDSCAPE

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Introduction

At first Product Lifecycle Management (PLM) was established typically for the manufacturing process. Product lifecycle management is a systematic approach to managing the series of changes a product goes through, from its design and development to its ultimate retirement or disposal. The goal of PLM is to eliminate waste and improve efficiency. Product Lifecycle Management can be defined in numerous ways (Aras 2014).PLM is associated with manufacturing, but the management structure can also be used for product development and service provision.

Product lifecycle management (PLM) should be distinguished from Product Life Cycle Management (PLCM) applied in marketing. How earlier was already recalled, PLM describes the engineering aspect of a product, from managing descriptions and properties of a product through its development and useful life; whereas, PLCM refers to the commercial (marketing) management of life of a product in the business market with respect to costs and sales measures. Integration of engineering, manufacturing and marketing metrics resulted in fully integrated PLM systems.

At present Product lifecycle management is an extensive approach for the innovation, the new product development and introduction and information management of the product from the ideation to the end of life. Product Lifecycle Management (PLM) as it is defined today, both within and among enterprises, is a growing focus in the industry.

Those capturing new market share have shifted from traditional Product Lifecycle Management (PLM) to the management of engineering intellectual property (IP) as a set of corporate assets. Thus, the ability to offer a New Product Introduction (NPI) is being governed through asset management of engineering IP.

In today's competitive industry environment, companies must focus simultaneously on innovation and operational efficiency. Intellectual Property

(IP), the main engine for profit and industry growth, must be accessed throughout the value chain (Xavor 2014).

On the more and more competitive and global market, it is more important than ever to capture the full benefits of innovation by making IP protections a core part of a company's strategic performance. Very often, the protection of intellectual property is not regarded as legal issue. The typical approach is to form a strategic plan, invest in research and development, produce and launch products and only then consider IP issues such as patentability and freedom to operate. In order to be effective, strategic planners and business managers must identify and secure the opportunities afforded by intellectual property much earlier in the innovation cycle, and then formulate and implement business strategies to handle potential IP risks before those risks appeared.

Patent landscaping as a business strategy

Patent landscaping has been widely characterized by Lee et all. (Lee 2011) in the review paper. This publication was a base below patent landscape describing.

One key to effective innovation planning and management is patent landscaping which can be defined as a competitive view of a technology area as seen through the light of patent ownership and patent coverage or scope.

Companies can use an effectively constructed patent landscape or patent mapping to identify risks and opportunities posed by IP-based issues, and to formulate responsive business strategies early in the innovation cycle.

Information from and about patent documents is becoming increasingly useful in a large number of areas, including research strategy and the search for potential business opportunities and licensing partners. Patent mapping allows creating a visual representation of information from and about patent documents. Using bibliographic data it is possible to identify which technical fields particular applicants are active in, and how their filing patterns and IP portfolios change over time. It is also possible to find out which countries are leading in which fields.

Companies can use patent landscape research to identify risks and opportunities caused by IP-based issues follow by formulation of responsive business strategies early in the innovation cycle of product development.

Patent landscape reports describe the patent situation for a specific technology in a given country or on the global level. They usually start with a state-of-the-art search for the technology of interest in suitable patent databases. Patent landscaping is a review of the technology related to a particular field. It enables to group the technology in the given area. The most

common technique is to organize technology according to a public index such as the US Patent and Trademark Office's technical classifications or the International Patent Classification.

The results of the search are then analyzed to answer specific questions, e.g. to identify certain patterns of patenting activity like: who is doing what or what is filed where? Certain patterns of innovation like: innovation trends, diversity of solutions for a technical problem can be also determined.

The useful feature of a patent landscape is mapping of patent assets to the company or index in order to provide a patent-inspired view of the technology. The patent assets usually include domestic or foreign patents and applications owned by the company's competitors and relevant third parties.

The patent landscape should allow an organization to ascertain areas of interest quickly and provide clarity as to which patents are owned by the client, its competitors and other parties. Patent landscapes often identify companies, technical literature, key engineers/scientists and related products to provide context to the patent data.

An essential component of each patent landscape report is the visualization of these results in order to facilitate their understanding, and certain conclusions or recommendations based on the empirical evidence provided by the search and analysis. Patent mapping (EPO 2014, Pawlak 2010) is a useful way of representing complex patent information. It uses statistical analyses of bibliographic data, along with text mining, to make data accessible. In order to ascertain the maturity of certain technologies or to identify technological trends patent statistics can be used. By comparing the number of applications with the number of applicants, it is possible to identify whether research activities are clustered or scattered.

An indication of the economic significance of an invention can be derived from the internationality of the application like PCT, EPO or USPTO and from citation analysis.

The next feature of a patent landscape is possibility to suggest a course of action that leads to a competitive advantage. A patent landscape enabling companies to identify patent issues and opportunities quickly, and shortening the time required to perform responsive actions. A patent landscape may enable a more efficient and effective prior art search during patent preparation. It may be used to identify areas to be addressed by a development team quickly during product design, and even to suggest an appropriate response to a potential problem, such as designing around a patent or acquiring a license. A patent landscape may also help a client to identify and prioritize potential acquisition targets or patent assertion targets.

A patent landscapes can be performed for essentially any business operation. The most common scenario is supporting the development and release of a new product across phases, avoiding errors and irrelevancies that might otherwise occur. At the phase of Initial product planning a patent

landscape can provide an initial competitive analysis of the companies that are active in a technical field from a patent perspective. At this point, a product may not be well defined enough to perform a freedom to operate or product clearance analysis. The goal of a competitive analysis may simply be to identify the competitors in the product field and to identify areas in which the company may be able to differentiate its product.

On the mid-product phase it is important to determine so called “Freedom to operate”. Patent landscapes reports form a basis for freedom to operate analysis by searching the validity of patents or by referring to legal status data.

A patent landscape can be used proactively to identify potentially relevant patents of some third-party. The efficiency of performed patent landscaping may increases the time available to redesign the product in order to avoid infringement and to obtain legal non-infringement or patent invalidity opinions. If not successful, a company may seek to license or acquire a potentially threatening patent.

However patent landscape can't completely eliminate risk from patent suits but provides a tremendous opportunity for a company to identify and neutralize risks proactively. Every company that makes, sells, offers to sell or imports technology should consider the benefits of a patent landscape. Patent landscapes can therefore be useful for policy discussions, strategic research planning or technology transfer.

Published Patent Landscape Reports

WIPO has been mandated to prepare patent landscape reports in areas of particular interest to developing and least developed countries, such as public health, food security, climate change and environment. Patent landscape reports on various topics have been published by international organizations, national intellectual property offices, non-governmental organizations and private sector entities. WIPO has compiled a list of such reports that are freely available or can be obtained upon request (WIPO 2013).

Exemplary patent landscape will be provided for graphene based on research done by Intellectual Property Office (IPO 2013). Graphene is a nanomaterial with promising exceptional properties. These properties caused, that an interest in this exceptional material was growing very much. The evidence for it is raising quantity of publication and patents. The earliest mention of graphene appears in a patent published in 1994. However, until 1997 only single patents appeared. The profile of patent publications in Figure 1 shows that following a slow take-off of patenting related to graphene in the early 2000s, there has been an almost exponential increase in worldwide patent publications since 2006. It is indicating the immeasurable growth of an interest in this material.

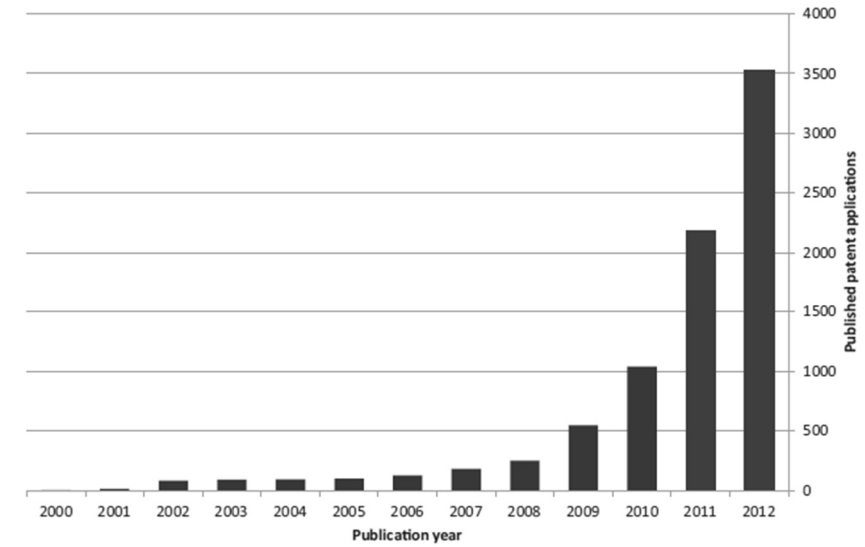


Figure 1. Worldwide patent publications by publication years

Source: IPO 2013

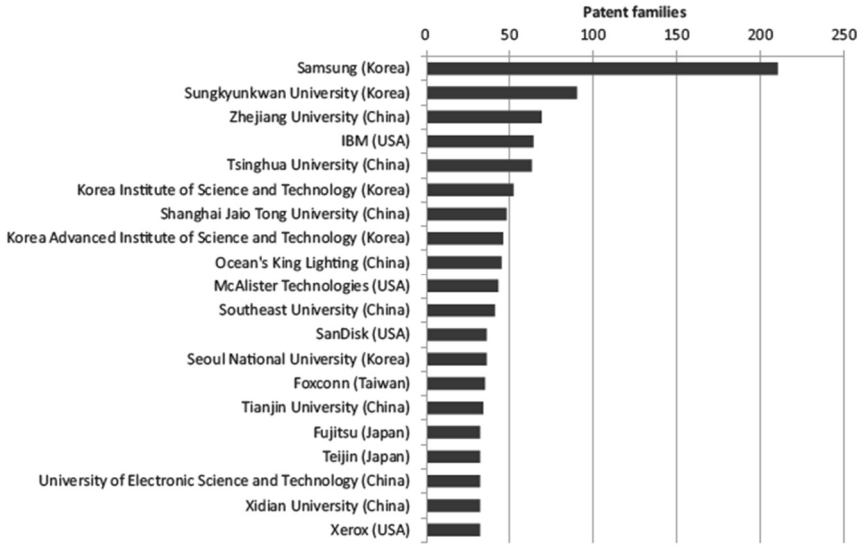


Figure 2. Number of patent families of the top 20 applicants

Source: IPO 2013

Figure 2 shows a chart of overall largest patent portfolios with Samsung being the clear leader with 210 patents. There are as many as 11 universities amongst 20 leaders in graphene patenting. Apart from Samsung many recognizable companies, like IBM, SanDisk, Fujitsu, Xerox, are carrying out

research above this technology. Figure 3 shows that the largest number of application comes from China follow by American, Korean, Japanese and German. In terms of absolute levels of patenting in graphene-related technology, the patent (inventions) from other countries applicants are orders of magnitude behind applicants from the top countries.

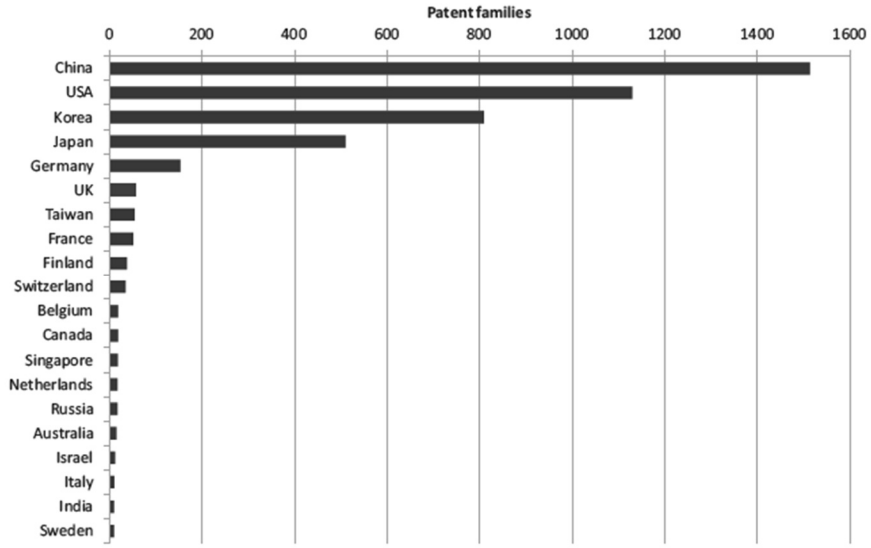


Figure 3. Applicants country distribution

Source: IPO 2013

Patent Landscape analysis of oxygen scavengers

We have known for more than a century that the presence of oxygen is one of the key factors effecting food quality. The amount of oxygen in the packaging can be reduced by increasing the concentration of carbon dioxide and/or another gas (e.g. nitrogen), using modified atmosphere packaging, vacuum packaging, or active packaging with oxygen scavengers(Packaging technology, 2012). Traditional commercial oxygen scavengers are based mainly on iron or its compounds. So far known oxygen absorbents based on iron and its compounds may be used only when at least small amounts of water are present in the packaging, what is limiting factor of their application. New type of oxygen scavengers based on nanoiron has been elaborated and patented (Foltynowicz 2011). Since we are going to commercialize this oxygen scavengers patent landscape have been done in order to establish the situation both in the area of intellectual properties (patents ownerships) as well as main market competitors.

Oxygen absorbents or oxygen scavengers belongs to the class A23L 3/3436 according to IPC-R (International Patent classification Register). The patent landscape is based on the data available from Polish Patent Office as well as European Patent Office. Patent landscaping in different patent basis gives more than 3000 indication of patents and patent pending. It means the great popularity of solutions of this type.

First, a list of companies showing the substantial amount of patent applications and patents was analyzed. The results presented on the Fig. 4 indicate that the Japanese concern Mitsubishi Gas Chemical is a leader of the oxygen scavenger market. Second in turn the Grace Company own over fourfold lower number of applications and patents.

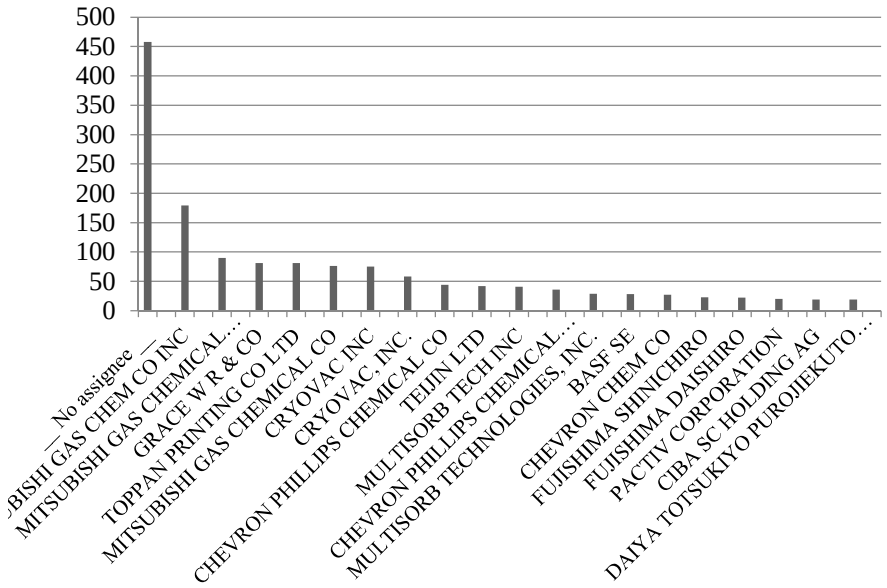


Figure 4. Number of patents from individual companies

Source: Thomson Reuters Patent Database 2014

In the Figure 5 are shown the most active countries in patenting in the analyzed industry. Analyses showed that USA and Japan were leaders of this industry and are much ahead of remaining countries. Essentially the same numbers of patents as Japan have the European countries indicated in the following balance sheet. Poland is holding 8 patents and was classified to 16 positions.

As one can see from the Figure 6 Western European countries are most often indicated for the protection with patents. Even though the majority of patents come from the USA and Japan, these countries weren't indicated as markets with the greatest potential.

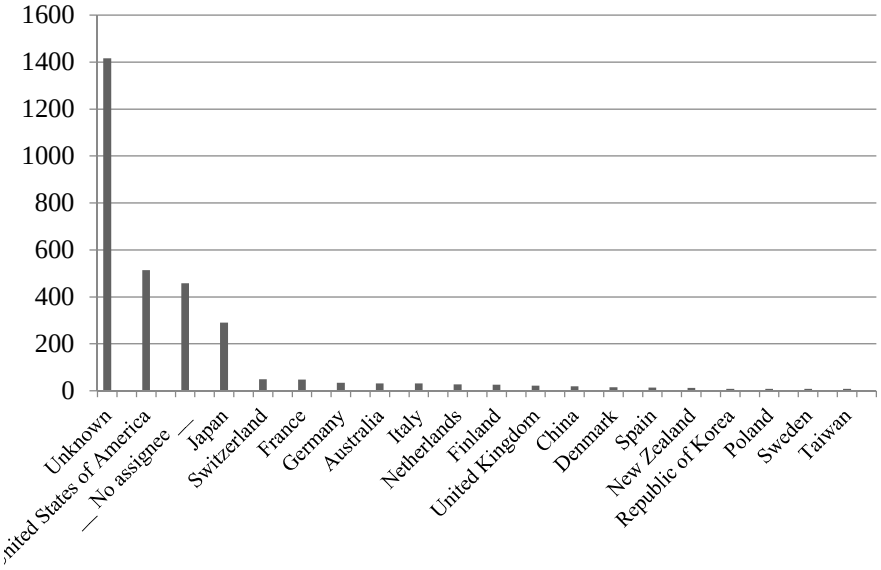


Figure 5. The most active countries in patenting in the analyzed industry

Source: Thomson Reuters Patent Database 2014

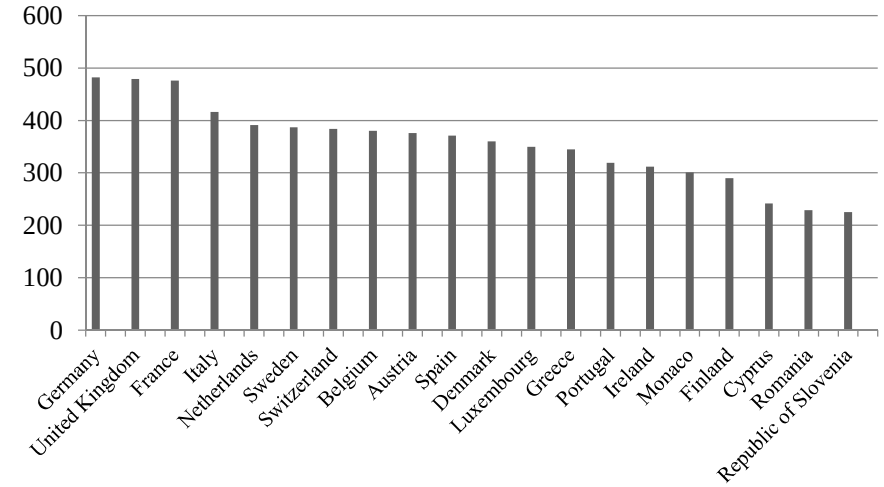


Figure 6. Countries most often indicated for the protection with patents for oxygen scavengers

Source: Thomson Reuters Patent Database 2014

Next a number of patents in last 20 years were examined. Analysis of the number of applications is showing that the subject of oxygen absorbents in the last ten years was far less attractive for the industry than in the end of the previous century (fig. 7).

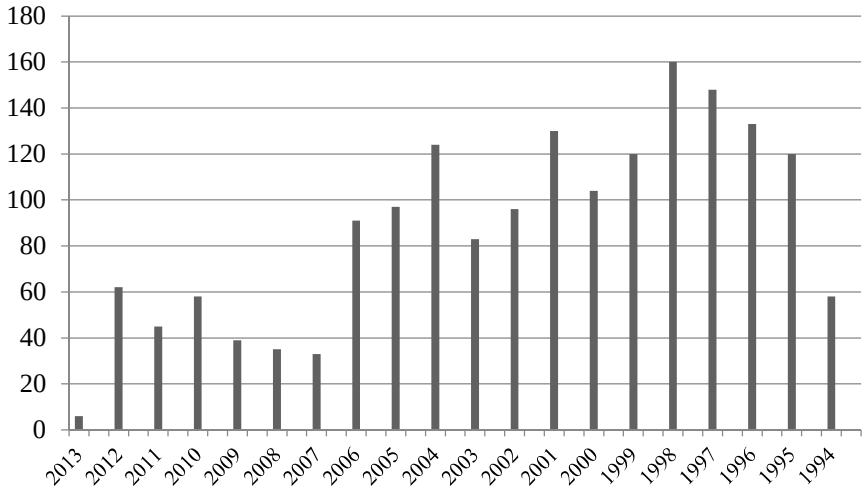
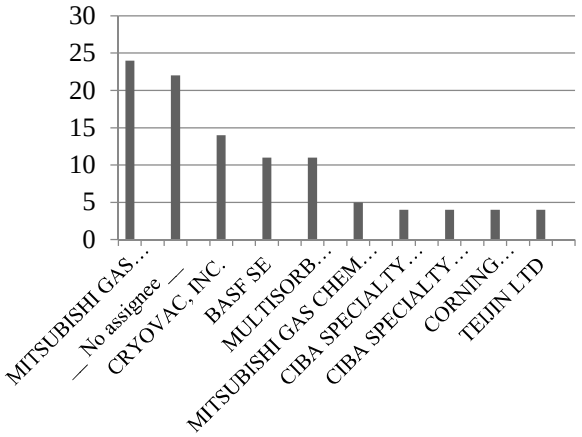


Figure 7. Number of patents in individual years

Source: Thomson Reuters Patent Database 2014



Patent search indicate that 25% of oxygen scavengers for food packaging is based on iron. As one can see from fig.8 Mitsubishi is the leader of this type of oxygen scavengers. Much less belongs to Cryovac, BASF, Multisorb or Ciba.

Figure 8. Number of patents on oxygen absorbents based on iron of individual companies

Source: Thomson Reuters Patent Database 2014

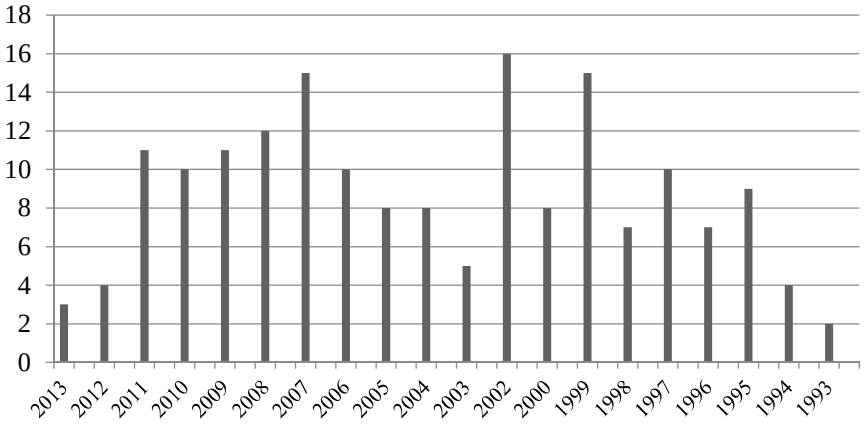


Figure 9. Number of patents on oxygen absorbents based on iron in individual years

Source: Thomson Reuters Patent Database 2014

Different kinds of oxygen absorbents are well-known. A kind of the active ingredient is a basis of the classification. The kind of the active ingredient undergoes changes over time. One of longest applied is iron.

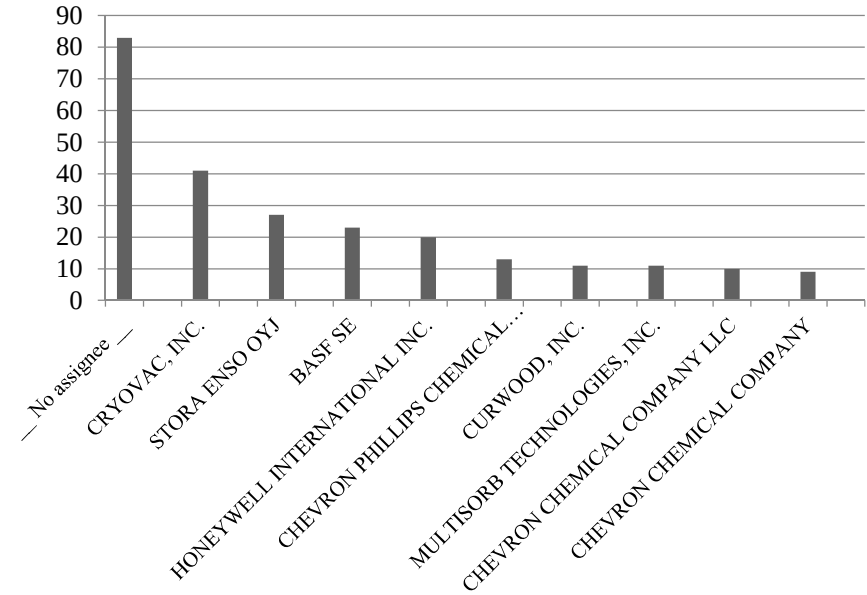


Figure 10. Number of patents on oxygen absorbents based on polymers of individual companies

Source: Thomson Reuters Patent Database 2014

Analysis showed that ten years ago an interest in oxygen absorbents based on iron had fallen very much (fig. 9). However since that time the number of applications again rose and is on the stable level. An appearance of the new type of oxygen absorbents is explaining this trend. This new kind of oxygen absorbents are the ones based on polymers.

Figure 10 shows a chart of patents on oxygen absorbents based on polymers of individual companies. On the basis of an analysis of the data from fig. 10 one can see, that the Mitsubishi Company isn't dealing with this technology at all.

On the fig. 11 the number of patents on oxygen absorbents based on polymers in individual years is different enough. Only it is possible to show a greater interest in this type of oxygen scavengers in years 2001-2007.It is an explanation why in the same period of time decreased the number of patents on scavengers based on iron!

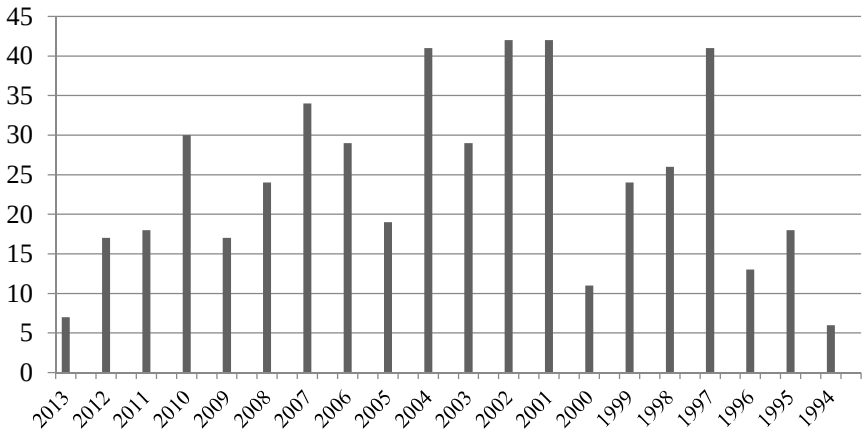


Figure 11. Number of patents on oxygen absorbents based on polymers in individual years

Source: Thomson Reuters Patent Database 2014

Conclusions

Patent landscaping provides an indication of technology novelty and presents information in a way that quickly identifies patent risks and opportunities. Based on patent landscape research on oxygen scavengers we are able to take decision on commercialization of our product, i.e. nanoiron based oxygen scavengers because so far there is no competitive patent application.

Acknowledgments

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FOOD DESIGN AS INNOVATION IN THE FOOD PRODUCTS DEVELOPMENT AND MARKET COMMUNICATION- MODEL ANALYSIS

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Introduction

The perception of food products by consumers on the modern market shapes the specific image of these products in the evaluation of buyers and is the basis for their decision. It is a multidimensional process of identifying the essential characteristics of these products in the communications market, with a strong influence of the specificity of nutritional consumer needs. The biggest challenge are the new needs of consumers towards food, which is a reflection of the market activities of producers, as a result of the processes of innovation and product commercialization processes. On the other hand, these attitudes to a large extent are determined by the prospect of aesthetic consumers, associated with a new style and new conditions of life, their cultural aspirations, etc.

This phenomenon, known as Food Design, in a special way creates a new, comprehensive approach to the development processes of food products and the creation of new solutions in the field of design cycle design and implementation of market-driven innovation (Lin 2012). The essence of this idea is the process of creating a comprehensive image of the new products and the impact on consumer perception, by satisfying their higher needs-recognition and self-realization. For the effectiveness of these activities requires the integration of process design and product management with marketing communication processes. Food products created and commercialized in accordance with the idea of Food Design are the same original synthetic, expressive and materialized form of a communication market, which is seen as the whole message. Such products are integrated with the needs of consumers and the image of companies, actually presented to attract the attention and interest of consumers, which facilitates the processes of market communication.

Earlier own studies indicate that the idea of shaping the design of products (Food Design) is not recognized Polish food market, which requires the definition of that term in relation to already identified consumer needs and major market opportunities. At the same time observed are distinct activities of companies in the field of product management and marketing communication, which are implemented in a convectional way, but did not give the expected results for the needs of the market.

This was the inspiration to undertake an analysis of the conditions of the process of product management and marketing communication in the food sector and seek solutions for the integration of these processes. The result is the possibility to use for this action the concept of Food Design, relative to the new needs of consumers. The analysis of global experience in this area were related to their own experiences and observations in the Polish food sector. Consequently, the analysis and use of the systemic approach, proposed a theoretical model of the process of shaping and managing food products in conjunction with the communication market in conjunction with the concept of Food Design and identifies areas of its application.

Material and methods

The work is a study of a new concept for development of products and markets food and analysis of a new area of food product management, in the context of the processes of creation and market communication. For the analysis used a systematic approach and modeling of market phenomena. For the construction of a theoretical model of the analyzed market phenomena used the available literature on the subject, the own observations of the market and its own previous studies related to the issues of the topic.

Management of the food product and communication in the new market conditions

Product management is now one of the basic elements of management, that lies between the processes of production and distribution, in conjunction with the processes of marketing management and commodity characteristics of our products. In the polish food market this specific area of management is usually the responsibility of the manufacturer (supplier). As the formation of the new organization of the market and the relationship between the participants view on the management food product evolved in the direction of a gradual expansion of this process on the entire food chain (Krajewski 2013). Product management should be treated as a "new" philosophy of approach to the planning and execution of the full product life cycle, meets and reflects the

requirements of the technology and manufacturing techniques, quality systems , consumer needs , market organization, the economics of the enterprise and ecology (Sojkin , Kall 2004)

The essence of management food product are all the actions and decisions of producers to shape the development of the product (its characteristics, attributes, and properties) and the organization of access to this market, usually through the supply chain with different level and method of integration, as well as in the area of trade (Krajewski 2013). This process is characterized by a wide range of decisions in the area of marketing, management and commodities, and it is important to also influence the conditions and processes in a changing market environment, which points to the need for systemic approach of this process.

Food product management includes so the decision making process, not only the company but also the entire supply chain and trade (Sojkin, Kall 2004), in conjunction with the new terms, affiliate management concepts such as the idea of the ECR (Krajewski 2009). In terms of the food market the most rational solution is only a cumulative and coherent action by the instruments typical for the product management and tools of integrated market communication (Górska-Warsewicz, Świątkowska, Krajewski 2009). These two areas of activity may provide the most durable and effective relationships between businesses and consumers of their products in the distribution channels (Krajewski 2010). Food products management in terms of functionality include any decisions and actions related to ensuring the availability of these products and communications manufacturer with clients – food consumers (Krajewski 2013).

As the market develops and improvement of marketing tools is observed to increase the scale and impact of the enlargement process communication companies in the market and its participants from advertising, by promoting the integrated marketing communications (Rydel 2001). The specificity of the organization of the food sector and the need for effective development of market relations imply the extension of the concept of marketing communications approach known as integrated market communication. It is a term covering more than communication market, account for the integration of communication processes market participants around a consistent message and image. It also means the interactive nature of the message, strengthening the role of ambient and the multi-stage process and the nature of the activities in the field of communication between the participants in communication processes (Górska-Warsewicz, Krajewski, Świątkowska 2008). Market communication in this sense is defined as "a set of information (signals), which the company produces a variety of sources in the direction of their customers, and other stakeholders of the marketing environment, using tools such as the marketing mix: product (including packaging), Brand, price and

availability (distribution), integrally, or as separate signals using a set of media and marketing communication tools, complemented by actions of independent companies, which also significantly affect the company's image (eg WoM)". (Górska-Warsewicz, Świątkowska, Krajewski 2009).

From the point of view of the specific foods and Food Design concepts are particularly important interactions between the processes of market communication and shaping and creating the image of the products and, consequently, taking into account the identity of the market, the entire message of the company. Communication plays a vital role in the identification and selection of food at the changing needs of consumers. Follows the adaptation of the model towards an integrated, two-sided and interactive system.

The basis for effective and efficient communication to the food market is, therefore, their integration around a coherent message as the message of the market, consistent with the widely espouses the image of the company and its products or brands and the integration of the strategies market. Perception of instruments used by companies marketing (product, brand, price, distribution and communication) is the basis for shaping the image of the company and its products and the perception of distinctiveness and originality of the overall offer by the consumer.

Reception by consumers in this way, integrated media market, takes place in the form of a total image perception: company, product and brand, and the inconsistency of one of these elements, would the integrity of the reception of whole market message. The perception of the whole integrated media market is conditioned by factors of economic, demographic and legal and technological factors associated with the development of technology and new products, against the perception of competitive products and companies. It should also take into account the characteristics of the receiving media by consumers in the context of socio-economic characteristics, lifestyles, value systems, preferences, etc.

Food Design-genesis, definition, scope

Food Design concept appeared only in the late 90's of last century in the area of creative design and business food. Birth concept is associated with the French "nouvelle cuisine", but the use of the term, began only in 1997 (Di Lucchio 2012). The author of the term is a Catalan Martí Guixé, an innovator in creating new solutions and applications of food. In the gallery of H_2O in Barcelona, designed by herself served techno-futuristic snacks in the Tapas bar SPAMT (Guixe 2010). Food (products, ready meals), he says, should be designed complex, due to the beam characteristics that has, not only features meet the nutritional needs of consumers (Guixe 2010). The very concept of

Food Design does not fully reflect the essence of the scope of this action and meaning. Food should be designed not only because of its nutritional value and sensory, but also because of the functionality and ergonomics. The aim should be to ensure that the same product or dish became the communication market, forced the positive reaction of consumers and clients.

Food Design concept recognizes that there is a close relationship between food, design and art. All of these areas interact with others, and their relationships are getting stronger in the new conditions of the market and to new attitudes of consumers. Should build a new, unconventional products, adapted to new materials, altered manufacturing technology, new market conditions and the needs of customers and market communication forms, using traditional recipes and local flavors, as carriers of cultural identity. (Vogelzang 2010). This means the search for a new approach to traditional products, food design in a surprising form of creating new properties and forms, often using humor, critical reference to reality.

Food by. Guixe is a plastic material, and although it is primarily intended for consumption, in the design process can be omitted reference to the tradition of food and cooking. Designing food in this approach is the point of re-evaluation of the functions and applications and the desire to rebuild the industry, the market and consumers around the food. (Guixe 2010). The approach based on lateral marketing gives good results in many areas food products development. Attributes of food products, such as aesthetics, functionality, communication and other aspects of the real perception of the products, in addition to its nutritional value or taste of consumers become more and more in the evaluation of higher value (Di Lucchio 2012). The project of many food products is now closer to art than a business assumptions, and the role of food in society designers and their responsibility is assessed higher and higher (Richards 2012).

A large range of knowledge and practice designing of food, is different interpretations of the concept Food Design, depending on the understanding of the concept and approach to him (Lin 2012). Some consider this idea as a formula for shaping and reproducibility of food in terms of quality assurance (Stummerer and Hablesreiter, 2010). Others recognize Food Design as food conversion formula as plastic material, is not always in accordance with the earlier application, as well as a message (Guixe 2010).

The concept of Food Design in literature is seen in many areas of management and utilization of food. Includes exploration and inventing new rituals concerning food and its applications, interprets food as a symbol of social and cultural status, explores and creates new dishes, smart packaging, alternative typologies of future developments, examines current trends in food consumption and shaping the structure of the food industry. (Sanderson and Raymond 2008; Maffei, Parini, 2010, Vogelzang, 2010). The concept of Food

Design can be considered also as an action unnecessary and narcissistic, because the quest for efficiency, aesthetics and innovative qualities of the food, takes place within the limits in excess of the current needs of a large part of the population (Di Lucchio 2012).

Discussion of the concept of Food Design in the literature, refers to a problem that its most important task should be to work on the shape of the sensory, the search for innovations in content and form of products (Niewiadomy 2011), or are more important are: the context of food consumption and the environment, consumer health and culture (Alonso, Plasencia, Kint 2012), or the selection mechanism and the desire to preserve the value of health food (Vogelzang 2010).

Very important is also the perception of products by consumers in the concept of Food Design. Assessment consumer food products is largely based on their their vision and visual information (Sanderson 2008). Therefore, the physical form of the product, its shape, texture, appearance and even the smell is critical reaction of customers and potential market success (Verhoef, 2009). Attractive designs of food can attract consumers through expressive patterns and forms of visual, color packaging, graphics, trademark or brand. The visual effect is a valuable source of information about the different characteristics of the product. Important is also the aesthetic side of the product and the packaging. For 55% of Americans good food product design not only makes it nicer, but also can increase its functionality (Richards 2012).

Consumers and designers do not have (apart from their own experience designers) generally means of direct communication with each other (Bombol 2010). In this situation, the designers communicate through contractual and invisible attributes of products, such as aesthetics, design or functionality and social significance through the same product (Creusen, Schoormans 2005).

An important element of the design is shaping the food ambient and the place of sale. Food Design is the most important part of the so-called. emotional branding. (Mruk, Sznajder 2008). Sensations customer in the store is the result of many carefully planned elements of the sales organization, with the same design is critical. An important element designing of food is also development of ambient and the place of sale. Food Design is the most important part of the emotional branding. (Mruk, Sznajder, 2008). Sensations customer in the store is the result of many carefully planned elements of the sales organization, with the same design is critical. As for the design of the room, the interaction of shapes, colors, smells, same space and its structure, systems exposure, and finally the products themselves, which are strongly affecting the well-being and mood of the client's affect on his behavior and purchasing decisions (Williams, Mullin 2011).

Theoretical model of product management and marketing communication based on the concept of Food Design

Effective communication on the food market requires a comprehensive integrated approach to communication processes and product management companies. As research your own market behavior of consumers and the experience of market leaders , the success of the market determines the use of all marketing elements operating in an integrated manner (Krajewski 2013) . The process of creating a comprehensive image of the new food products and their perception by consumers, increasingly conditioned by new expectations of consumers for products (such as aesthetics , color , shape), and due to their aspirations associated with the style and the new conditions of life, the needs of the creation of their own lives , participation in the arts , etc. this means that feedback, because the products formed by the concept of Food Design are themselves expressive form of a communication market , presented attract the attention and interest of consumers, which significantly shapes the processes of market communication .

Using a systemic approach can therefore talk about the rationale for the creation of an integrated communication system of market and product management based on the concept of Food Design. This represents a significant new approach to communication and management product on the market, which combined effects of the development of the food market (by its terms, structure), innovation, communication processes (instruments, forms of communication, new tools), forming products (new technologies, commercialization) and the new consumer attitudes to product and market communication (higher needs, new attributes, needs and attitudes) in the conditions of market full of products and to meet the basic needs of consumers.

Market of food products, at a relatively high level of saturation and diversification, entering a new higher stage of development, as well as a higher level shape consumer needs and a high level of acquired products offered under the new conditions of sale. Identified conditions resulting from own research and observation of the market, were the inspiration for considering the concept of integrating communication processes of market and product management using the concept of Food Design. Their goal is to increase the efficiency and effectiveness of both processes to ensure long-term customer loyalty. Conclusions from the analysis of the development of the concept of Food Design in many countries indicate the possibility of its development in the Polish food market conditions, but it is important to link this concept with process management of food products and market communication.

Adopted perspective determines considerations indicate the need for the essential features of the communication process of the market against the

background of the characteristics of marketing communications (and selected components of social communication, and other market processes), in the context of the needs of the development processes and commercialization of products should take into account the needs of heuristic processes to create new attributes such products as: aesthetics , functionality, communication and other aspects of perceptions of products based on the new characteristics of creative consumers. As a result, the analysis undertaken it was possible to propose the concept of integration of marketing communication and product management, adapted to the current stage of development of the food, using the recognition model to describe this phenomenon.

The starting point for the proposed theoretical model of integrated marketing communication and product management, based on the concept of Food Design, are coupled together four models describing these phenomena:

- market communication model - based on instruments of communication and interactive processes information from the market and within companies (Z_{ic}),
- model of product management - resulting from the needs of the development of new attributes, commercialization and conduct product distribution channels, based on close relationships with business customers and consumers (Z_{im}),
- creative process model (compared to the product and communication), the creation of the original design, which reflects the needs of consumers and the perception of the product, conducted in an interactive process of decision-making information to the market and within the company (Z_{ih}),
- model of integration processes (creation, management and communication), and participants in these processes around a clear consistent communication (design of products and companies) (Z_{id}),
- which simultaneously provides three models of the environment and space strategic links in this model.

In such a complex model IDCM - Integrating Design, Communication and Management product, all these elements constitute a starting point for reflection on the nature of these integrated market participation processes (products, companies, design), while the basis for the theoretical approach problems functioning food market. In terms of econometric model IDCM forming relationships can be described can be described as a function of a single equation:

$$\mathbf{IDCM} = \mathbf{f}\,(\,Z_{ic},, Z_{im}\,, Z_{ih}, Z_{id}\,, \zeta\,)$$

where: Z_{ic} - variables reflecting the impact of communication and information processes,

Z_{im} - variables representing the interaction product management processes,

Z_{ih} - variables reflecting the impact of heuristic processes and creations,

Z_{id} - variables reflecting the impact of the integration processes around design,

ζ - a random element.

Targeting companies their product offerings to consumers and market participants and product management, supported remittances various communication tools, as the traditional form of interaction companies on the market, it loses significance in the current market conditions. This approach no longer provides the high efficiency of the activities in the field of development of products and markets and long-term consumer loyalty in the case of higher-level selection. This requires a new integrated approach and recognition system processes a variety of marketing and product management, conducted in space creative approach to these activities by all participants, and track receipt of these actions by the equally creative consumers. This comprehensive approach gives a good chance of success.

More and more arguments in favor multidirectional relationships between all market participants and comprehensive approach to the complex process of product management and marketing communication. Market communication and product management are now focused on creative development and continuous stimulation of the interaction between the participants of this process based on the new market conditions, which dynamically and continuously generate new needs of consumers of products and media in the form of design.

Conclusions

1. The concept of Food Design captures well the needs of creations in new areas of the food market, in the area disclosed needs of new groups of consumers and the market, in conjunction with heuristic areas of management, marketing, commodities and artistic creation.
2. As an innovative design concept is also integrated solution development and management products, and market communication in the new space needs of consumers and the media, which increases the efficiency of the processes of commercialization of these products and lead to obtaining the loyalty of clients in a constantly, but at a higher level of experience and needs.
3. The implementation of this approach will require the integration of activities in development, management and marketing communication, in

particular; development of new products in a continuous manner with the participation of designers and beneficiaries, the study of consumer needs and manage new knowledge, effective product management, creative approach to marketing communication and the use of new media in the creation of new style media offering, in its traditional sense for food consumers.

4. The effectiveness of communication processes and product management in the creative dimension of the food market decide about the need for the integration of the area and the construction of these measures adequate to model solutions that were proposed for the construction of communication strategies and the management of food products and their design. The proposed model IDCM represents a new approach to the processes of product management and marketing communication based on the concept of Food Design, which integrates the market space and the actions of market participants around the compact image (design) of the product, created for consumers with higher needs.

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EFFECT OF ENRICHMENT WITH FE^{3+} AND ZN^{2+} IONS ON PROPERTIES OF TYPE 4 RESISTANT STARCH

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Introduction

Starch is the most important carbohydrate in human diet (FAO/WHO 1997b), it is easily and quickly digestible source of energy value providing 15 kJ/g. However some starch fractions are not fully digested in human body determining their nutritional and energy value, which may be reduced up to 8 kJ/g (Fuentes-Zaragoza et al. 2010). The portion of starch that can resist digestion by human pancreatic amylase has been defined as resistant starch (RS) and classified into five general subtypes (Fuentes-Zaragoza et al. 2011):

- **Type 1** resistant starch is locked within cell walls or food matrixes and its physically inaccessible for amylolytic enzymes. RS1 is mainly present in partially milled grains.
- **Type 2** refers to native and ungelatinized starch that possess B-type crystalline structure. RS2 is present in such food products as: bananas, raw potatoes or high amylose corn starch.
- **Type 3** is specified as retrograded or crystalline nongranular starch. Process of starch retrogradation occurs during cooling of previously gelatinized starch. RS3 is present in wide range of food products containing starch that has been cooked and cooled (i.e. bread, corn flakes potato chips).
- **Type 4** resistant starch is prepared during certain chemical modification of starch such as esterisation, etherification or cross-linking. RS4 can be added to various industrially manufactured food products.

– **Type 5** refers to amylose-lipid starch complex, which can be formed from high amylose starches. RS5 is characterized by high gelatinization temperature and high retrogradation susceptibility.

Type 3 and 4 resistant starches are of particular interest to food industry due to their stability in food processing. However most of resistant starch preparations offered on the market do not exhibit desired rheological properties required in food industry (Śmigielska, Lewandowicz & Le Thanh-Blicharz 2013). Therefore many scientists are developing new technologies for obtaining resistant starch (Zięba et al. 2010; Le Thanh-Blicharz et al. 2011b; Wronkowska et al. 2011; Zięba, Szumny & Kapelko 2011; Wronkowska & Soral-Śmietana 2012)

Modified starches are found as a good carrier for fortification with micronutrients. Especially recommended are starches modified by oxidization - due to presence of polar carbonyl groups which increase the absorption efficiency Śmigielska & Lewandowicz 2007; Pietrzyk et al. 2013). Unfortunately the use of oxidizes starches is mainly limited to pudding and jelly desserts (Lewandowicz et al. 2003), thus starches modified by acetylation and cross-linking are subject of research on fortification (Śmigielska & Lewandowicz 2007) . Enrichment of starch with microelements may lead to changes in pasting, rheological and texture properties as well as color (Śmigielska & Lewandowicz 2007; Śmigielska, Białas & Lewandowicz 2008; Śmigielska & Le Thanh-Blicharz 2011; Pietrzyk et al. 2013). Therefore the aim of the work to evaluate effect of fortification with iron and zinc ions on quality of type 4 resistant starch of potato and waxy corn origin.

Material and methods

Commercial native potato and waxy corn starch were initial working material. Starches were modified with cross-linking agent containing adipic and acetic anhydrite according to method developed by Department of Institute of Agricultural and Food Biotechnology in Poznań (Le Thanh-Blicharz et al. 2011b). So prepared starches meet the requirements of Codex Alimentaruis for E/INS1422 chemically modified starch (FAO/WHO 1997a) and were characterized by following content of modifying groups:

Table 1. Chemical characterization of examined modified resistant starches.

Starch	Adipic groups [%]	Acetic groups [%]	Digestibility [%]
Potato	0.06 ± 0.01	0.11 ± 0.01	52.7 ± 1.1
Waxy corn	0.08 ± 0.01	0.43 ± 0.13	48.4 ± 0.7

Source: (Le Thanh-Blicharz et al. 2011b)

Starch enrichment was performed by adsorption of iron (III) or zinc (II) sulfate salts according to Śmigielska & Le Thanh-Blicharz (2011) with certain modification. In short adsorption process was carried out in suspension at temperature of 45±1°C for 15 minutes, salt concentration was 1 mg ion per 1 g of starch and stirring speed set up at 300 rpm.

Determination of iron and zinc content in starches was performed with Flame Atomic Absorption Spectroscopy (F-AAS) using Varian SpectrAA 800 (Australia). Starch samples of about 0,5 g were wet mineralized with 10 cm^3 of nitric acid in microwave digestion system CEM MDS-200 (USA). Standard AAS solutions used for calibration were purchased from Fluka Chemie AG (Switzerland).

Color measurements of investigated starches were made using Minolta Chroma Meter CR-310 (Japan) colorimeter with assistance of attachment for granular materials CR-A50. Measurement conditions: observer 2°, illuminant C, color space CIE L*a*b*. Absolute color parameters and total color difference $\Delta E = \sqrt{(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2}$ were determined.

Pasting properties of 5% starch suspensions were determined with Brabender Viscograh (Germany). Standard measurement parameters were set: measuring cartridge 0.07 Nm, heating and cooling rate of 1.5°C/min (within the 25-92.5-25°C range), thermostating period of 20 minutes at 92.5°C.

Universal Texture Profile (TPA) of 5% starch pastes was determined with TA-XT.2 texturometer, Stable Micro Systems (England). Standard "double bite test" was performed with aluminum cylindrical probe (35 mm diameter) on depth of 20 mm with speed of 0,5 mm/s. Hardness [N], adhesiveness [N*s], cohesiveness, springiness and gumminess [N] were determined.

Rheological properties of 5% starch pastes were determined using RotoVisco1 rheometer, Haake (Germany) equipped with Z20 DIN measuring sensor. Before the measurement samples were relaxed and thermostated in measuring cylinder for 5 minutes. Data collection and the calculations were made using RheoWin 3.40 software. Following measurements were performed:

– Flow curves, were determined at controlled shear rate ranging from 1 to 600 s^{-1} for the increasing and decreasing share rates in time of 120 [s] and at temperature of 20°C. Obtained flow curves were described with Ostwald de Waele equation: $\tau = K * \dot{\gamma}^n$, where: τ - shear stress [Pa], K - consistency index [Pa*s^n], $\dot{\gamma}$ - shear rate [s^{-1}], n - flow behavior index (dimensionless number that indicates the closeness to Newtonian flow).
– Viscosity vs. time curves at constant shear rate of 50 s^{-1} in time of 300 s at temperature of 20°C.

Experimental data was studied using analysis of variance and Tukey's multiple comparison test to detect significant differences between investigated

starches. Statistical analysis was performed at significance level of 0.05 using GraphPad InStat3 (USA).

Results and discussion

Efficiency of ion adsorption on starch is dependent on ion concentration in solution used for adsorption only in narrow range. At relatively low concentrations for example 0,5 mg of ion per 1 g of starch adsorption efficiency is roughly 100% (Śmigielska & Lewandowicz 2007). With increase of concentration to 2 mg per 1 g the effectiveness decreases to 40-60%. Further increase of concentration to 5 mg per 1 g results in adsorption effectiveness of 15-35% (Śmigielska, Białas & Lewandowicz 2008; Śmigielska & Le Thanh-Blicharz 2011).

Efficiency of both iron and zinc adsorption was highest on potato starch (83% and 57% respectively) rather than on waxy corn starch (63% and 13% respectively). Moreover iron ions were adsorbed on starch to much larger extent that zinc ions, especially in case of resistant waxy corn starch. Similar relationship was reported by Śmigielska & Le Thanh-Blicharz (2011) for starches of the same botanical origin but modified by oxidation. Based on adsorption efficiency, resistant waxy corn starch cannot be recommended as carrier for zinc ions.

Table 2. Adsorption efficiency of iron and zinc on resistant starches

Starch	Iron content [mg/g]		Zinc content [mg/g]	
	Before adsorption	After adsorption	Before adsorption	After adsorption
Potato	0.04 ± 0.00[a]	0.87 ± 0.01	0.02 ± 0.00[a]	0.59 ± 0.01
Waxy corn	0.03 ± 0.00[a]	0.66 ±0.00	0.02 ± 0.00[a]	0.15 ± 0.00

Explanatory notes: mean value ± standard deviation. Mean values marked with the same letter do not significantly differ at significance level of 0.05.

Source: own research

Color is an important distinguishing trait of starch products. Especially in case of starch enriched with micronutrients, because adsorption of different ions may lead to undesired changes of its color. Previous studies showed that adsorption of iron, zinc and copper ions decreases lightness of starch products. Moreover copper shifted color of starch products towards blue whereas iron towards yellow (Śmigielska & Lewandowicz 2007; Śmigielska & Le Thanh-Blicharz 2011). In the case of both resistant starches fortified with iron similar changes in color could be observed. On the contrary to previously mentioned studies lightness of resistant starch fortified with zinc increased. Furthermore overall changes of color of resistant starches due to enrichment with zinc were

beneficial. Unfortunately enrichment of starch with iron ions resulting in shift of color towards yellowish may contribute to limitations in their applications. However in most of food products thickened with starch (i.e. ketchup, mayonnaise, pudding) slightly yellowish color of starch may be considered as added value to this product.

Table 3. Values of chromatic coordinate parameters of resistant starches

Starch	L	a	b	ΔE
Potato	92.45 ± 0.33[a]	-1.22 ± 0.02	2.17 ± 0.14	-
Potato + Fe	90.84 ± 0.21	-2.36 ± 0.01	10.86 ± 0.25	8,91
Potato + Zn	94.51 ± 0.15[b]	-1.39 ± 0.03	1.52 ± 0.12[a]	2,17
Waxy corn	94.30 ± 0.35[b]	-1.58 ± 0.02[a]	3.54 ± 0.25	-
Waxy corn + Fe	92.08 ± 0.08[a]	-1.58 ± 0.03[a]	12.49 ± 0.09	9,22
Waxy corn + Zn	96.07 ± 0.19	-1,52 ± 0.03	1.52 ± 0.06[a]	2,69

Explanatory notes: mean value ± standard deviation. Mean values marked with the same letter do not significantly differ at significance level of 0.05.
ΔE calculated with regard to non fortified starch of the same botanical origin.

Source: own research

Adsorption of different ions may influence pasting characteristics of starch, inter alia: increase in gelatinization temperature, lower peak or final viscosity (Śmigielska, Białas & Lewandowicz 2008; Śmigielska & Le Thanh-Blicharz 2011). Previous studies performed by different investigators have shown that starch saturated with sodium ions achieves peak viscosity at 65°C whereas starch enriched witch calcium or zinc ions achieves peak viscosity at 95°C (Śmigielska & Le Thanh-Blicharz 2011).

Adsorption of iron and zinc ions on resistant starches resulted only in minor changes in pasting properties (Figure 1.). Obtained Brabender viscosity curves were characterized by similar gelatinization temperature of 66°C and lack of peak viscosity. The only significant difference was noticeable in paste final viscosity. Fortification with iron ions on both potato and waxy corn resistant starches lead to slight decrease of paste viscosity at the end of cooling period. Similar effect could be observed for waxy corn starch fortified with zinc. On the contrary potato starch fortified with zinc had higher final viscosity in comparison to non fortified resistant potato starch. Recorded values of "setback" parameter were relatively higher for resistant potato starches indicating that these preparations should be recommended for cold food applications. Due to slight changes in pasting properties, all resistant starch preparations with special regard to resistant starch fortified with zinc can be recommended in food applications.

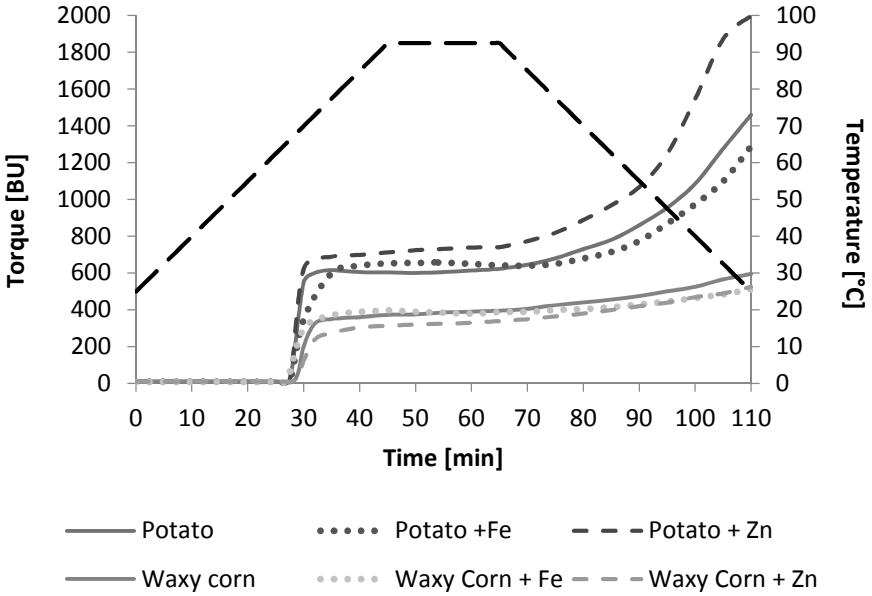

Figure 1. Pasting characteristics of investigated resistant starches

Source: own research

Texture profile analysis revealed significant differences in hardness, adhesiveness and gumminess between potato and waxy corn starch pastes (Table 4.). On the other hand cohesivenes and springiness differed just slightly, which is typical for semisolid foodstuffs (Śmigielska, Lewandowicz & Lubiewski 2007; Le Thanh-Blicharz et al. 2011b; Śmigielska & Lewandowicz 2013). Recorded values of texture profile parameters were higher for waxy corn starch compared to potato starch. However adsorption both iron and zinc ions on resistant waxy corn starch resulted in decrease of value of texture profile parameters. Whereas adsorption of these ions on resistant potato starch increased the paste texture "strength". Moreover changes in starch pastes texture due to fortification with zinc were significantly higher that due to fortification with iron. The effect of fortification on texture properties of starch paste is dependent on both type of ion and botanical origin of starch. Similarly to pasting properties the course of changes in texture of starch paste due to ion adsorption cannot be predicted for starches from different botanical sources.

Flow curves of analyzed resistant starch pastes are presented in the figure 2. In turn Ostwald de Waele equation parameters used to describe flow curves are presented in table 5. Investigated resistant starch preparations were thixotropic, non-Newtonian, pseudoplastic fluids. Highest shear stress in whole range of shear rate was recorded for potato starch fortified with zinc.

This starch was also characterized by highest viscosity on Brabender viscograph. Similar relationship can be observed for the rest of investigated resistant starch preparations. However differences between: potato starch fortified with iron, waxy corn non-fortified and fortified with zinc are much lower in comparison to Brabender viscosity. This is most likely due to differences in: measuring sensor, temperature and shear forces (Le Thanh-Blicharz et al. 2011a).

Table 4. Texture profile parameters of 5% resistant starch pastes

Starch	Hardness [N]	Adhesive-ness [N*s]	Cohesive-ness	Springi-ness	Gumminess [N]
Potato	0.49 ± 0.01^{a}	-1.52 ± 0.15^{a}	0.78 ± 0.01^{a}	1.00 ± 0.00^{a}	0.38 ± 0.01^{a}
Potato + Fe	0.52 ± 0.01^{ab}	-1.70 ± 0.06^{a}	0.80 ± 0.01^{ab}	1.01 ± 0.00^{a}	0.42 ± 0.01^{ab}
Potato + Zn	0.55 ± 0.03^{bc}	-2.49 ± 0.19^{b}	0.80 ± 0.01^{ab}	0.99 ± 0.01^{a}	0.44 ± 0.03^{bc}
Waxy corn	0.67 ± 0.01^{d}	-4.34 ± 0.19^{c}	0.83 ± 0.03^{bc}	1.00 ± 0.01^{a}	0.56 ± 0.02^{d}
W. corn + Fe	0.69 ± 0.01^{d}	-3.95 ± 0.22^{c}	0.80 ± 0.02^{ba}	1.00 ± 0.01^{a}	0.55 ± 0.01^{d}
W. corn + Zn	0.57 ± 0.02^{c}	-2.59 ± 0.22^{b}	0.85 ± 0.01^{c}	1.00 ± 0.00^{a}	0.49 ± 0.02^{c}

Explanatory notes: mean value ± standard deviation. Mean values marked with the same letter do not significantly differ at significance level of 0.05.

Source: own research

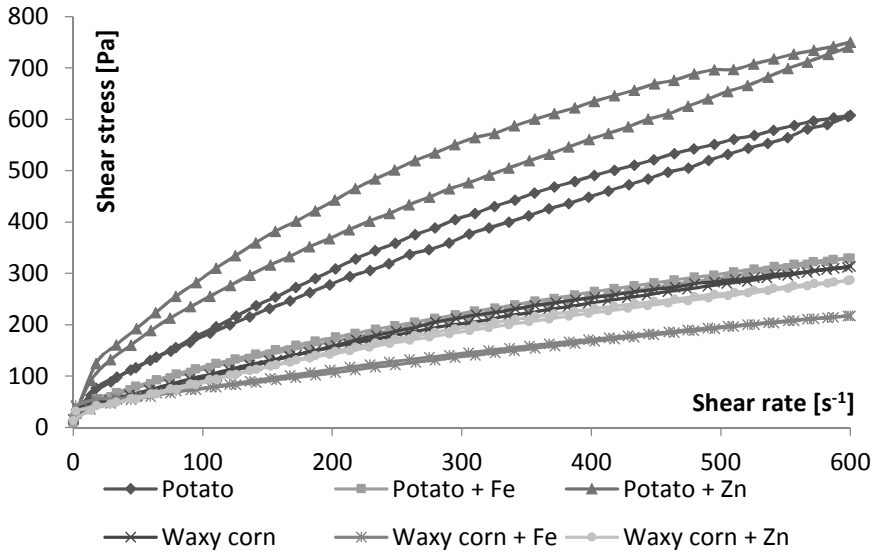

Figure 2. Flow curves of 5% resistant starches pastes

Source: own research

Ostwald de Waele equation was very well fitted to experimental data, and lowest calculated value of correlation coefficient (R) was 0,9862. Consistency index (K) of potato starches changed in wide range of 8,852 - 29,270. Very high value of consistency index compared to other starch preparations calculated for resistant potato starch enriched with zinc is partially result of high paste viscosity and low value of flow behavior index (n). Consistency index of waxy corn starches ranged in narrow scale of 5,313 to 6,200 and obtained differences were statistically irrelevant. Adsorption of both iron and zinc ions on starches resulted in decrease of flow index value, indicating that these preparations exhibited more non-Newtonian behavior.

Table 5. Ostwald de Waele equation parameters used to describe flow curves

Starch	K	n	R
Potato	9,941 ± 0,182^{a}	0,6466 ± 0,0019^{a}	0,9988 ± 0,0001
Potato + Fe	8,852 ± 0,455^{ab}	0,5604 ± 0,0163^{b}	0,9992 ± 0,0001
Potato + Zn	29,270 ± 1,160	0,5102 ± 0,0076^{b}	0,9985 ± 0,0005
Waxy corn	6,200 ± 0,684^{bc}	0,6175 ± 0,0170^{a}	0,9965 ± 0,0004
Waxy corn + Fe	6,015 ± 0,870^{c}	0,5571 ± 0,0238^{b}	0,9862 ± 0,0001
Waxy corn + Zn	5,313 ± 0,074^{c}	0,6267 ± 0,0023^{a}	0,9975 ± 0,0004

Explanatory notes: mean value ± standard deviation. Mean values marked with the same letter do not significantly differ at significance level of 0.05.

Source: own research

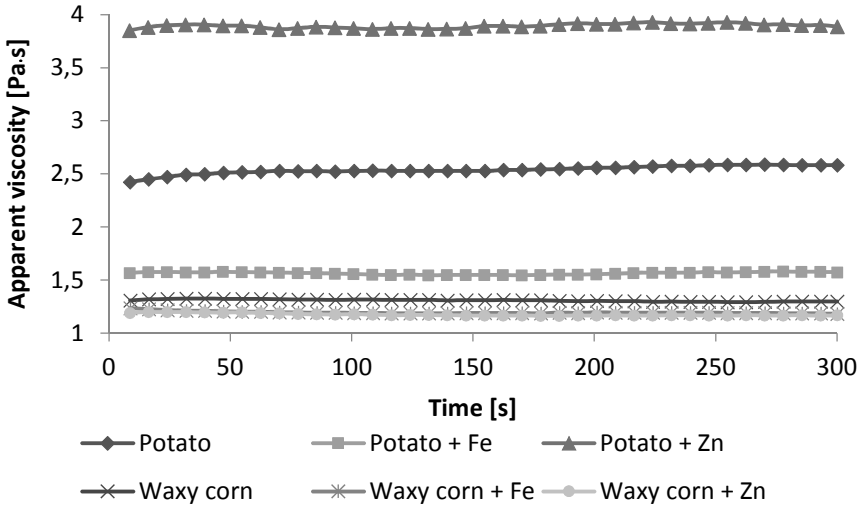

Figure 3. Apparent viscosity versus shear time curves of 5% starch pastes

Source: own research

Although starch pastes are non-Newtonian fluids and their viscosity is dependent on the time of shearing, viscosity of investigated resistant starch pastes changed to rather small extent (Figure 3.). This fact indicates that all investigated starches are quite resistant to shear forces. Obtained apparent viscosity values are coherent with data presented on Brabender viscograph (Figure 1.) as well as with flow curves (Figure 2.). However at relatively low shear rate applied in this examination (50 [s^{-1}]) the difference in viscosity of resistant potato starches are much greater. On the other hand apparent viscosities of resistant waxy corn starches are very similar, although fortification with iron as well as with zinc lead slight decrease of viscosity.

Conclusions

It was found that potato starch should be used for manufacturing fortified type 4 resistant starch. Especially recommended is resistant potato starch enriched with zinc ions, due to particularly beneficial changes of rheological properties and color. Moreover:

- Potato starch revealed higher adsorption efficiency of both iron and zinc ions. Furthermore better adsorption was observed for iron rather than on zinc ions.
- Adsorption of zinc lead to increase of lightness of starch, whereas iron shifted color of starch towards yellow.
- Pasting characteristics of fortified starches changed to a small extent. Adsorption of iron ions lead to decrease of viscosity of starch pastes whereas effect of zinc adsorption was dependent on botanical origin of starch.
- Due to fortification, value of texture profile parameters of pastes increased in case of potato starch and decreased in case of waxy corn starch.

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CAPACITY OF ECO-INNOVATION DEVELOPMENT THROUGH LIFE CYCLE ASSESSMENT USE IN POLISH MANUFACTURING SECTOR – SMALL EVIDENCE FROM EMPIRICAL STUDIES

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Introduction

Eco-innovation are, at present, one of the key factor of building market competitiveness of companies that is going in line with improvement of environmental performance. Development and implementation of eco-innovation is quite complex and demanding venture and therefore, needs strong support throughout the decision processes related to them. Without considering the type of eco-innovation (product, process or organization oriented) it could be noted that information support should be oriented on their economic potential and as well as on their ecological performance and capacity. Environmental management tools, such as life cycle assessment (LCA), should be regarded as integrated part of eco-innovation development, implementation and assessment.

The definitions of eco-innovation differ depending on the context and source, but the definition presented here, comes from the most recent EU initiative called *Innovation for a sustainable Future - The Eco-innovation Action Plan*. The definition states, "eco-innovation is any form of innovation resulting in or aiming at significant and demonstrable progress towards the goal of sustainable development, through reducing impacts on the environment, enhancing resilience to environmental pressures, or achieving a more efficient and responsible use of natural resources" (COM, 2011, p.2).

The role of eco-innovation in making an economy more sustainable should not be underestimated. Eco-innovation should join the ecological effect with the build-up of competitive advantage and efficiency gain (Strojny, 2010). Through the synergy effect, eco-innovation could bring out the unexpected effects of pursuing sustainability strategies (Hitchcock & Willard,

2006). Eco-innovation lies at the very heart of eco-efficiency based sustainability strategy, and its role is to deliver the best possible solutions for the optimisation of the functioning of companies (Orsato, 2009). The range of eco-innovation implementation is multidimensional from the perspective of a company and should spread out on such areas of its functioning as market, technology, finances, organisation, culture, and certainly environmental issues (Strojny, 2010). Finally, eco-innovation is considered the milestone of any sustainability strategy if it is used in a systemic integrated approach and is focused on constant improvement of company operations, products, and services (Werbach, 2009).

As some authors complain, including Miedzinski (2010) and Kalinowska (2010), there is no consistent system for defining, classifying or measuring eco-innovation globally nor in the EU itself. Miedzinski (2010) indicates that eco-innovation is quite often limited to certain sectors or branches of the economy, while its core and potential effects could be achieved in any type of economic activity. Finally, it is important to mention information requirements of eco-innovation and the need of the assessment of their environmental impact in a precise, robust and clear way. According to the possible range and scope of eco-innovation, environmental management tools, such as life cycle assessment, provide appropriate platform for measuring their environmental performance (Nitkiewicz, 2013).

The use of LCA is recently very significant topic of scientific research in Poland (Kulczycka, 2011), (Pikoń, 2011; Mesjasz-Lech, 2012) (Lewandowska, 2011; Lewandowska et al., 2011; Lewandowska, et al, 2013). Presented studies focus on specific LCA use in relation to given object of its usage (investment, technological system or environmental management system). The advantages of LCA making it solid tool for different but complex assessments of environmental impacts of diversified objects (products, ecological undertakings or whole manufacturing systems), destined it as a tool for information support of decision making processes orientated on eco-innovation. The intention of this paper is to find out what specific circumstances drive companies to undertake LCA while developing and implementing eco-innovation.

Material and methods

Rough set theory (RST), a method developed by Z. Pawlak, is used to induct decision rules that lead to life cycle assessment use in companies engaged in eco-innovation development and implementation (Pawlak, 1982). Rough set theory enables the induction of decision rules basing on the behaviors and phenomena presented in datasets. It is assumed that making life cycle assessment studies on products and processes is a domain of

environmentally aware companies with some experiences in ecological ventures implementation. Therefore, the set of condition attributes includes undertaken pro-ecological activities, the use of tools and instruments to support them in financial and organizational sense and implemented diagnostic and monitoring actions in the scope of environmental impact assessment. All of the attributes included are somehow related to eco-innovation. Justification of such an approach to life cycle assessment use in companies sector is related to the designed scope of its use (complex assessment of environmental pressures and impacts in whole life cycle of a product, process or a company venture) and research on business sector preferences in its use (as observed in PARP study, survey made by Department of Product Technology and Ecology on Cracow University of Economics (Adamczyk, 2013), or historical research, such as cross could be fully explored only if complex environmental information is needed in eco-innovation decision-making, mainly within the context of products and process design and ecological optimization of a company. Rough Set Approach includes four steps (Forsman, 2012, p. 8): 1) design of decision table, 2) calculating the approximation, 3) the reduction of attributes and 4) creating the decision rules. The detailed explanation of RSA calculation procedure could be found in Nitkiewicz (2013).

Results and discussion

The following pro-ecological activities are included in the analysis in a role of condition attribute:

1. Inclusion of environmental issues in strategic objectives
2. Implementation of environmental management systems
3. Plans of environmental management systems implementation
4. Monitoring of environmental issues
5. After sale product servicing
6. Product designing
7. Process designing
8. Innovation implementation
9. Sources of implemented innovation
10. Financing of innovation
11. Research of consumers ecological preferences

Altogether there are 11 condition attributes considered in rough set analysis procedure. According to the survey, the time horizon for the parameter value of the most of the condition attributes is settled to 5 years. Tab. 1 presents the condition attributes, decision attribute and their parameterization

Tab. 1. List of attributes and their parameters

Symbol	Name of attribute	Attrib. parameters coding		
		0	1	2
Condition attributes				
a1	Inclusion of environmental issues in strategic objectives	no	yes	
a2	Implementation of environmental management systems	no	yes	
a3	Plans of environmental management systems implementation	no	yes	
a4	Monitoring of environmental issues	no	yes	
a5	After sale product servicing	no	yes	
a6	Product designing	no	yes	
a7	Process designing	no	yes	
a8	Innovation implementation	no	yes	
a9	Sources of implemented innovation	none	own	external
a10	Financing of innovation	none	own	external
a11	Research of consumers ecological preferences	no	yes	
Decision attribute				
d1	LCA use	no	yes	

Source: own work

The sample of companies is divided into 2 groups of companies according to the decision attribute, that describes the types of decision made at least once in last 5 years by companies: (1) decision of using life cycle assessment method to support their environmental decisions and (2) of not using LCA. According to the rough set analytical approach, basing on condition attributes parameters and the decision on life cycle assessment use, the dataset is transformed into decision table. The data on all of the condition attributes is taken from the survey results and was normalized to 0, 1 and 2 values in order to simplify the decision table. The decision table including 56 entries is presented Tab. 2. The decision problem covered in this decision table could be formulated as: finding the reference between using LCA (d1 is equal to 1) and the values of condition attributes parameters, which are determining its use (values of attributes a1-a11) in the process of eco-innovation development and implementation. The results of such a procedure should consist of number of attributes with specific values of their parameters aligning to the decision rules.

Tab. 2. Coded decision table

	Condition (a) and decision (d) attributes											
Units	**a1**	**a2**	**a3**	**a4**	**a5**	**a6**	**a7**	**a8**	**a9**	**a10**	**a11**	**d1**
1	1	0	0	1	1	1	1	0	0	0	0	0
2	1	0	0	1	0	0	1	0	0	0	0	0
3	1	0	0	0	0	1	1	1	1	1	0	0
4	1	0	0	0	0	1	1	0	0	0	0	0
5	1	0	0	0	1	1	1	0	0	0	0	0
6	1	0	0	0	0	1	0	1	2	1	1	0
7	1	1	0	1	0	0	1	0	0	0	0	1
8	1	1	0	1	1	1	1	0	0	0	1	0
9	0	0	0	0	1	1	1	0	0	0	0	0
10	1	0	0	0	1	1	1	0	0	0	0	0
11	0	0	0	0	0	1	1	0	0	0	0	0
12	1	1	0	1	0	1	1	1	1	1	1	1
13	1	1	0	1	0	0	0	0	0	0	1	0
14	1	0	1	0	0	1	1	1	1	2	0	0
15	1	0	0	1	0	1	1	1	1	1	0	0
16	1	1	0	1	0	1	1	1	1	1	0	1
17	1	0	1	1	0	1	1	1	1	1	0	1
18	1	1	0	1	0	0	0	1	1	1	0	0
19	1	1	0	1	0	0	0	1	2	1	0	1
20	1	1	0	1	0	1	0	0	0	0	0	1
21	1	1	0	1	0	1	1	1	1	1	0	1
22	1	1	0	1	0	1	1	1	1	1	0	1
23	1	0	0	1	1	1	1	1	1	1	0	0
24	1	0	0	0	1	1	1	0	0	0	0	0
25	1	1	0	1	0	1	1	0	0	0	0	1
26	1	1	0	1	1	1	1	0	0	0	0	0
27	1	1	0	1	0	0	0	1	1	1	1	1
28	1	0	0	1	1	1	1	1	1	1	0	0
29	1	1	0	1	1	1	1	1	1	1	0	1
30	1	1	0	1	1	1	1	1	1	1	1	1
31	0	0	0	0	0	1	1	1	1	1	0	1
32	1	1	0	1	1	1	1	1	1	1	0	1
33	1	1	0	1	0	0	0	1	1	1	0	0
34	0	0	0	0	0	1	0	0	0	0	0	0
35	1	0	1	0	1	1	1	1	1	1	0	0
36	1	1	0	1	0	1	0	1	1	1	0	1
37	1	0	0	1	0	0	0	0	0	0	0	0
38	1	0	0	1	1	1	1	1	2	1	1	1
39	1	1	0	1	0	1	1	0	0	0	1	1
40	1	0	0	0	0	1	0	0	0	0	0	0
41	1	0	0	1	0	1	0	0	0	0	0	0
42	0	0	0	0	0	1	1	0	0	0	0	0
43	1	0	1	1	0	1	1	1	1	1	0	0
44	0	0	0	0	1	1	1	0	0	0	0	0
45	1	1	0	1	0	1	1	0	0	0	0	0
46	1	0	0	0	1	1	1	0	0	0	0	1
47	1	0	1	0	0	1	1	0	0	0	1	0
48	1	0	0	1	0	1	0	1	1	1	0	0
49	0	0	0	0	0	1	1	1	1	1	1	1
50	1	1	0	1	0	1	1	1	1	1	1	1
51	1	1	0	1	1	1	1	1	1	1	1	1
52	1	0	0	1	0	1	1	1	1	1	0	0
53	1	1	0	1	0	0	1	1	1	1	1	0
54	1	0	1	0	1	0	0	0	0	0	1	0
55	0	0	0	1	1	1	0	1	1	1	1	0
56	1	0	0	1	1	1	1	0	0	0	1	0

Source: own work on the basis of survey results

Tab. 3 presents the structure of survey results that are used in decision rules induction process. The most important parameter that determines the following steps of rough set analysis is the value of decision attribute. The share of LCA users in the sample accounts for 37,5% and indicates uneven distribution of companies between two groups. This division will affect the strength of LCA use decision rules later in the analysis.

Tab. 3. Structure of parameters values for attributes

Parameter	Share of parameter value		
	0	1	2
a1	14,3%	85,7%	--
a2	58,9%	41,1%	--
a3	89,3%	10,7%	--
a4	33,9%	66,1%	--
a5	64,3%	35,7%	--
a6	17,9%	82,1%	--
a7	26,8%	73,2%	--
a8	46,4%	53,6%	--
a9	46,4%	48,2%	5,4%
a10	46,4%	51,8%	1,8%
a11	71,4%	28,6%	--
d1	62,5%	37,5%	--

Source: own work on the basis of survey results

Calculating the lower and upper approximations

In the following step, the bottom and upper approximations are calculated in order to define LCA users and non-users sets and identify the companies lying at the borders of both sets according to the parameters of their condition attributes. The RST procedure used here adopts approach presented in Pawlak's work (Pawlak, 1982; Pawlak, 2001; Pawlak, 2004).

The number of units in LCA non-users set accounts for 30 units in bottom approximation (certain life cycle assessment non-users) and 38 units in upper approximation (possible life cycle assessment non-users). LCA users set is less numerous and accounts for 18 units in lower approximation and 26 in upper approximation respectively. The above results in much higher precision in defining LCA non-users set with 0,7895 value of accuracy measure, while for LCA users set its value is 0,6923. The set of LCA users is therefore more diversified according to the parameters of condition attributes and harder to be classified. The quality of classification expressed by consistency measure is 0, 8571 and therefore, is should be assessed as sufficient.

Tab. 4. Lower and upper approximation and their accuracy and consistency measures

Decision attribute: LCA use	Number of companies	Lower approximation	Upper approximation	Accuracy	Consistency
Yes(1)	21	18	26	0,6923	0,8571
No (0)	35	30	38	0,7895	

Source: own work

The reduction of attributes

The set of condition attributes is reduced to the smallest possible set enabling decision rules induction. Only one reduced set is defined with only one condition attribute removed, namely the financing of innovation is identified as a futile attribute in the analysis that follows. It is related to its high correlation with another attribute – sources of innovation – that covers similar issue and stays in the attribute set for the following analysis. Removing financing of innovation attribute from the set does not affect classification quality and settles the core set of condition attributes. Since the core is the intersection of all reducts, all its elements belong to every reduct. Thus, the non-empty core consists of the most important subset of attributes, and none of its elements can be removed without affecting the classification power of attributes (Pawlak, 2004, p. 4).

Creating the decision rules

The final step of analysis is the use of LEM2 algorithm and ROSE2 software to induct actual decision rules leading to LCA use in companies making eco-innovation attempts. Inducted decision rules are interpreted as: <if> set of condition attributes and their parameters <then> LCA use (or not use) to support eco-innovation implementation process. The use of LEM2 algorithm to create decision rules follows the explanations given by Słowiński (2013).

Findings

The decision rules induced with the procedure presented above are presented in the Tab. 5 and in form of flow graphs (**Błąd! Nie można odnaleźć źródła odwołania.** and **Błąd! Nie można odnaleźć źródła odwołania.**). The decision rules should be interpreted according to the desired and undesired performance of companies from the point of view of the scale of LCA use in eco-innovation oriented decision making process. Using LEM2 algorithm led

to induction of 21 decision rules. 8 of them referred to decisions of LCA use, 10 referred to decisions of not using it, while 3 remaining rules were approximated rules for decisions of not using LCA but covering single companies only.

Only 3 rules for using LCA and 5 rules for not using LCA are included in Tab. 5, **Błąd! Nie można odnaleźć źródła odwołania.** and **Błąd! Nie można odnaleźć źródła odwołania.** for further interpretation. This is due to the high coverage of the classes by those rules. Rules 1-3 cover 67% of LCA users class. Rules 4-8 cover 74% of LCA non-users class. In both cases the coverage is representative enough.

The most important decision rule leading to the use of LCA is the rule no. 1 that includes implemented environmental management system, self-engagement in product designing and self-innovating. Using LCA is not related to any strategic commitment to environmental objectives or including them development strategy of a company.

Concerning the class of companies not using LCA in their eco-innovation oriented decision making processes there is no dominant decision rule. The most important decision rules (no. 4 and 5) cover only 34% of companies in a class. Rule 4 covers 17% of companies from LCA non-users class and sets such condition attributes as: including environmental issues in strategic objectives of a company, lack of environmental monitoring and lack of after sale servicing of company products. Rule 5 is similar to rule 4 while its coverage and strength parameters are concerned. Again, including environmental issues in strategic objectives of a company is a condition attribute, together with lack of implemented environmental management systems and no plans to implement them, and using own sources of eco-innovation.

Flow graphs are illustrating the most important decision rules and indicating the paths towards given decisions (Pawlak, 2004). **Błąd! Nie można odnaleźć źródła odwołania.** and **Błąd! Nie można odnaleźć źródła odwołania.** present the most important paths leading to use of LCA and not using it, respectively. It is important to mention that the sequence of attributes used on flow graphs should not be treated as real one. The sequence is resulting from symbols used for condition attributes only, and does not refer to the real chronology of undertaking given actions. The numbers presented on graphs represent the number of companies that are following given paths towards using or not using LCA. The way of presenting flow graphs follows the approach used by H. Forsman (2012).

It is worth to mention that rules leading to LCA use include specific type of innovation activity that is independent product designing in a company. That gives us an insight in eco-innovation development process and indicates that orientation on products motivates to LCA use. On the other hand,

innovation implementation appears as a condition attribute in a decision rule covering LCA non-users class. These lead to the finding that using LCA is not an attribute conditioning the eco-innovation implementation, especially not on the general level. But, going into details, if eco-innovative products are concerned then LCA becomes of use and constitutes itself as a part of innovation process.

Tab. 5. The most important decision rules for LCA use and LCA no-use classes

No. of a rule	a1	a2	a3	a4	a5	a6	a7	a8	a9	a10	a11	d1	No. of comp.	Strength	Coverage
decision rules for LCA use class															
1		1				1			1			YES	10	17,86%	47,62%
2	0			0					1			YES	2	3,57%	9,52%
3		1				1	0					YES	2	3,57%	9,52%
decision rules for LCA no-use class															
4	1			0	0							NO	6	10,71%	17,14%
5	1	0	0						1			NO	6	10,71%	17,14%
6	0								0			NO	5	8,93%	14,29%
7		0		1					0			NO	5	8,93%	14,29%
8	1			0				1				NO	4	7,14%	11,43%

Source: own work on the basis of survey results

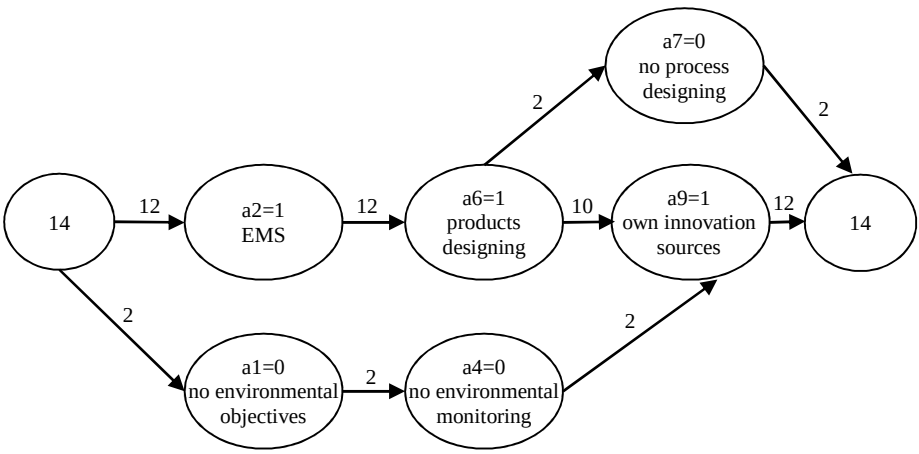

Fig. 1. Flow graph for decision rules for LCA users class

Source: own work on the basis of survey results

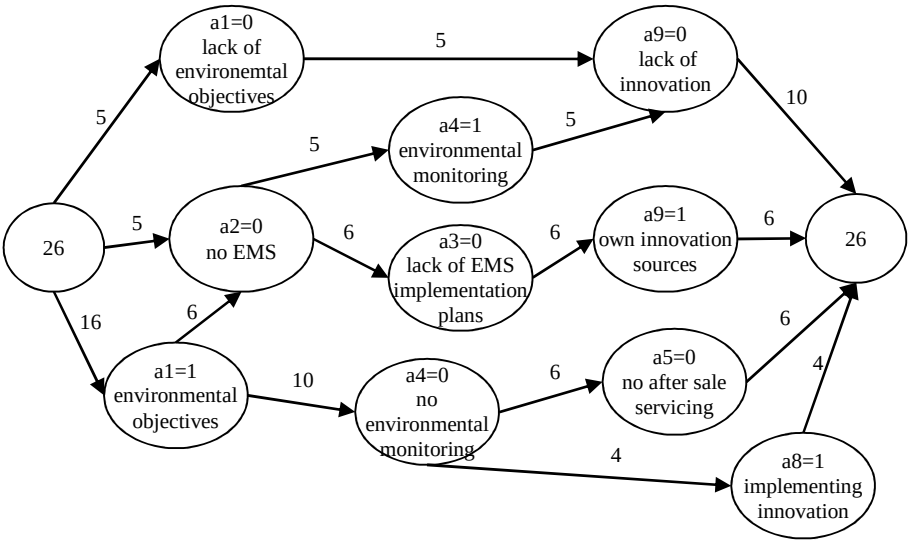

Fig. 2. Flow graph for decision rules for LCA non-users class

Source: own work on the basis of survey results

Conclusions

It is worth to mention that rules leading to LCA use include specific type of innovation activity that is independent product designing in a company. That gives us an insight in eco-innovation development process and indicates that orientation on products motivates to LCA use. On the other hand, innovation implementation appears as a condition attribute in a decision rule covering LCA non-users class. These lead to the finding that using LCA is not an attribute conditioning the eco-innovation implementation, especially not on the general level. But, going into details, if eco-innovative products are concerned then LCA becomes of use and constitutes itself as a part of innovation process.

In a set of manufacturing companies engaged in eco-innovation the decision rules leading to LCA use are rather diversified. In fact, there is no certain set of condition attributes leading to LCA use. Instead, it is possible to picture more general path motivating companies to LCA use. This path is certainly including implemented environmental management systems, independent product designing and own R&D work. It seems, that one pro-ecological initiative is enough to justify LCA use and to include rational environmental criteria in decision making process.

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INNOVATION BY DESIGN AS AN ESSENTIAL CONNECTION BETWEEN TECHNOLOGY AND MARKET

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Introduction

The importance of innovation when it comes to attracting new consumers is even more evident nowadays. A new term appeared: innosumer, the consumer who himself is an innovator or "a technology-literate, intelligent, informed and learning consumer that is well capable of configuring the technological environments he or she deems desirable" (Peine, Rollwagen and Neven 2014).

Using new technologies is a way to obtain innovative products that change the market so thoroughly that they end up creating consumer demand. For example, RIM produced its first Blackberry device after the company's founder decided to evolve from the existing technology of pagers to that of cell phones with integrated e-mail communication (Martin 2010).

Troung (2013) states that consumers value different characteristics of an innovation. So retailers and producers should adapt the way they present and promote their products, from country to country. The example given is that the characteristics that are most important to the customers should be the ones that are stated in the selling proposition. As such, the customers are more prone to have a positive attitude when considering whether to buy the product.

As an example for the reactions of the consumers to new and innovative products, Gladwell (2005) presents the case of the Aeron chair. While technologically it was a huge step in the evolution of the modern office chair it was also considered aesthetically unpleasant at the time of its conception. The manufacturing company had to rethink its market introduction by first presenting it to trendsetters: architects, designers, ergonomics experts and interior designers. Only after the chair started winning design awards and being featured on television did the rest of the market finally embrace it.

As such it is common for twenty years to pass between the moment when a new product is tested in laboratories and the moment it becomes a commercial product and then ten or twenty more for it to become a common household product (Norman 2013).

In emerging economies the consumers' main criterias when choosing a mass market product are its price and degree of acceptability. Thus, companies that develop new products will resume to just simplify an existing product from a mainstream market (Ray and Ray 2011). For that target of consumers and that market, the product might seem new and acceptable but not innovative. For the company it will only be a convenient redesign of an existing product and not a completely new and costly endeavour.

Products with new technologies signify increased costs both for the manufacturer and the consumer.

Consider the consumer in a situation he is a familiar with or doing a common everyday activity. Of course, in this situation, when presented with innovative products the consumer will evaluate them according to the cost incurred if they decide to pick those products over their current choice of product for the task in question. Seen as a switching cost, it includes, besides the obvious financial cost, the following other costs (Huang and Hsieh 2012): the procedural cost (which is seen as a time related cost, referring to economic risk costs, evaluation costs, learning costs, and setup costs) and the relational cost – concerning the emotions involved in adopting the new product.

Besides these costs, when coming up with innovative products companies also have to take into consideration the possibility that consumers will not embrace the products. This consumer reaction is now as consumer resistance and is manifested in one of the following three instances: rejection, opposition and postponement (Kleijnen, Lee and Wetzels 2009). Because opposition also entails the propagation of negative opinions about the product it is the form of consumer resistance that has the most severe consequences for the company. Postponement is more related to timing and the consumers' values or beliefs. Thus it is the most harmless because it is the position that is the most likely to lead to the acceptance of the product.

Another aspect that has to be considered when developing new products is ecology. Companies that innovate while taking the environment into consideration are part of the green product innovation trend (Lin, Tan and Geng 2013). The new technologies are used in order to make products that will require less raw materials, pollute less during their life cycle and produce less waste when discarded.

Moreover, according to a survey applied to 700 businesses in the USA, 89% of them consider that products with environmental benefits are desired by consumers and are seen as a long-term market opportunity (PricewaterhouseCoopers LLP 2010).

Many innovative products are also suitable candidates for innovations of the retail areas. New technologies such as touch screens, mobile applications, 3D scanners, interactive displays are often associated with such products if retailers think that the costs of setting up such systems can be surpassed by the profits resulted from selling them (Pantano and Viassone 2014).

Material and methods

In the attempt to identify the importance of innovation and design and to establish a connection between the new technology and the market, this research paper aims to find the answer to one main question: *To what extent does design help customers to get used to new technology items?* In order to find some concrete elements that may contribute to the psychological impact of design, we have outlined a series of sub-questions: *Are consumers willing to pay more for a product with an innovative design? If so, how much more would they be willing to pay? Can a product's design influence consumers' perceptions about its utility?* The ultimate question of the current research is also the most complex of all and aims to discover through what methods can design contribute to the successful insertion of innovative products on the market: *How does a product's design influence the market success of a new technology?*

To answer the questions of this study, a research was conducted between January and March 2014, based on a quantitative approach with a questionnaire distributed among young people aged between 20 and 26 years. The participants' selection was based on compulsory basic design, innovation and economic knowledge, for more relevant responses. Participants in the survey were students who have previously completed a course in design and innovation during bachelor or master studies. Given their interest in purchasing products that integrate innovative technologies and the degree of familiarity with new technologies, the research is intended to be a conclusive one for the current economic period. The sample constructed this way consists of 416 respondents.

The questionnaire evaluates design's importance in facilitating market access for products that integrate new technologies, and the extent of its influence on customers' buying decision process, being considered a psychological stimulus for value and usefulness perception of an innovative product.

Results and discussion

After processing the results of the questionnaire, there was conducted a statistical data analysis which has pointed out that the majority of respondents

consider that a product's design has a significant psychological impact on consumers, 68.5% of respondents appreciate the impact as being important and very important. This result proves the importance that companies must attach to a product's design in order to influence consumers to purchase their products. In these circumstances, the first hypothesis tested in this study is:

H1: The product design has a direct and positive psychological impact on the purchasing decision of consumers.

After validating the first hypothesis, it was desired to quantify the psychological impact in terms of consumer willingness to pay more for a product with an innovative design. Thus, it was observed that 14.9% of respondents are willing to pay more than 10% for a particular design, while the majority of respondents, 43.8%, agreed to pay between 10% -40% more for a product with innovative design, and the remaining 39.7% are willing to pay more than 40% for such a product. A brief overview of these results can be observed in table 1.

These results emphasize that an innovative product design is an important competitive factor for a company, which also uses an appropriate business model, in order to obtain a greater value from the products and services they sell on the market. As stated by Gary Hamel (2002) in his book *Leading the Revolution*, Jonathan Ives, coordinator of industrial design at Apple, managed to redefine how a computer looks by introducing a new dimension of differentiation in the computer industry - aesthetics.

Table.1. How much more are consumers willing to pay for a product with an innovative design

Respondent category	*Percentage*
not willing to pay more	1,7%
1% - 10%	14,9%
10% - 40%	43,8%
40% - 70%	26,9%
70% - 100%	11,8%
more than 100%	1%

Source: Data analysis using SPSS

In 2002 Apple introduced iMac, a computer with a radically new design compared to the others available on the market, which until then came in one color and were 'the worst items in the house'. The company succeeded to

record 400,000 units' sales for iMac in the first month after its launching on the market (Hamel, 2002). This confirms the second hypothesis of the study:

H2: Innovative design leads consumers to pay more for a product, attracting higher revenues for the company.

Besides the aesthetic function of the design which has a psychological influence on consumers, as the interpretation of the results shows, design's contribution on the perception of utility is also an important one. This is shown by the 62.3% of respondents who consider design an important and very important element in assigning a utility degree to the purchased products. A good example in this respect is the test conducted by Sonderegger and Sauer (2010) among 60 young people who have assigned a phone with a more attractive design a better performance rather than a phone that incorporates the same technology but has a less attractive look. The third hypothesis of this research is thus validated:

H3: Design has a significant contribution to the usefulness perception of a product.

The recorded answers for the fourth question show that 76.7% of the respondents considered that design helps customers to a larger extent to familiarize with new technology, as it results in *Figure 1*. Design can help reduce the time needed to learn new characteristics of the product, either through the use of symbols, of colors or through the assignment of certain forms. Design, coupled with an efficient business model, is able to transform new technology into a successful product which is appreciated by consumers. Taking into account these considerations, the fourth hypothesis is:

H4: Design significantly helps customers to familiarize with new technology.

To answer the last question and to identify *how* does design contribute to the market success of a new technology, there were identified a number of concrete outcomes which design has, as a result of the beneficial effects previously recorded. Therefore, the relevant advantages were: the increase in product quality, the assignment of unique elements to the product, the development of new markets, better adjustment to the market's requirements, creating an interface between technology and user, diversification of products' range. Results achieved through these outcomes are summarized in the following figure.

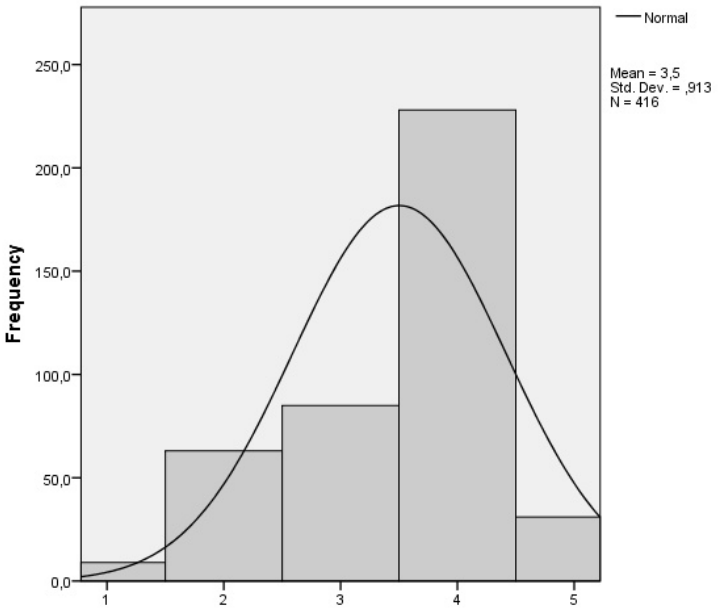

Figure 1. Design contribution for familiarizing customers with new technology

Source: Data analysis using SPSS

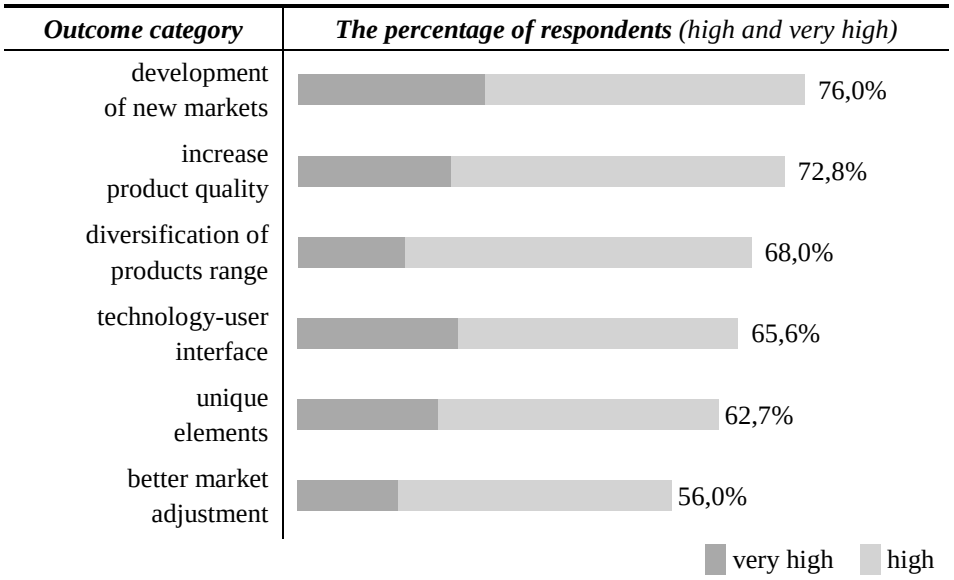

Figure 2. Outcomes for using design for new product

Source: Data analysis using SPSS

The fifth hypothesis that emerges from this study is:

H5: Product design facilitates the access of new technologies on the market by increasing the quality and the assignment of unique elements to the product, developing new markets and better adjustment to their requirements through the diversification of product's range and creating a better interface between technology and user.

For an overview that can integrate all these results, which highlight the importance of innovation through design in order to establish a connection between technology and market, the next logical sequence, which makes the connection between the company and the market, was built:

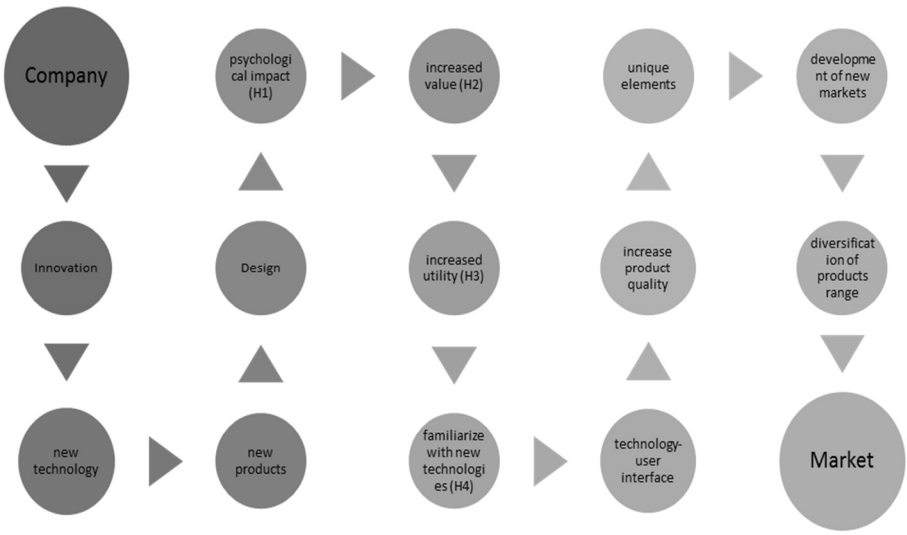

Figure 3. Graphical representation of the contribution which innovation through design has in order to connect technology with market

Source: own research.

Therefore, it is proven that design is a vital element which companies need to consider when they try to include new technologies on the market and all the five hypothesis and the previous examples show that design is the one that can turn a bad product into a successful one, a cheap product in an expensive one, a common product in an unique one.

Conclusions

In this research, the responses received from the 416 respondents confirmed the working hypotheses and enabled us to come to a series of conclusions regarding the role and importance of design as an innovation tool connecting technology with the market.

Thus we can state that product design influences the purchasing decision of consumers. Innovative design leads consumers to pay more for a product, attracting higher revenues for the company, 43.8% of them agreeing to pay between 10% -40% more for a product with innovative design. This represents an incentive for companies to innovate and develop products.

Design also has a significant contribution to the usefulness perception of a product as stated by 62.3% of respondents who consider design an important and very important element in assigning a utility degree to the purchased products.

Design significantly helps customers to familiarize with new technology, 76.7% of the respondents considered that design helps customers to a larger extent to familiarize with new technology.

The final and most complex part of our research was to pinpoint how does design contribute to the successful insertion of innovative products on the market: by increasing the quality and the assignment of unique elements to the product, developing new markets and better adjustment to their requirements through the diversification of product's range and creating a better interface between technology and user.

Acknowledgments

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ATP BIOLUMINESCENCE METHOD IN SURFACE HYGIENE MONITORING

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Introduction

The bioluminescence method uses the capacity of organic matter to release adenosine triphosphate (ATP), which is the principal energy source in all living organisms. This capacity is characteristic of bacteria, fungi and other microbes as well as food and food debris, including that on disinfected surfaces. The principle of the assay is based on the following enzymatic reaction:

$$\text{ATP} + \text{luciferin/luciferase} \rightarrow \text{AMP} + \text{PP} + \text{light}$$

Luciferase catalyses the oxidation reaction of luciferin to the form of higher energy state. The reaction can proceed properly only when energy carried by ATP is delivered. ATP breaks down to adenosine monophosphate (AMP) and phosphoric residues (PP). The oxidized form of luciferin returns to its primary energy state by emitting light with the wave of 562 nm, the precise measurement of which enables indirect assessment of ATP concentration. The amount of light emitted is directly proportional to the concentration of ATP. Thus, it is assumed that the amount of ATP in the sample is directly proportional to the amount of the microbial biomass. The amount of light emission, which results from the luminescence reaction, is measured with the use of a luminometer. This device contains a measuring chamber isolated from external light sources and a detector that processes the optic signal to the electrical one, which is expressed in relative light units (RLU).

Detection of microbial contamination with ATP assay is applied in clinical trials, environmental examinations (of water from bathing sites or ground waters) and food industry. In practice, the material for investigations is collected from solid samples, such as meat, and fluid ones: water, milk or wastewater [Deininger and Lee, 2001, Samkutty et al., 2001]. However, it must be noted that food products contain large amounts of ATP which may

considerably exceed the signal obtained from microbes when contamination is not high. In 1 g of meat or orange juice there is 10^{-7} g of ATP whereas a single bacterial cell usually contains 10^{-15} g of this compound. The amount of released ATP depends on the type and physiological condition of microbes. It is assumed that Gram-positive bacteria contain more ATP than Gram-negative ones, and the presence of ATP on spores is nearly undetectable (Kręgiel, 2012).

It should be considered a rapid method in comparison with the other techniques used to assess the number of microbes, since the time of measurement is several seconds. In commonly applied culture-based methods, one has to wait for microbes to grow for a long time. Molecular techniques based on DNA, despite their sensitivity and reliability in terms of both quantity and quality, require time and are expensive due to the reagents used. Microscopic methods, in turn, determine the total number of microbes (living or dead) and require their high concentrations (Squirrell et al., 2002, Seshardi, 2009).

ATP test in hygiene monitoring in food industry

ATP bioluminescence assay may be used for hygiene monitoring in food industry. The microbiological methods assessing cleanliness of the surfaces in contact with food, such as swabbing and contact plate method, are broadly used, but time-consuming due to the culturing stage. In manufacturing conditions, a method for rapid evaluation of microbiological cleanliness is sought for. This is associated with the requirements of the systems that assure safety of food production, which consist in rapid and efficient hazard detection and estimation in the control points of the HACCP system (Champiat et al., 2001). The technique of bioluminescence is applied in sectors producing animal products, in particular meat, and in farms with dairy and slaughter animals as well as in dairy industry (Finger and Sischo, 2001). Not only does this technique allow microbial ATP to be measured, but also indicates the ATP level of food debris and other organic contaminants, which might become a culture medium for microbes. This enables to detect incorrectness in the process of cleaning and disinfection, but it requires establishing certain critical limits. Moreover, this method may be used on a continuous basis during the production process, which, if incorrectness has been detected, enables to undertake immediate action so as to make corrections and establish hazards in real-time (Aycicek et al., 2006, Kręgiel, 2012).

A practical nuisance of the method is the fact that it is not easy to recount the luminometric results to the number of microbes. To interpret the luminometric results obtained at individual control points in a given industry or factory, it is necessary to establish the acceptable level of ATP. This

depends of various factors, such as type of resources, production and processing procedures, materials which the analysed surfaces are made of and risk associated with the product. Therefore, the limits for values cannot be unequivocally standardised. However, the manufacturers of luminometers indicate approximate limits for the main groups of food products. The most frequently proposed idea is to accept the median value (based on numerous measurements conducted at one point) as the acceptable limit, in which case the inadmissible limit would be the acceptable value multiplied by three. The introduction of limits to the software of the device helps to accelerate the measurements and work in the pass/fail system, where all values above "fail" attest to incorrect cleaning and disinfecting process and indicate the necessity to repeat it. The level "pass" indicates a satisfactory sanitary level (Hy-Lite Merck information materials).

Luminometric analyses conducted in dairy industry are primarily associated with investigating the surfaces of instruments: milking equipment, milk containers, pipelines, milk receivers etc., Vilar et al. (2008), assessed the hygienic effect after the application of various automatic and manual cleaning practices. The highest ATP level (100 000 RLU) was observed on surfaces cleaned with cool water without any cleaning agents. Low ATP levels were found in closed systems, particularly those cleaned automatically, and in large containers that are easy to clean. The most discrepant results (ranging from 9 to 38 570 RLU) were obtained in animal farms in which non-chlorinated water was used for cleaning. Low pressure and too low temperature were the reasons for the lack of adequate hygiene. These studies revealed that the luminometric method is a fast and easy tool that may help breeders to control the effectiveness of cleaning processes.

The ATP-based method was also used to compare the level of hygiene in fish-processing factories where the HACCP system has been implemented and in those operating without such a system. Hwang et al. (2011), used this technique in the critical control points on individual production stages in order to evaluate the hygiene level on the surfaces that have direct contact with food (transporters, baskets, knives or tables for cutting). The outcomes were compared with the results of swabbing tests performed on the surfaces of 10 cm^2. The level of ATP on the surfaces ranged from 460-85 000 RLU/10 cm^2, which corresponded to 1.0 – 3.5 log CFU/10 cm^2 of bacteria cultured. Despite certain discrepancies between the results, it was agreed that the tested method enables to rapidly determine statistically significant differences in hygiene levels in factories with and without HACCP system.

Research on improving the luminometric method to detect microbial contamination in food is underway. Luo et al. (2009), obtained a very good correlation of the measurements with the culture-based method by using an additional stage of extracting intracellular ATP from bacteria. There are

various methods of ATP extraction from cells based on ultrasounds: microwaves, organic solvents, strong acids and surfactants. It was shown that complete lysis may be achieved with the use of trichloroacetic acid (TCA) and cetyltrimethylammonium bromide (CTAB). Partial lysis, in turn, may be achieved using sodium dodecyl sulphate (SDS). The level of ATP detected in suspensions of bacterial cells lysed this way was considerably higher, which increases the reliability of assays when non-bacterial ATP is present in food samples. However, the chemical extraction method may negatively affect enzymatic activity of reaction-inducing luciferase. The residue of CTAB and TCA in the mixtures extracted, if not neutralized, may inhibit luciferase activity and decrease the level of detectable ATP. On the other hand, alkaline substances, used as neutralizers, may also decrease activity of this enzyme. Again, the authors emphasise that the usage of this method to directly determine the presence of bacteria in food is limited due to a high non-microbial ATP levels.

Bioluminescence in environmental studies

The bioluminescence method is also applied in checking and validating devices used for environmental measurements. Seshadri et al. (2009), tested the ATP-based method for rapid assessment of bioaerosol samples collected by impaction in air microbiological tests. The number of RLU units that corresponded to the number of bacteria was verified by direct count of acridine orange-stained cells under the fluorescence microscope. The study revealed high correlation between the methods for determining the microbial count for the two tested species, *Pseudomonas fluorescens* and vegetative cells of *Bacillus subtilis*, in filter extracts on which air samples were aspirated in different sampling flow rates. It was concluded that the bioluminescence method gives better outcomes in assessing efficacy and bacterial bioaerosol sampling than the microscopy and culture-based methods since it enables to localise and quantitatively assess losses in bacterial recovery resulting from their depositing on the sampler's elements. It was indicated that the method could be applied in the validation procedures of samplers used for collecting air for microbial testing. Moreover, when determining the ATP level that agreed with the number of *Pseudomonas fluorescens* and *Bacillus subtilis* bacteria in reference suspensions as calculated under the fluorescence microscope, the differences between these two species were identified. In suspensions of the same density with $10^4 – 10^7$ cells, the content of ATP was higher for *B. subtilis* than for *P. fluorescens.* This confirmed the necessity to draw up separate reference curves for each microbial species tested. In both cases, this method enabled to detect bacteria with the concentration of $10^5 – 10^9$ CFU/ml. It gave representative outcomes with high concentrations of bioaerosols which are seen in highly contaminated environments.

The bioluminescence method is also recognised in hygiene monitoring of materials used in installations for conditioning and distributing drinking water. Apart from technical properties, the materials used to build water supply systems, predominantly plastic ones, must be corrosion-resistant. In accordance with the EU Directive 98/83/EC, the substances and contaminants which accompany these materials must not be present in water intended for human consumption in concentrations which may be noxious for health. Apart from testing migration of hazardous chemical substances, microbiological testing concerning the susceptibility of material surfaces to form biofilms, is also required. A given material or product may be used in contact with water intended for human consumption only if it has the authorisation of the National Sanitary Inspectorate based on the hygiene certificate issued by the National Institute of Public Health - National Institute of Hygiene. The research method used in this institution consists in bioluminescence assay of swabs from materials following sample exposition to a dynamic water flow for 8-10 weeks. These studies are conducted with control plates: positive ones - paraffin-coated glass plates, and negative ones - stainless steel plates. The examined material is approved when the bioluminescence level measured on its surface after a given time period is not greater than its tenfold value for the negative control. The fact that the bioluminescence level tends to change during tests and the size of the surface which will remain in contact with water intended for human consumption are also taken into account when issuing the opinion. It is not easy to interpret the results. The analyses demonstrate numerous fluctuations of bioluminescence on various polyethylene and polypropylene materials, particularly in the first weeks of testing [Szczotko and Krogulski, 2010]. In other countries, the phenomenon of bioluminescence is also adapted to such testing. In the Netherlands, the BPP test (Biomass Production Potential) is conducted. It is used to measure ATP in static conditions without water flow (van der Kooij et al., 2001).

The usefulness of ATP assay in food assessment and the capacity of bacteria to adhere to bioactive polymers were analysed by Gutarowska et al. (2012). They demonstrated that it is possible to obtain well-correlated results concerning antimicrobial activity of polymers with the analyses performed using fluorescence microscopy. This method was considered a good marker of viability of cells in which, according to the literature, we observe their atrophy and inhibition of ATP synthesis as well as decomposition of this compound by ATP-ases and phosphatases. For certain species of bacteria, this was observed as soon as after several or several dozen hours of culturing on a bioactive polymer. In these studies, ATP measurement also demonstrated differences in viability and adhesion between the strains examined.

Bioluminescence in hygiene monitoring in healthcare facilities

The ATP-based method is not widely acknowledged in the assessment of cleanliness of surfaces in healthcare institutions. This is because monitoring usually concerns frequently cleaned and disinfected surfaces, and the expected number of microbes on these surfaces is low, which, in turn, translates into a weak bioluminescence signal, and is a limitation of this method. Different studies reveal numerous discrepancies concerning the accuracy of measurements resulting, among other things, from using various types of luminometers or manners of sample preparation (Davidson et al., 1999, Larson et al., 2003, Boyce et al., 2009, Aiken et al., 2011). For instance, during the studies reported by Brown et al. (2010), one device showed the value of 3 352 RLU whereas the other displayed the value of 163 RLU for the same fluid. Moreover, of six measurements performed, one was false positive. Discrepancies were also noted in reproducibility of assays using the same device. In many cases, such inaccuracy of measurements may be explained by the usage of various cleaning detergents and chemical washing agents which may affect luminometric readings. However, the validation of the measuring procedure and establishing critical limits seems to be impossible in such a situation. Shama and Malik (2013) emphasise that the ATP-based method is not appropriate for monitoring microbial pathogens, particularly those with low infective doses. They also mention difficulties associated with material sampling from uneven or coarse surfaces in hospital settings, such as fabrics covered with biofilm enclosed by polysaccharide matrix. The authors draw attention to significant differences in the degree of intracellular ATP release depending on the species and physiological condition of a microbe. Such differences may even amount to 250% in the cases analysed by these authors. In the studies of Willis et al. (2007), the attempts to correlate the results of bioluminometric tests and culture-based analyses, conducted in hospital settings on various surfaces, such as floors, tables, windows or bathrooms, produced discrepant outcomes. The correlation coefficient indicated was very low and equalled 0.078 which is typical of this type of environment. It was, however, possible to find more contaminated surfaces, which was the floor under patients' beds, and less contaminated ones, such as personal belongings.

Bioluminescence method in textile hygiene monitoring

It was attempted to use the ATP-based method to detect microbial contamination on textiles. A common method to dispose of microbes from textiles is washing them. Hence, in the analysed case, the presence of bacteria was investigated on highly contaminated materials washed prior to the measurements. It was also checked whether bacteria can be detected on fabrics which might become contaminated while being washed together with other

contaminated fabrics. Moreover, the presence of microbes was also investigated in the washing bath and water after rinsing.

A suspension with *Escherichia coli* with the concentration of 6 x 10^8 CFU/ml was placed on two different textile types (100% cotton fabric - warp and weft and blend fabric: warp - 100% cotton and weft - 100% polyester). Both contaminated fabrics and non-contaminated samples were washed with the use of a standard washing agent in the temperature of 40 ± 2ºC. Subsequently, the samples underwent extraction in order to recover the microbes. The count of living bacteria in the samples washed was conducted with the culture-based method using selective medium. The outcomes were compared with luminometric signals recorded for the corresponding samples. Prior to conducting tests on fabrics that did not undergo extraction, a sample material was taken with a swab free from ATP, which was then placed in a reaction mixture, and bioluminescence tests were conducted with the use of a HY-LiTE®2 device (Merck). The average results from three measurements for each of the methods, including standard deviation values, are presented in table 1.

Table 1. The number of *E.coli* bacteria in extracts of fabrics washed together with textiles contaminated with a suspension with *E.coli* measured using culture-based method, and a corresponding level of ATP signal

Samples of textiles and water after washing	Bacteria count in textile extracts [CFU/ml]	ATP level in textile samples after washing [RLU/25cm^2]
contaminated textiles, without washing		
cotton fabric	13.33 x 10^6 ± 7.57 x 10^6	3 267 ± 1 358
blend fabric	8.67 x 10^6 ± 5.18 x 10^6	9 867 ± 6 493
contaminated textiles, after washing		
cotton fabric	absent[1]	85 ± 12
blend fabric	absent	187 ± 38
non-contaminated textiles, after washing with contaminated cotton fabrics		
cotton fabric	40 ± 30	44 ± 8
blend fabric	absent	31 ± 7
washing bath	absent	1 433 ± 58
water after the last rinsing	70 ± 18	61 ± 3
non-contaminated textiles, after washing with contaminated blend fabrics		
cotton fabric	83 ± 77	43 ± 3
blend fabric	absent	38 ± 18
washing bath	absent	850 ± 132
water after the last rinsing	115 ± 21	51 ± 14

[1]absent - bacteria undetected by the culture-based method

Source: own research

The outcomes presented in table 1 indicate that when textiles are highly contaminated a reliable bioluminescence signal may be obtained - at the level of several thousand units. It corresponds to several million CFU per 1 ml of textile extracts analysed with the culture-based method on microbiological medium. Following washing, the bioluminescence signal decreases considerably in the case of previously contaminated samples and those that could become contaminated in these washing process. Nevertheless, it indicates the presence of microbes in the fabrics whereas the culture-based method failed to detect bacteria in extracts from numerous textile samples. Bacteria were present in washed fabrics, which is demonstrated by their growth on Endo media plates (fig. 1). The bioluminescence signal was also registered to a satisfactory degree in fluids after washing, particularly in washing baths. Therefore, it may be concluded that this methods enables to indicate the path of textile contamination during washing.

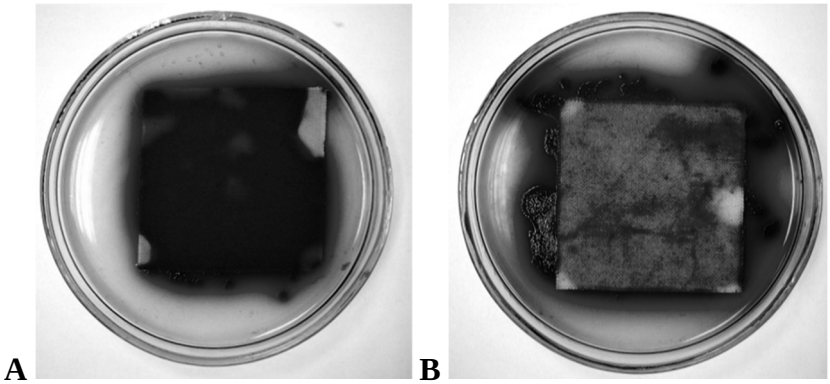

Figure 1. Growth of *Escherichia coli* on cotton textile samples placed on the Endo medium after 24-hour incubation
A – samples of unwashed textiles
B – samples of washed textiles

Source: own research

Conclusions

The bioluminescence method is being acknowledged as a tool to monitor the efficacy of cleaning and disinfecting practices in both food industry and health care. However, microbial contamination monitoring by ATP measurement cannot be commonly applied due to considerable limitations of this method. Among others, these limitations result from: low sensitivity of commercially available luminometers used for detection of microbes, poor reproducibility of results, particularly between surfaces with various properties and purposes, as well as unfavourable influence of environmental

factors on the measurement outcomes. Nevertheless, it must be emphasised that the bioluminescence method may serve as a good educational and informational tool which is capable of indicating sites of higher susceptibility to microbial contamination in an easy and rapid way.

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POTENTIOMETRIC TASTE SENSOR APPLICATION FOR LIQUID PRODUCT TASTE ESTIMATION

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Introduction

The taste of food is important for human beings. It affects not only the man frame of mind but also it has an influence on the price of a product. In norms (PN-EN ISO 5492:2009) five kinds of basic qualities of taste have been described: saltiness, produced mainly by sodium chloride, sourness caused by acid hydrogen ions (hydrochloric, acetic or citric), bitterness produced by quinine hydrochloride or caffeine, sweetness due to different types of sugars (e.g. sucrose, fructose) and umami caused mainly by monosodium glutamate content (Skolik 2011). It is proposed to use fatness as sixth taste (Stewart et al. 2010, Mattes 2005).

The taste of food depends on the substances present in the product. In general, the taste is mainly estimated by organoleptic methods (PN-ISO 6658:1998). Taste molecules reach biological membranes of gustatory cells situated on the tongue surface and information is transformed into electric signal transmitted by the nerve fibbers to the brain. Two different approaches of taste estimation are used: organoleptic testing and sensory analysis (PN-ISO 6658:1998, Skolik 2011). The first method can be used by each consumer independently on his experience, hence it is very subjective, meanwhile the second one is more objective as conducted by experts in standard conditions. The percentage of objectivity obtained depends on the nature and predisposition of vivid organism. To avoid these disadvantages a lot of investigations have been focused on elaboration of an artificial taste sensor for quality control of food or for recognition of similar products from different branches (Toko 1996, Ciosek 2006, Lvowa 2006, Szpakowska 2006). The artificial sensors consisting of a few membrane electrodes should exhibit cross-selectivity. This means that electrode responses should be correlated

with the composition of substances present in a sample. This approach demands elaborating a new composition of broadly selective polymeric membrane.

Artificial taste sensors are based on potentiometry (Toko 1998, Szpakowska 2009, Ciosek 2006) or voltametry (Winquist el al. 1998). The potentiometric sensors consist either of several ISEs or of several ASSEs. Both types of electrodes contain a polymer film composed of a polyvinyl chloride membrane with lipophilic compound and plasticizing agent attached to the electrode body. ISEs are filled with KCl inner solution of appropriate concentration. In case of ASSEs, KCl inner solution is replaced by an electroactive polymer acting as ion to electron transducer and it is attached to the glassy carbon disc. PVC membrane with lipophilic compounds embedded is covering the electroactive polymer layer. Such lipid membranes are useful materials to transform taste to electric signals. The membrane is fitted on a given electrode body and immersed in solution containing appropriate taste substances together with reference electrode. The electrodes' responses depend on taste or quality of soluble substances in a tested solution.

The information is extracted from the responses of working electrodes using mathematical analysis PCA. This is a kind of multivariate analysis used for reduction of data dimensions without losing much information (Holm & Brun 2000). In taste sensor, a multidimensional space of electrode outputs is reduced to two or three dimensions. The results obtained by this method are compared with taste test performed by experts (sensory analysis). PCA plot shows grouping of the tested solutions or foodstuffs according to a given attribute (e.g. similar taste).

The Pattern Recognition method (Dillon &Goldstein 1984) may be also used for the interpretation of electrodes' responses of potentiometric taste sensor. The multidimensional sensors' outputs may also be presented as radar plots (electrodes' responses vs. substance concentrations). Comparison of this radar plots with standardized pattern databases enables identification of unknown samples as well as detection of adulteration.

First multichannel potentiometric taste sensor with ISEs was proposed by Japanese scientists (Toko 1996, 1998, 2005). This sensor is composed of eight electrodes containing different lipid - polymer membranes. The following lipophilic compounds were used in the polymer membrane: dioctyl phosphate (DOP), cholesterol, oleic acid, decyl alcohol, methyltrioctylammonium chloride, octadecyl amine, dimethyloctadecyl ammonium bromide, trimethyloctadecylammonium chloride (TOMA). In some cases mixtures of particular ratio of few lipophilic compounds (DOP:TOMA = 9:1, or 5:5, or 3:7) have been used in the polymeric membrane. (Toko 1998). In 1993 the authors elaborated the commercial taste-sensing system called SA401, which was sold by Anritsu Corporation. In this model the detecting part was made

up of seven working electrodes containing lipid/polymer membranes. The sensor was controlled mechanically by a robot arm. Such sensor was successfully applied for discrimination of different commercial products such as sake (Iiyama 1996), milk (Yamada 1995). Different brands of beer were also distinguished by the electric potential patterns obtained from the sensor results (Toko 1994). Diverse kinds of commercial mineral water were also tested (Toko 1998). Apart from beverages, this sensor was also applied to commercial products in gelatine or solid form such as canned tomato juices or soybean paste (Toko K. 2005, Kikkawa et al. 1993). It is also proposed (Toko 1998) to use such potentiometric sensor in environmental science e.g. for water purity estimation. Recently, the Japanese scientists have developed a new portable taste sensor chip with lipid-polymer membranes and they found that the sensor's responses to a standard astringency substance showed good accuracy and reproducibility (Tahara et al. 2013).

The other taste sensor with five ISEs was proposed by polish scientists (Szpakowska et al. 2004, 2006, 2008). The following lipophilic compounds were used in the polymeric membranes: benzylhexadecyldimethylammonium chloride monohydrate, hexadecylamine, elaidic acid, 1-dodecanol, cholesterol. It was found that electrodes' responses were sensitive to bitter, sour and salt substance and not sensitive to sucrose concentration (Szpakowska 2006). Five channel taste sensor with ISEs was applied for some groups of soft drinks composed of sucrose, citric acid, quinine hydrochloride and carbon dioxide (Szpakowska et al. 2006, 2008).

The other polish group (Ciosek & Wróblewski, 2004, 2006) has elaborated taste sensor based on an array of ISEs combined with selective membranes. Analysis of multidimensional data from this sensor requires use of various pattern recognition tools. Such sensor was applied to qualitative analysis of mineral waters, apple juices (Ciosek &Wróblewski 2004) as well as milk and tonics (Ciosek 2005). This device was capable of reliable discrimination between different brands of mineral waters and fruit juices, milk and tonics. These authors elaborated so called flow–through electronic tongue based on miniaturized solid-state potentiometric sensors. The ion-selective and partially selective microelectrodes were applied in this flow-through sensor array. The beer from different brands and different manufacture dates were analysed. It was shown that the combination of such microelectrodes in the flow-through sensor array led to the recognition of beer from different brands with high correctness (Ciosek &Wróblewski 2006). Such miniaturized electronic tongue system based on proper choice of polymer membrane sensors can be used for the quality control of other commercial drinks.

All solid state electronic tongue chips based on a carbon paste modified with Prussian Blue was proposed by Russian and Korean scientists (Lvova et

al. 2002).This electronic tongue was applied for discrimination of potable waters, soft drinks and beer.

As it was shown above potentiometric sensors may be an attractive tools for various taste sensors (electronic tongues) which may be used in the wide area of applications, mostly in foodstuff technology, but also in environmental protection and even in drug development and pharmaceutical industry (Sohi 2004)

In this work the application of potentiometric taste sensors with a set of ISEs and ASSEs differing in the choice of lipophilic compound for discrimination or quality control of different kind of soft drinks has been presented. Analysed soft drinks are composed of sucrose, citric acid, quinine hydrochloride and carbon dioxide (tonics and orangeades).

Material and methods

The following reagents of analytical grade were used from Fluka Chemie or Aldrich: lipid analogues or lipophilic salts (benzylhexadecyldimethylammonium chloride monohydrate, dodecyltrimethyl ammonium bromide, benzyldimethyltetradecylamminium chloride, hexadecylamine, elaidic acid, palmitic and stearic acids, 1-dodecanol, cholesterol), dioctophenyl phosphonate (DOPP) as plasticizer, polyvinyl chloride (PVC), 3,4-ethylenedioxythiophene monomer (EDOT) and poly (sodium 4-styrenesulfonate (NaPSS)). Tonics and other drinks were commercial products.

Preparation of ISE: The polymer film attached to the electrode body is composed of lipid analogue or lipophilic salt embedded in polyvinyl chloride (PVC) with plasticizer. The internal filling of electrode contains 0.1M KCl solution.

Preparation of ASSE: The electrode consists of two layers covering glassy carbon disc: a layer of electroactive polymer (pEDOT/PSS^{-}) and a layer of plasticized PVC containing lipophilic compound.

The experimental set-up consisting of several working electrodes (1), reference electrode Ag/AgCl/Cl^{-} (2) and high-input-impedance voltmeter is presented in Fig. 1. The five ISEs or four ASSEs and a reference electrode were immersed in the appropriate solution containing a given commercial drink. The electrodes were conditioned in 0.1 M KCl prior to and between measurements.

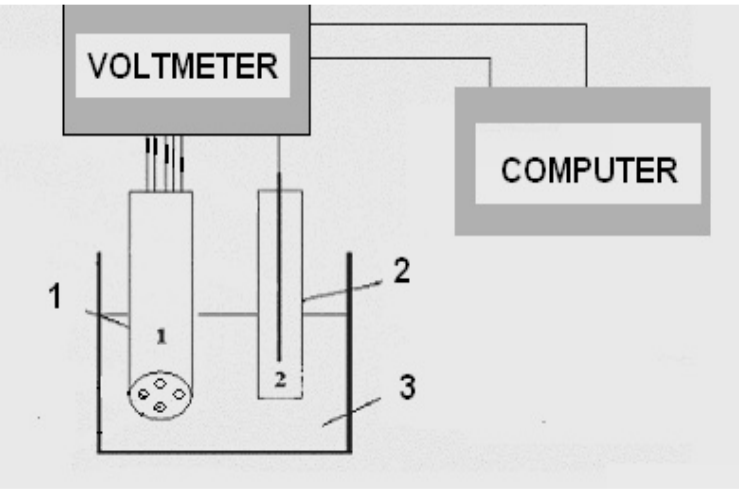

Figure 1. Potentiometric taste sensor: 1 – set of working ISEs or ASSEs 2 – Ag/AgCl/Cl$^-$ reference electrode, 3- tested solution

Source: self elaboration

The organoleptic discrimination tests were executed in order to provide interpretation of the principal components resulting from the multivariate analysis (PCA). Ranking test was chosen out of discrimination tests to rank examined soft drinks according to increasing taste intensity. 12 testers were selected out of 30 persons (ISO 8587, ACTIA, 2001). Each tester received eight coded samples of soft drinks during one session and the results were written down on the evaluation cards. The results of ranking were analyzed with Friedman test in order to detect significant differences between the sums of the ranks of samples.

Results and discussion

The potentiometric taste sensor with ISEs (Szpakowska 2004) and ASSEs (Szpakowska 2009) was tested in sour solutions (hydrochloric, acetic and citric acids). It was found that the response of electrodes containing positively charged membranes (benzylhexadecyldimethylammonium chloride monohydrate, dodecyltrimethylammonium bromide or hexadecylamine) decreases with increase of sour substance concentration, meanwhile the effect is opposite in case of negatively charged (elaidic acid) or neutral membranes (1-dodecanol or cholesterol). In the case of bitter substances, three electrodes: one containing elaidic acid (negatively charged membrane) and two with 1-dodecanol or cholesterol (neutral membranes) were only sensitive to quinine hydrochloride. It was also found that all the membrane electrodes were almost not sensitive to sucrose concentration (Szpakowska 2006, 2008).

In case of ASSEs it was found that electrodes with both positively charged polymeric membranes (dodecyltrimethyl ammonium bromide, benzyldimethyltetradecylamminium chloride) and negatively charged membranes (palmitic or stearic acid) behave similarly (Szpakowska et al. 2009).

The potentiometric taste sensors with ISEs or ASSEs were successfully applied for discrimination of different kinds of soft drinks, which contain mostly sucrose, quinine hydrochloride and carbon dioxide. These were commercial tonics from different brands as well as homemade tonic and bitter lemon type beverages (Szpakowska 2006). The electrodes' responses were transformed by multivariate analysis PCA (Dillon 1984) and combined with organoleptic tests.

In this work the results obtained by potentiometric taste sensor with five ISEs or four ASSEs for several commercial tonics of different brands are presented. In case of sensor with ISEs (Figure 2) it was found that the tested soft drinks can be classified into three main groups - of different sour and bitter taste intensity according to ranking test performed by 12 selected testers (Szpakowska 2008). The taste within the same group was similar to each other. The points 1 and 2 (Figure 2) related to polish market tonics: Jurajski and Hellena respectively, are characterized by the least intensive sour and bitter tastes. The greatest intensity of sour taste was observed for Schweppes Indian tonic (no 3 in Figure 2) and Kinley (no 4 in Figure 2). This observation was confirmed by the organolpetic ranking test.

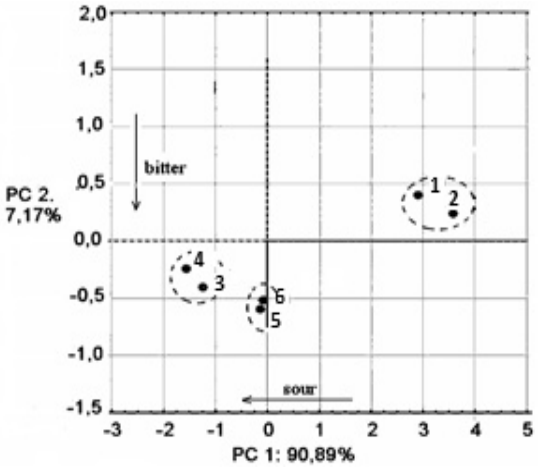

Figure 2. PCA plot for the first two principal components of data obtained for different brands of tonics: 1 – Jurajski, ,2 –Hellena, 3 – Schweppes Indian, 4 – Kinley, 5 – Kinley Lemon, 6 – Schweppes Bitter Lemon (Szpakowska 2008)

Source: self elaboration

Orangeades were also examined by potentiometric taste sensor with ISEs (Fig. 3). Such drinks contain mainly sucrose, citric acid and carbon dioxide. Hence, in this case the first two principal components were interpreted in respect to sour (PC 1) and sweet (PC 2) tastes. The following orangeades were examined: Lemoniada jurajska (no 1), Ustronianka cytrynowa (no 2), Oranzada Helena (no 3), Oranzada Nata (no 4). As can be seen they may be classified into two groups, each of different taste intensity profile. Lemoniada jurajska (no 1) and Ustronianka cytrynowa (no 2) are less sweet then orangeades Hellena (no 3) and Nata (no 4). It was also confirmed by organoleptic tests, that the taste of drinks within the same group is similar. Drinks no 1 and no 2 belong to the typical lemon taste beverages. The second group, drinks no 3 and 4, belong to the sweet fruity taste beverages.

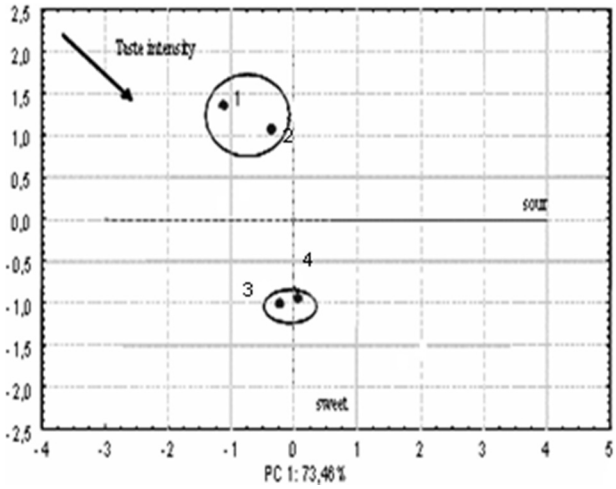

Figure. 3. PCA plot for the first two principal components of data obtained for various commercial orangeades: 1- Lemoniada jurajska, 2- Ustronianka cytrynowa, 3-Oranzada Hellena, 4-Oranzada Nata, 5-Sprite, 6-Hoop Premium Lemon

Source: self elaboration

From the results presented in Figures 2 and 3 it can be concluded that ISE potentiometric taste sensor with lipophilic compound (benzylhexadecyldimethylammonium chloride monohydrate, hexadecylamine, 1-dodecanol, elaidic acid, cholesterol) - polymer membranes could be successfully applied for discrimination of different kind of soft drinks (tonics and orangeades).

ASSEs based on lipid-polymer membranes with conducting polymer PEDOT/PSS^- and lipophilic compound (dodecyltrimethyl ammonium bromide, benzyldimethyltetradecylamminium chloride, palmitic and stearic

acids) in the membrane were also applied to chosen tonics and another soft drinks. The ASSEs responses analyzed by PCA method are presented in Figure 4. Tonics (no 1, 2) are made of sucrose, citric acid, quinine hydrochloride and carbon dioxide and are characterised mainly in terms of bitter taste. Meanwhile soft drinks: 7up (no 3), CIT Nata (no 4), Sprite (no 5) do not contain quinine hydrochloride and are characterized by lemon taste. Grouping of the points corresponding to appropriate beverages presented in Figure 4 is analogous to grouping according to taste attributes determined in organoleptic tests.

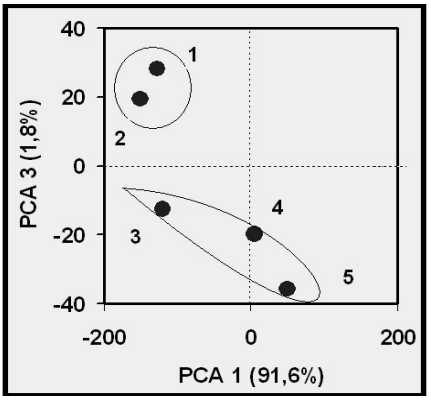

Figure 4. PCA plot for the first two principal components of data obtained by sensor with ASSEs for tonics: 1- Kinley, 2- tonic Nata, and 3 - 7up, 4- CIT Nata, 5-Sprite.

Source: self elaboration

Actual trends in taste sensor technology

Since the year 1993 when the collaborative research between Anritsu Corporation and Kyushu University resulted in development of commercial Taste Sensing System SA401 up to now there were three other, improved taste sensors made commercially available by Insent Inc. The actual version is called Taste Sensing System TS – 5000Z and it was introduced to the market in 2007. This model is designed to be used for both quality control and in laboratory. This Taste Sensing System, as all previous ones, is based on potentiometric measurements and employs ion selective electrodes with membranes with lipophilic compounds. Since 2007 there have been 100 units of TS – 5000Z sold in Asia and Europe (Insent Intelligent Sensor Technology**,** Inc. Web).

As it was already mentioned, actually there exits an approach towards the development of a miniaturized taste sensor chip for a portable type taste sensing systems (Tahara, 201, 20131)

Conclusions

From the results presented above it seems that potentiometric taste sensor with ISEs or ASSEs containing lipophilic compounds could be successfully applied for discriminating different kinds of soft drinks composed of sugar, citric acid, quinine hydrochloride and carbon dioxide. Application of PCA method for processing of acquired data enables classification of soft drinks according to specific taste involving influence of CO_2 content on taste. The ASSEs seem to be more advantageous than ISEs in potentiometric taste sensor due to simpler electrode construction (no internal electrolyte solution). However more investigations are necessary for technical improvements.

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INFLUENCE OF ETHNICITY ON THE PERCEPTION OF FOOD THROUGH THE LENS OF A UNIT PACKAGE

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Introduction

Individual packaging is now recognized in most countries of the world as one of the basic instruments of product strategy whose task is to ensure the desired quality, create a positive image and brand on the market.

Contemporary expansion of self-service stores, where the organoleptic assessment of the product is often impossible, causes that packaging becomes a kind of "silent seller " and it plays the key role in making a purchasing decision .

A unit package is a link that through trade connects the manufacturer with the end recipient of the product - the consumer. Hence, so much attention is given to the visual aspect of packaging. Properly selected components of packaging, in particular, the type of the packaging material used, its structural form and shape, color, graphics, the size and method of closure, allow one to create the desired image of the product, which is particularly important in the case of food products. The image of the packaging should be harmonized and taking into account the ethnic, social and legal factors as well as consumer habits .

Appropriate design of the packaging should therefore be a planned activity because it is to become a stimulus of choice and a factor affecting profitability of the organization.

The aim of this study is to investigate the influence of selected packaging elements on customers' purchasing decisions as regards food products with a particular focus on ethnic factors using the example of Polish consumers (representatives of the EU) and Norwegian ones (representatives of the EFTA countries).

Packaging as a tool of marketing strategy

Packaging is a very important tool of a company's marketing strategy in the market of consumer goods.

The popular J. McCarthy's concept, the so called marketing mix, including four elements: product, price, place and promotion, known as 4P, draws attention to harmonization of the individual elements making this composition up (Mruk, Pilarczyk, Szulce 2005). As a result the economic entity can effectively use them to interact with buyers and stimulate the desired attitudes and behavior. In the case of food products - packaging is inextricably linked to the product; actually it is its equal partner (Altkorn 1995). Increasingly, the classic 4P mix is extended by the fifth element - packaging which, on the one hand, competes with other elements of the marketing mix for the resource pool anticipated in the company's marketing plan, but on the other hand is a complementary factor to other elements of the marketing-mix, because every tool in the available instrumentarium plays a specific role in achieving the market success (Ciechomski 2008).

Properly selected components of packaging are the instruments of building up a product image, which is particularly important for widely used products including food products. The design process of a unit package for a consumer product should take into account marketing determinants: the target user profile, consumption trends, elements of the package image, comparison with competitive packaging. The aim of designing new packaging is to attract the consumer's attention and provide a possibility of identifying the characteristics and attributes of the product through the lens of the package (Romek, Tarnowski 2007).

The design work on packaging should start with understanding of the specificity of the product introduced to the market for which the package is to be designed. One must pay attention to the history of the brand, the cost of product manufacture and the technical characteristics of the product .

An important element of the design work is also an analysis of the company's marketing strategies including the target group of buyers, the time of introducing the packaged product to the market and marketing trends. Therefore, to meet the consumer demands, i.e. to satisfy their needs and the desire to buy, market research should be carried out among the people to whom the product will be addressed. Such a study should collect consumer opinions about unit packages of the product placed on the market and should provide results in the form of suggestions concerning the design for the product packaging. Usually the opinions collected regard labeling of the packaging, the shape and material of the packaging, possibilities of using the entire contents of the package as well as the possibilities of opening the package (Szymczak, Ankiel - Homa 2008).

A concept of a package design should consider guidelines concerning both technical and communication requirements. A conceptual package design should pay attention to an easy identification of the characteristics and attributes of the product. Excessive information should be avoided as it can become confusing for consumers (Walecka 2009).

While designing a package, one should bear in mind that each and every element of the packaging carries a specific message for the consumer, for example:

– packaging material can communicate the quality of the product;
– the shape-related structure of packaging can communicate the ease of use, economics or luxury of the product;
– color can communicate the nature and characteristics associated with the use of the product (Szymczak, Ankiel - Homa 2008).

A unit package is one of the most important elements of the supply chain linking the manufacturer to the end user of the product. Hence so much attention is given to its image.

Specificity of food sales in retail chains in Poland and Norway

In the situation of supply exceeding demand and the development of modern Polish and, to a large extent, foreign retailers, the contemporary Polish consumer can make choices from a multitude of various food products (Kosicka - Gębska, Tul - Krzyszczuk, Gębski 2011).

The Norwegian consumer goods market is dominated by only four groups of retailers, all of them of national character, including: Coop Norge AS, Norgesgruppen ASA, Rema 1000 Norge AS and ICA Norge, which are responsible for 99 % of the turnover in the retail market. (Department of Trade and Investment Promotion, Polish Embassy in Oslo, 2010).

Norwegians usually make purchases in shopping malls. The products available in Polish stores are different from the range offered in Norway. This is due mainly to traditions adopted in both countries, social and climatic factors, manifesting themselves in different tastes and preferences of customers. It can be noted that the range of goods in Norwegian food retail chains is much less diversified and poorer than in the Polish ones. What is more, in Norway one can observe exceptional and unprecedented in the Polish culture commitment to indigenous goods. We should not forget that an average Norwegian consumer is much wealthier than the average Polish consumer and he can easily afford a purchase of a more expensive Norwegian product instead of a cheaper foreign one.

Thus, the ethnic factor is very important when it comes to choosing food products.

Analysis of the impact of the visual aspect of packaging on customers' purchasing decisions

The study of the impact of packaging on the customer's perception is not an easy task. Very often customers' opinions on this topic are mutually exclusive. The research proves, however, that in practice customers yield to the influence of the package image - its form, graphics, colors, information, innovative forms, and the packaging itself is a very important element of the product and brand identification.

Comparative analysis of the Polish and Norwegian consumer behavior considering perception of the visual aspect of packaging and packaging innovations has become the aim of the presented study.

Research methodology

Primary information was collected using the method of direct interview. In order to assess the impact of the visual aspect of packaging on purchasing decisions of buyers, a questionnaire formulated in two respective languages was used. What was investigated was the importance assigned by customers to selected quality attributes of a food product which are most often referred to in literature and, in particular, the position of packaging among these quality criteria. The main task of the respondents was to evaluate the significance of individual features of the products and the information placed on selected food products against a nine-point scale. The study was conducted on a sample of 150 people who do food shopping in Poland and Norway. The study involved a random sample of 75 Polish customers of the Tesco retail chain and 75 Norwegian consumer of the Coop Obs self-service shops. The age of the group participating in the study ranged from 18 to 65 years. The time horizon of the study covered the period from February to May 2013.

Results and Discussion

The study of the role of packaging among other product marketing attributes when choosing a food product has shown that for both groups of respondents it has a smaller impact on the purchasing decision than the quality, price and brand but bigger than advertising.

The Materials and methods section should provide sufficient detail to allow the work to be reproduced. Methods already published should be indicated by a reference: only relevant modifications should be described.

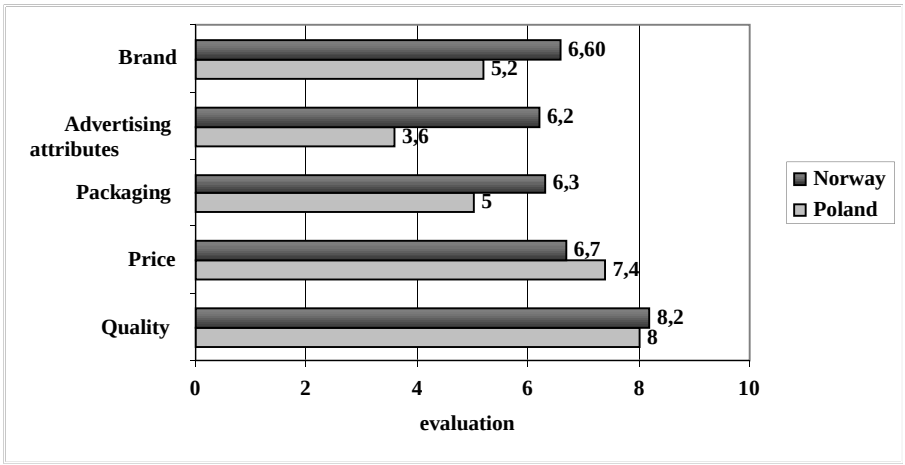

Figure 1. The importance of product marketing attributes for Polish and Norwegian customers while choosing foods – the average in the nine-point grading scale

Source: own research.

In addition, the research has shown a strong influence of packaging on purchasing decisions in the case of Norwegian buyers as 19% of Norwegian respondents pointed to packaging as the most important factor affecting their purchasing decisions, whereas only 4 % of Polish respondents identified packaging as a factor determining their purchasing decisions.

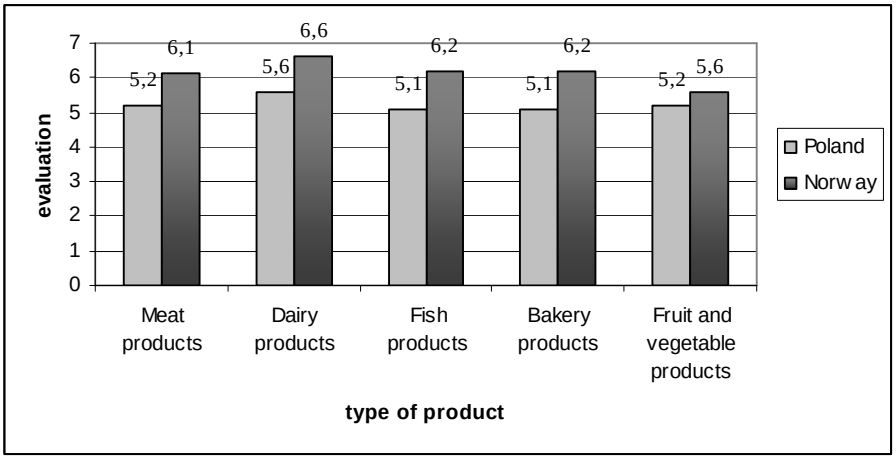

Figure 2. The influence of packaging in particular groups of food products as perceived by Polish and Norwegian customers

Source: own research.

Analyzing the perception of unit packaging in the context of the type of the food industry, it was found out that respondents from both countries attach the greatest importance to packaging of the dairy industry products. The variety of forms of packaging, functionality, and their weight cause that both Polish and Norwegian customers can adjust their purchases of dairy products to current needs. However, the dominating position of the TINE company functioning on the Norwegian dairy market results in a poorer variety of forms of packaging in Norway in comparison to the Polish dairy market.

It is worth noting that in the case of the surveyed customers from Norway the average rating of the importance of dairy product packaging was higher (6.61 in the nine-point rating scale) than in the case of the of Polish respondents (5.56) .

Analyzing the survey results it is clear that in comparison to Poles Norwegians attach more importance to packaging in all the examined groups of products. Norwegian respondents attach the least importance to packaging of fruit and vegetable products, whereas Polish clients consider packaging of fish products the least important. This may be due to the fact that Norway is a country rich in both freshwater and saltwater fish. Hence, they are an important component of the daily diet of the inhabitants of Norway who eat fish more frequently than Poles and therefore they ranked fish product packaging higher than for example that of meat products. In Polish culture, fruit and vegetables are consumed more often because they are simply more common than in Norway, so greater importance is assigned to fruit and vegetable product packaging. The attitude of Norwegians to bakery product packaging is also worthwhile. When buying bread, customers usually cut bread themselves, and then pack the sliced product into additional packaging in the form of foil bags to keep it fresh for a longer time.

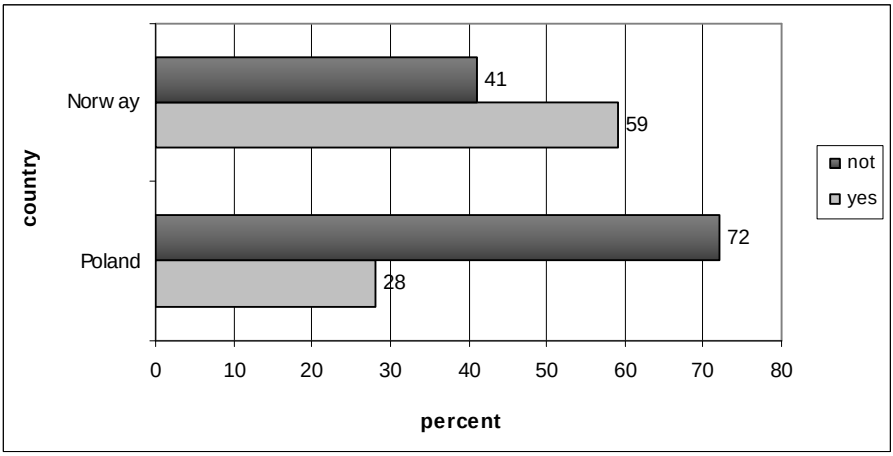

Figure 3. Yogurt packaging vs. its quality in the opinion of Polish and Norwegian customers

Source: own research.

The perception of the product through the lens of packaging was examined also on the basis of the Activia flavored yogurt. Figure 3 shows that the surveyed respondents from both countries have different views on this subject.

Over 50% of the surveyed inhabitants of Norway expressed the view that yogurt packaging creates for them the image of the quality of the product. This opinion is shared by only 28% of Polish respondents.

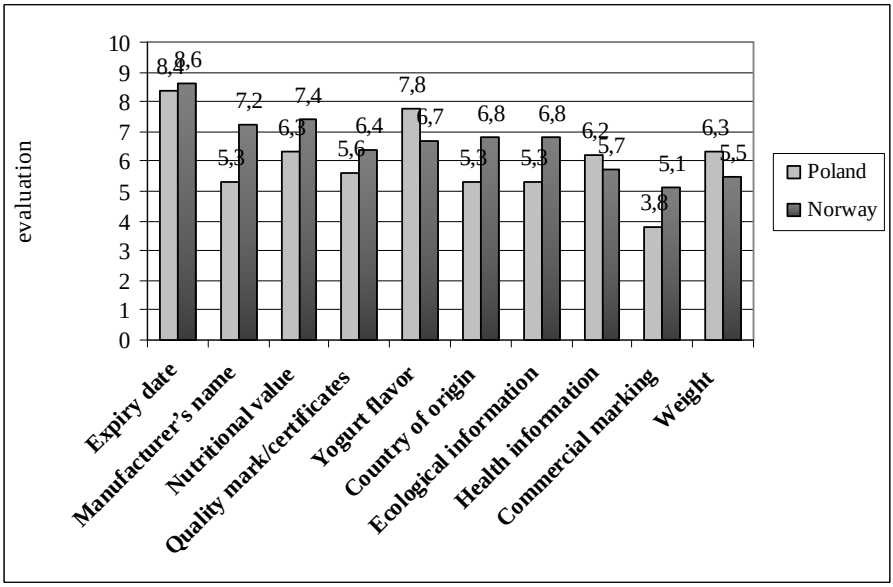

Figure 4. The importance of packaging information for buyers from Poland and Norway

Source: own research.

Analyzing the importance of the information comprised on dairy product labels (Activia yogurt), it must be noted that Norwegian consumers rated it much higher than the Polish ones (Norwegians: 8.06 ÷ 5.08 ; Poles : 8.43 ÷ 3.77). Most respondents in both countries considered the expiry date to be the most important information on packing (Polish customers rated the importance of the expiry date at 8.43 in the nine-point grading scale, and Norwegians - at the level of 8.60).

Further assessments vary in both countries. Apart from the expiry date Norwegian customers regard the company name, nutritional value, country of origin and ecological marking as important information. On the other hand, Polish consumers rate flavor, its weight, nutritional and health information high. Only in the case of the product flavor and weight Polish ratings were

higher than those of Norwegians. The lowest average rating (3.77 – the average rating in the nine- point scale) was assigned by Polish consumers to advertising information, which suggests a limited trust of the Poles surveyed in the gimmicks used by manufacturers.

Table 1 Perception of the properties of the packaging by a Polish client

Packaging properties	Answers to the question: do you pay attention to the following selected elements of packaging?				
	Definitely yes	Rather yes	Rather not	Definitely not	I don't have any opinion
[%] of answers					
Visual aspect of packaging	6.7	48.0	37.3	2.7	5.3
Form of packaging	26.7	56.0	14.7	0.0	4.0
Type of packaging material	17.3	28.0	36.0	6.7	12.0
Ecological aspects of packaging	12.0	40.0	30.7	10.7	6.7
Clarity and legibility of information	21.3	37.3	29.3	12.0	0.0
Freebie packages (extra yogurt free of charge)	28.0	56.0	9.3	6.7	0.0
Increased yogurt cup size at a fixed price	29.3	49.3	16.0	0.0	5.3

Source: own research.

In fact, the Norwegian consumers also gave the lowest score to commercial information but still the result was higher (5.08 – the average rating in the nine-point scale).

In addition to the information placed on yogurt labels which was suggested in the questionnaire, respondents most often mentioned information about high contents of large pieces of fruit, marking the yogurt as a bio–product and information about low contents of sugar or fat as important.

Table 2. Perception of the properties of the packaging by a Norwegian customer

Packaging properties	Answers to the question: do you pay attention to the following selected elements of packaging?				
	Definitely yes	Rather yes	Rather not	Definitely not	I don't have any opinion
	[%] of answers				
Visual aspect of packaging	30.7	41.3	22.7	0.0	5.3
Form of packaging	38.7	52.0	6.7	0.0	2.7
Type of packaging material	33.3	44.0	10.7	6.7	5.3
Ecological aspects of packaging	50.7	24.0	18.7	5.3	1.3
Clarity and legibility of information	16.0	53.3	21.3	9.3	0.0
Freebie packaging (extra yogurt free of charge)	46.7	42.7	5.3	5.3	0.0
Increased yogurt cup size at a fixed price	34.7	56.0	6.7	0.0	2.7

Source: own research.

To analyze the role of packaging in food marketing it was particularly interesting to know how important the properties of packaging were to consumers from both countries. To learn this a question was asked: "do you pay attention to the following selected elements of packaging?"

Distribution of results obtained from the analysis of the importance of various elements of packaging for customers in Poland and Norway indicates that Norwegian consumers are more decisive in their opinions and also much more environmentally aware than Poles. Nearly 75% of Norwegian respondents pointed to the important role of environmental packaging, whereas in Poland only 9 out of seventy-five respondents admitted that environmental packaging is very important. The ecological function of packaging is inextricably connected with the type of material from which the package was made. Hence, also in the case of the perception of the packaging material significance, more than 75% of Norwegians recognized it as an

important element of packaging. A similar distribution of results was obtained in the case of the increased yogurt size offered at a fixed price. Ca. 50% of respondents in both countries indicated the important role of this factor. Ca. 45 % of Norwegian respondents choose a freebie package of yogurt. The answer "definitely yes" to the freebie package (some extra yogurt free of charge) is chosen by only 21 Polish consumers representing 28% of all respondents .

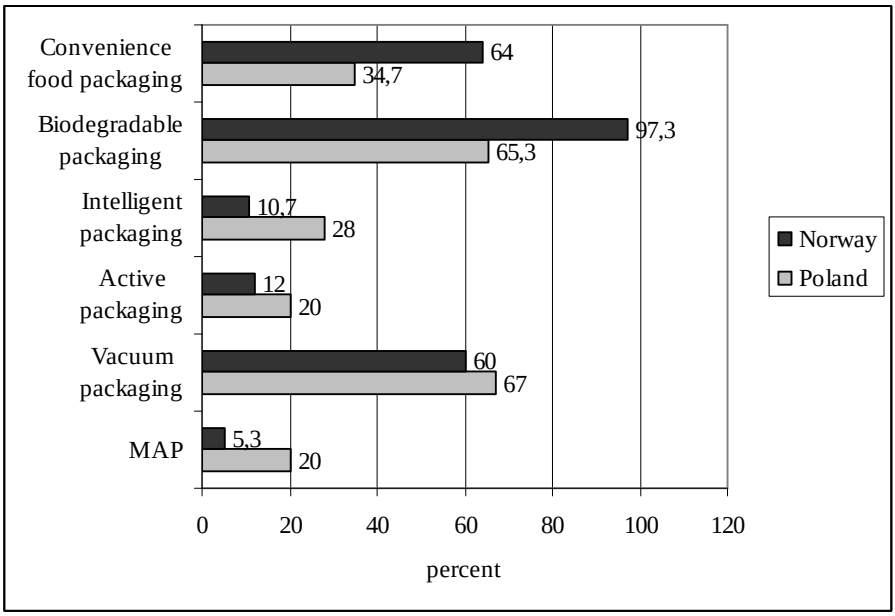

Figure 5. Knowledge of new techniques of food packaging among Polish and Norwegian consumers (%)

Source: own research.

Survey results revealed that Norwegian customers are best-acquainted with biodegradable packaging, whereas in the case of Polish respondents it turned out that vacuum packaging is best-known to them. A new trend which is increasingly used in Poland is vacuum packaging of food items. In addition to many ready-made products available on store shelves, packaging of, for example, meat products at the customer's request so as to extend their use-by date is becoming a commonplace practice on the market.

In the case of Norway, common familiarity with biodegradable packaging is the result of the consumers' high ecological awareness. While segregating waste packaging Norwegians are well acquainted with packaging materials. Packaging of food products is adapted to the selective waste

collection system (4 fractions: paper and cardboard, glass, organic waste, scrap metal) which has been introduced in Norway.

The least known types of food packaging for consumers from both countries have been active packaging and modified atmosphere packaging but in the case of Polish consumers, this knowledge was at a much higher level.

Conclusions

1. Packaging has a smaller impact on the purchasing decisions of customers both in Poland and Norway than other product attributes such as quality, price or brand but a greater impact than advertising .
2. Packaging is a determinant of five time more likely product purchases among Norwegian consumers than Polish ones.
3. After analyzing packaging from a few selected industries, consumers in both countries attributed the greatest significance to dairy product packaging.
4. More than a half of Norwegian respondents identified packaging as a quantifier of product quality, while only 28% of Polish respondents shared this opinion.
5. Norwegian consumers assessed the importance of the information contained in the packaging much higher than the Polish ones, and for both groups the expiry date of the product was a priority.
6. Norwegian customers regarded the name of the manufacturer, the nutritional value of the product, the country of origin and ecological information and marking as the product attributes of crucial importance, whereas Polish consumers attached great importance to the kind of yogurt flavor, its weight, nutritional value and health-related information on the packaging.
7. Only in the case of the type of flavor and weight was the Polish consumer rating higher than that of Norwegians.
8. The ethnic factor (customs, culture, wealth) has an indisputable impact on the perception of the product through the lens of packaging and so has the type of product packaging.
9. Studies have shown that Norwegians have a much better ecological knowledge than Poles and hence the importance of the material criterion while selecting the packaging material.
10. Norwegians are well acquainted with such new packaging techniques as biodegradable packaging, food packaging and convenient vacuum packs. On the other hand, Polish consumers have a better knowledge of all the

analyzed new technologies (exceeding that of Norwegians by 20%), but the vacuum technique is the best-known.

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INTELLIGENT FOOD PACKAGING – RESEARCH AND DEVELOPMENT

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Introduction

Packaging food technologies are developing as a response to consumer demands or industrial production trends towards mildly preserved, fresh, tasty and convenient food products with prolonged shelf-life and controlled quality. In addition, changes in retailing practices, or consumers lifestyle, present major challenges to the food packaging industry and act as driving forces for the development of new and improved packaging concepts that extend shelf-life while maintaining and monitoring food safety and quality (Dainelli *et al*. 2008). Introduction of active and intelligent packaging can extend the shelf life of food or to improve its organoleptic properties and thus prevent food losses. According to the FDA report of 2011, every year is thrown away about 1.3 billion tons of food. Every year only in Europe, 89 million tons of wasted food, and the average European household rubbish thrown on 20-30% of food purchased. New packaging solutions allow to improve the economic aspect. Each year is grows interest in active and intelligent packaging. This is evidenced by the fact that the global market for food and beverages of active and intelligent coupled with controlled/modified atmosphere packaging (CAP/MAP) increased from $15.5 billion in 2005 to $16.9 billion by the end of 2008 and it should reach $23.6 billion by 2013 with a compound annual growth rate of 6.9%.

The interest in intelligent packaging is also reflected in the increasing number of patents granted within the field of TTIs as well as freshness and gas indicators that have been granted in the recent years. It is related not only to the change in consumers' lifestyle, but also to the opportunity to use the produced food in a better way. The use of intelligent packaging, i.e. freshness indicators, would help optimise the time limit of product storage. Research shows that although the majority of respondents perceive perishable food

products as safe, about 90% of them is sure that freshness indicators would help them monitor the quality of food products kept at home. The respondents would accept the increase of product price related to equipping the packaging with the indicator. The acceptable increase would be USD 0.14 for fresh meat and USD 0.25 for salads (Fortin *et al*. 2009).

Inteligent Packaging

Intelligent packaging (also more loosely described as smart packaging) is packaging that in some way senses some properties of the food it encloses or the environment in which it is kept and which is able to inform the manufacturer, retailer and consumer of the state of these properties. Although distinctly different from the concept of active packaging, features of intelligent packaging can be used to check the effectiveness and integrity of active packaging systems (Hutton 2003). Intelligent packaging devices are capable of sensing and providing information about the function and properties of packaged food and can provide assurances of pack integrity, tamper evidence, product safety and quality, and are being utilized in applications such as product authenticity, anti-theft and product traceability (Summers 1992, Day 2001). Intelligent packaging devices include sensors, time-temperature indicators, gas sensing dyes, microbial growth indicators, physical shock indicators, and numerous examples of tamper proof, anti-counterfeiting and anti-theft technologies. Information on intelligent packaging technology can be obtained from other reference sources (Summers 1992, Day 1989, 2001).

Another division may be made in relation to the use of measurement instruments: indicators that can be read without using measurement instruments and indicators that require such instruments. From the perspective of an individual customer, who usually uses products in unit packaging where the indicator is to show the quality of the bought product, the necessity to use measurement instruments is unacceptable. Smart packaging can be divided into three groups:

1. indicators of product exposure to high temperature and duration of activity,
2. indicators of freshness,
3. indicators of the presence of gas and indicators of integrity.

Besides, each indicator used in packaging should be characterised by the following features (Mills 2005):

- low price,
- ability to read without having to use the apparatus,
- non-toxic,

- stability,
- sensitivity,
- reaction should be irreversible,
- easily introduced into the package.

Time-Temperature Indicators (TTIs)

Time–temperature indicators or integrators (TTIs) are defined as simple, cost-effective and user-friendly devices to monitor, record, and cumulatively indicate the overall influence of temperature history on the food product quality from the point of manufacture up to the consumer (Taoukis & Labuza 1989; Giannakourou *et al*. 2005). Temperature indicators show whether products have been heated above or cooled below a reference (critical) temperature, warning consumers about the potential survival of pathogenic micro-organisms and protein denaturation during, for example, freezing or defrosting processes. Furthermore, TTIs have also been applied to assess the pasteurization and sterilization process (Mehauden et al. 2007, Tucker et al. 2007, 2009).

The visible response thus gives a cumulative indication of the storage temperature to which the TTI has been exposed. TTIs may be classified as either partial history or full history indicators, depending on their response mechanism. Partial history indicators do not respond unless a temperature threshold has been exceeded and indicate that a product has been exposed to a temperature sufficient to cause a change in product quality or safety. Full history TTIs give a continuous temperature-dependent response throughout a products history and constitute the main focus of interest for research and commercial exploitation (Kerry et al 2006). Besides, time table indicators display a continuous temperature-dependent response of the food product. The response is made to chemical, enzymatic or microbiological changes that should be visible and irreversible, and is temperature dependent (Rodrigues & Han 2003). Wu et al. (2013) prepared TTI indicator on the basis of the chemical reaction between urease and carbamide was developed. The discoloration kinetics of urease-based TTI was explored. The mathematics formula that revealed the relationships of the change of TTI color with time and temperature has been established. The activation energy of urease-based TTI was 23.05 ± 1.15 kJ/mol (±95% confidence interval). This type of TTI indicator has the potential to apply to some time–temperature dependence foods with similar Ea values. The most popular commercial TTIs are apparently TEMPTIME (formerly LifeLine™) 3M Monitor Mark®, and Vitsab®. TEMPTIME Fresh-Scan test operates on the basis of polymerisation process. During polymerisation, the absorption of radiation is shifted in such a way that it becomes visible. Before it is used, the indicator must be stored in

low temperature in order to avoid premature reaction. A suitable solution for customers is provided by the indicator TEMPTIME Fresh-Check® on self-adhesive labels. The indicator is of round shape and it is encircled with a ring of the reference colour. As the product ages, the shade of the circle surface becomes deeper. In 3M Monitor Mark, if the set parameters are exceeded, it is signalled by the change of colour of a rectangular window on the label and a moving colour. The pace of colour movement depends on temperature. The colour changes within less that 24 hours upon exceeding the set temperature by 1˚C.

VISTAB is an indicator that provides comprehensive information about all deviations from the optimal temperature during the whole distribution cycle. The indicator consists of an external rectangular body and a transparent container located inside it. The container is divided into two parts. One of them contains lipase and pH indicator, while the other - suitable fatty substance. After the activation of the indicator, which is effectuated by the destruction of the barrier between the two containers, the process of enzymatic hydrolysis of fats starts. It results in the change of pH and, at the final stage, change of the solution colour. OnVu ™ indicator is another proposal introduced in cooperation with BASF. At present, it is offered in the form of a label, but it can also be printed directly on packaging. After activation with UV radiation, the ink becomes intensely blue. During exposition to temperature, this part of the drawing is becoming more and more bright. The product is suitable for use as long as there is a marked contrast between the ink and the surface of the model.

Freshness Indicators

The indicators of freshness are used in order to signal when the condition of the product becomes unacceptable during storage, transport, retail sale and in the consumer's house (Smolander 2003). The signalisation operates on the basis of the change of the look of the indicator, which occurs as a result of the change of the composition of packaging atmosphere, which is a consequence of chemical and microbiological changes of the packed product. As a result of these changes, various chemical compounds, such as carbon dioxide, volatile amines, acetic acid, are emitted to the atmosphere of packaging (Smolander 2003, Kuswandi et al. 2013). These metabolites react with the substances contained in the indicator, usually causing the change of the metabolite colour. The metabolite used most frequently for the structure of indicators is carbon dioxide. The indicator consists in a solution with a dye that changes its colour due to pH alternations, and a membrane which passes carbon dioxide which separates it from solution environment. Carbon dioxide from the atmosphere of packaging permeates through the membrane and dissolves in the solution, which leads to the change of pH. The balance is achieved very quickly, and

the colour of the solution changes when the relevant concentration of hydrogen ions is exceeded. The colour change can be measured and compared with the model. The solutions based on this mechanism were suggested in numerous patents and publications.

One of the examples of application is the suggestion presented in the work of Nopwinyuwonga (Nopwinyuwong et al. 2013). The work presents the relation between the amount of volatile compounds emerging during the storage of Thai desserts and the number of microorganisms developing within them. The products of metabolism are compounds of low molecular mass such as organic acids, ethanol, carbon dioxide, and sometimes also aldehydes or ketones. Carbon dioxide emerging as a result of decomposition was used in order to change the colour of the indicator. Freshness indicators based on the measurement of carbon dioxide are used also in order to assess the freshness of kimchi, a popular Korean dish. It consists of fermented vegetables, mainly napa cabbage, a large amount of garlic, onion and seafood. Unfortunately, the commercially available packed products still undergo fermentation; therefore, they cannot be tested without destroying the packaging. For this reason, there has been suggested a solution using carbon dioxide sensor. Another suggested way to control the composition of product packaging atmosphere is the use of the suspension of chitosan and 2-amino-2-methyl-1-propanol in distilled water. The suspension is packed in packets and placed in the packaging. Studies show that when the dish was stored, pH of the solution dropped to 5.8. At the end of the storage period, the transparency of the liquid changed considerably. When pH drops, the non-transparent white solution of chitostan gradually transforms into a solution which is visibly transparent. According to the authors, the indicator can easily be used in order to determine which product packaging is not fermented and to detect the beginning of optimal fermentation (Jung et al. 2013).

Another proposal is a colourful indicator based on bromophenol blue. It was suggested in order to assess the freshness of guava fruit (*Psidium guajava L.*). It operates similarly to the solutions described earlier. When the fruit ripens, the colour of the indicator changes from blue to green. Green colour means that the fruit is too ripen. The authors claim that the cost of the indicator should be relatively low (about USD 0.15) in industrial production and mass use.

A more interesting solution is the use of quaternary ammonium salts in order to solubilise pH factor in a hydrophobic polymer, e.g. ethyl cellulose. This sensor does not contain the classic water buffer, and its role is performed by tetraoctylammonium hydroxide (TOA-OH). The indicator also includes a polymer which permeates gases. The process of detecting carbon dioxide consists of several stages. In the first place, there should emerge an ion pair between protonated indicator (DH) and quaternary ammonium base (QOH).

As a consequence, there emerges a hydrate with an intense colour ($D^+Q^-\cdot H_2O$). The hydrate is then dissolved in polymer. The indicator obtained this way can react with CO_2 in the atmosphere (Mills et al. 1992).

Oxygen and Carbon Dioxide Indicators

Oxygen and carbon dioxide indicators can also be used to monitor food quality. They can be used as a leakage indicator or to verify the efficiency of, for example, an oxygen scavenger. Most of these indicators are based on colour change as a result of a chemical or enzymatic reaction. These indicators have to be in contact with the gaseous environment inside the package and hence are in direct contact with the food (De Jong et al. 2005). Conventional oxygen indicators are known to use methylene blue (methyl thionine chloride) MB, a dye that reversibly changes its color upon oxidation and reduction (Sumitani et al. 2004). Lee et al. (2008) developed a new range of colourimetric oxygen indicators that are irreversible, reusable, and UV-light activated. Such "intelligent ink" oxygen sensors comprise a UV-absorbing semiconductor, such as TiO_2, a redox-indicator, such as methylene blue, a sacrificial electron donor, such as triethanolamine, and an encapsulating polymer such as hydroxyethyl cellulose; the ingredients are mixed together, with water as the solvent, to form an ink. The ink can be coated or printed subsequently onto a variety of substrates to produce a blue oxygen indicator film, which, when activated by UV light, becomes colourless. The activated, that is, UV-photobleached, film remains colourless unless, or until, exposed to oxygen, at which point the reduced methylene blue is reoxidised back to its original blue form. Indicator is not active until it is exposed with UV light.

There are indicators based on fluorescence. The reaction is based on the the phosphor layout has been extinguished when in contact with molecular oxygen. Luminescent compounds are placed in the gas permeable and impermeable to ions materials such as silicone rubber or an organic polymer, such as poly(vinyl chloride), to create thin film, oxygen indicators (Mills & Thomas 1997). One of most popular is tris (4,7-diphenyl-1,10-phenanthroline) ruthenium (II) perchlorate, i.e. $[Ru(dpp)_3](ClO_4)_2$, where dpp is the complexing ligand, 4,7-diphenyl-1,10-phenanthroline. The most commonly-employed leak indicator used in food packaging is a colorimetric redox dye-based indicator (Mills 2005).

Changes in the concentration of organic acids such as n-butyrate, L-lactic acid, D lactate and acetic acid during storage offer potential as indicator metabolites for a number of meat products (Shu et al. 1993). Colour based pH indicators offer potential for use as indicators of these microbial metabolites. Another example of microbial indicators is system based on immunochemical reactions that occur in the barcode (Goldsmith 1994), and the barcode will

become unreadable when a particular microorganism is present (Rodrigues & Han 2003).

Ethanol, like lactic acid and acetic acid, is an important indicator of fermentative metabolism of lactic acid bacteria. Randell et al. (1995) reported an increase in the ethanol concentration of anaerobically MA packaged marinated chicken as a function of storage time. The Lawrence Berkeley National Laboratory has developed a sensing material for the detection *of Escherichia coli* 0157 enterotoxin (Cheng & Stevens 1998). The material is composed of cross-polymerized polydiacetylene molecules that can be incorporated into the packaging film. As the toxin binds to the molecules, the color of the film changes permanently from blue to red (Smolander 2000).

According to Mills, an ideal oxygen indicator for the food packaging industry should also exhibit an irreversible response towards oxygen. Indicator should illustrate why this latter feature is so desirable it is worthwhile considering the response of a reversible oxygen indicator in a MAPed food package that, in a not too unlikely scenario, sometime later develops a small leak. Obviously, the indicator will show no oxygen is present in the package until the leak develops, at which time it will indicate the presence of oxygen. However, if the leak is small, it is very possible that the subsequent rapid increase in microbial growth will be such that within a short time the oxygen in the atmosphere in the package will be converted to carbon dioxide and the rate of bacterial metabolism will be matched by the rate of oxygen ingress. Besides, an ideal oxygen indicator should be easily incorporated into the food package and so is best applied as an ink, which must be printable on paper and plastic. In the food industry such an ink falls under the umbrella heading of intelligent packaging. Besides, this is technology able to monitor and/or give information about the history and/or quality of the packed food (Mills 2005).

Conclusions

Changes in consumer preferences have led to innovations and developments in new packaging technologies. Research and development in the field of active and intelligent packaging materials is very dynamic and develops in relation with the search for environment friendly packaging solutions. Active and intelligent packaging is becoming more and more widely used for food products. Application of this type of solution contributes to improve the quality of consumer life, undoubtedly the consumer. Besides, innovation systems will improve the product quality, enhance the safety and security of foods, and consequently decrease the number of retailer and consumer complaints.

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APPLICATION OF MULTILAYER POLYMER FILMS FOR PACKAGING ELECTRONIC DEVICES AND EQUIPMENT

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Introduction

To safeguard the materials used for packaging and storage of electronic devices and equipment are additional requirements nominated, which combine functions of conservation and packaging in a single technological process. Using single-layer polymer films as packaging material requires additional use of protective equipment to provide partial or complete neutralization of the air and aggressive component of the atmosphere, which entered through the coating. As a mandatory requirement is the using of corrosion resistant materials with the volatile corrosion inhibitors, which have the ability to be adsorbed on the metal surface from the gas phase in the methods of surfaces protection of metal products from atmospheric corrosion. Most volatile inhibitors are the derivatives of amines which allocate free amine, its hydroxyl form, organic cation and anion, during hydrolysis and dissociation. The character (disposition) of their protective action requires substantial sealing of packing space, which may not always be achieved using single-layer films. That's why, it is considered reasonable to create multilayer protective polymeric materials with the aim a prevent of non-manufacture inhibitor from losing and reduce the permeability of aggressive environmental factors.

Most inhibitors used in multilayer protective coatings are projected as a universal corrosion inhibitor of steel, copper and zinc and some other non-ferrous metals.

Material and methods

As an object for the study multilayer films with an internal layer were selected, based on high-pressure polyethylene with additions of inhibitors and plasticizers.

The investigation of surface microstructure of polymer films was carried out by electron microscopes “UEMV-100K” and the “Tesla-250”. The pre-deposited layers of copper or argentums were deposited for providing contrast microphotographs of polymer films.

Samples of the films were fabricated on a laboratory extruder. The inhibitors are brought into a polymer matrix during the stage of a bloating near zone of an exit film hose near the shaping head. The additional supplementary of a plasticizer into polymer composition reduced processing temperature and simplified overlapping inhibitors with a polymer substance.

As the inner layer of coating is the film of high-pressure polyethylene PEHP used, which is a modified volatile inhibitor of atmospheric Dicyclohexylamine benzoate (DCHAB – (C6H11)2NH2+·(C6H5CO2-) and Cyclohexylamine benzoate (CHAB) – (C6H11)NH3+· (C6H5CO2-) and plasticizers – Dioctyl phtalate (DOP) - C6H4(COOC8H17)2, Dioctyl sebate (DOS – H4C2OOC(CH2)8COOC2H5, Di-2 –etylhexyl phtalate (DEHP) – C24H38O4, The outer layer is polystyrene or polyethylene terephthalate (Fig. 1).

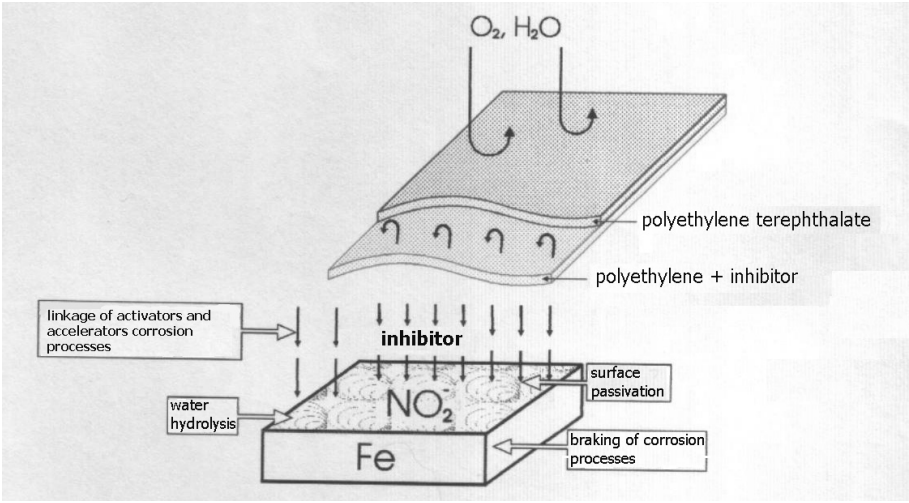


Figure 1. The scheme of the multilayer corrosion protective coating

Oxygene permeability determined by the change of current strength sensors of oxygen.

Results and discussion

A sharp increase of coating oxygene permeability during the first 6 days was established, when in the processes of adsorption-desorption of atoms on the metal surface within a closed volume of $5 \cdot 10^{-5}$ m^3 packing space, the

equilibrium was created. The initial value of the coefficient of oxygene permeability of single-layer films was quite low – from 0,8595 · 10^{-14} for inhibitor and plasticizer contained films to 1,007 · 10^{-14} – for the unmodified films. Introduction inhibitor (DCHAB) to the composition of films significantly decreases the original value of oxygene permeability index. The exceptions were for films with CHAB-inhibitor, which oxygene permeability was higher that the value of initial un-modified samples. Adding of such plasticizers as DBP, DOS and DOP decrease initial oxygene permeability coefficient of polymer films. Such tendency to reduction of diffusion coefficient value is characteristic for all polymer films with plastificator additions during the time of exploitation (Fig. 2).

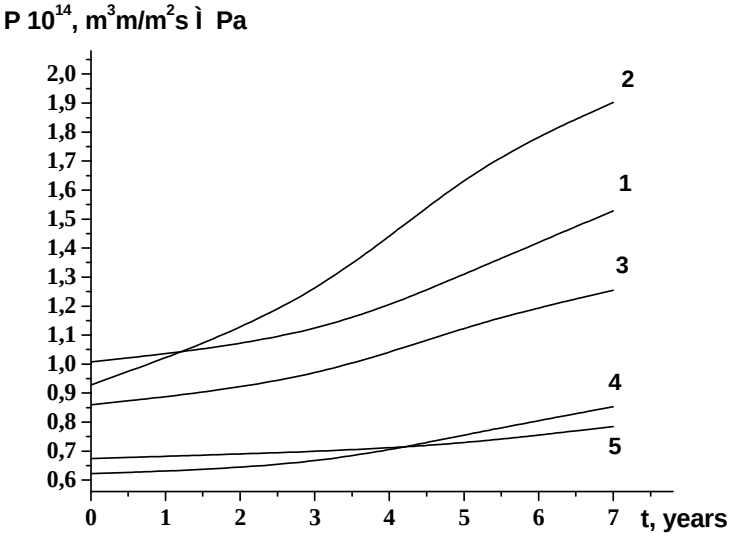


Figure 2. The time change factor of oxygene permeability of modified polymer films in a closed storage:
1 – PEHP (additions free, h = 160 microns), 2 - PEHP + 0.5 weight % amine inhibitor CHAB + 1 weight % plasticizer DBP (h = 170 microns), 3 - PEHP + 0.5 weight % amine inhibitor DCHAB + 1 weights. % DBP (h = 210 microns), 4 - polystyrene / PEHP + weight % DCHAB (h = 210 microns), 5 - PET / PEHP + 0.5 weight % DCHAB + 1 weight % plasticizer DOS (h = 300 microns).

Source: own research.

Low rates of the oxygene diffusion process of polymer films are kept for 1 - 3 years, after which the diffusion of oxygen through the surface film

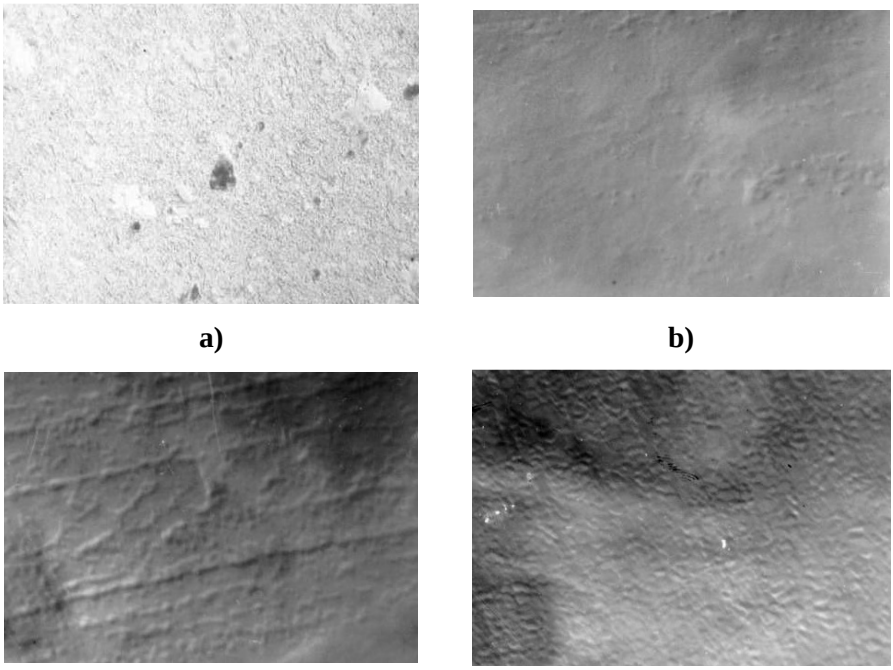
significantly is activated. This may be associated with the initial stages of destruction of the polymer matrix, which takes place in terms of data (Domantsevych N., 2001; Domantsevych N., 2002). Oxygene permeability of inhibited films after 4 years is much higher compared with non-inhibited samples. Inhibited plasticized films have consistently good index for 5 - 6 years of exploitation (in contact with the metal). Double layer coating is characterized by consistently low permeability index during the whole period of operation (exploitation). The aging over 4 - 5 years leads to increasing the film permeability index, that's why oxygene permeability becomes equal with single-layer coatings. Activity passage oxygene diffusion process in laminated films was quite low even with prolonged aging.

Electron microscopic investigations showed that the introduction of inhibitor leads to the changes in structure and, consequently, the properties of polymer films. Initial sample of an unmodified film is characterized by a smooth surface with few surface formations (less than 3% of the total area) with the size ℓ = 5-9 · 10-9 m (Gul V.E., 1971; Domantsevych N., 2000). Initial samples of polystyrene and polyethylene terephtalate films were characterized by larger size crystal formations.

Addition of inhibitors CHAB and DCHAB lead to changes in the structure of the surface film that develop to enhance crystalline formations of the polymer matrix up to size $\ell > 3 \cdot 10\text{-}8$ m. The initial effect of inhibitors in the multilayer films was determined, mainly, by changes in these layers, in which directly during extrusion the modifying components were insert. The initial effect of modifiers on the outer layer of polystyrene or polyethylene terephtalate was negligible, despite the technology of multilayer coatings.

The activation process of crystallization after exploitation coatings during 0.5 year was observed. Such process had most active form in films containing inhibitor CHAB. The increased structure was observed even in such multi films as polystyrene/inhibited polyethylene. This fact was associated with the inhibitor exposure of contacting polyethylene film (Fig. 3).

Increased exploitation time leads to the activation of structure formation and the initial destructive processes that occur mainly on the interface of amorphous and crystalline phases. It is observed that the destructure processes in bilayer films (polyethylene terephtalate/inhibited polyethylene or polystyrene/inhibited polyethylene) occur in the inner layers more active. More active structure formation also are observed in the outer layers of polystyrene, thus the effect of inhibitor was reduced in films that received by adhesive compared to the same receiving co-extrusion films that determined their higher physical and chemical characteristics. The barrier effect of special glue is based on Sevilen, which partially reduced the effect of inhibitor on the outer layer was revealed in this case (Fig. 4). A surface film that was glue to polyethylene had characteristic decor.



a) **b)**

c) **d)**

Figure 3. Morphological characteristics of polymer films (x 10700): a) monolayer coating of polyethylene with the addition of 1 weight % inhibitor DCHAB after exploitations on an open platform for 12 months b) inner layer of two-layer coating (polyethylene with the addition of a 1 weight % DCHAB after 6 months storage, c) an outer layer of two-layer coating - polystyrene film after 6 months of storage, d) the outer layer of two-layer coating - polyethylene terephtalate film after 6 months of storage.

Source: own research.

Exploitation of protective coatings for more than 5 years results in rapid destruction of the inner cover with insignificant changes in morphology of the outer layer.

It is known that the equilibrium distribution of adsorbate molecules between the surface of the adsorbent and the gas phase depends on pressure, temperature, nature and the surface of the adsorbent, also as on itself nature of the adsorbate. Using protective inhibited coatings, which are creating a closed volume around metal manufactures, first of all changes the composition of air mixture environment due to the presence of volatile inhibitors. Partial pressure of oxygen decreases, leading to the reduced activity of atomes and molecules

of oxygen in the processes of condensation on the metal surface. The saturation of limited space protection package by inhibitor vapour does not pass immediately. Sustaining the balance between the partial pressure activators and inhibitors process of oxidation occurs during parallel processes passage of their adsorption on metal.

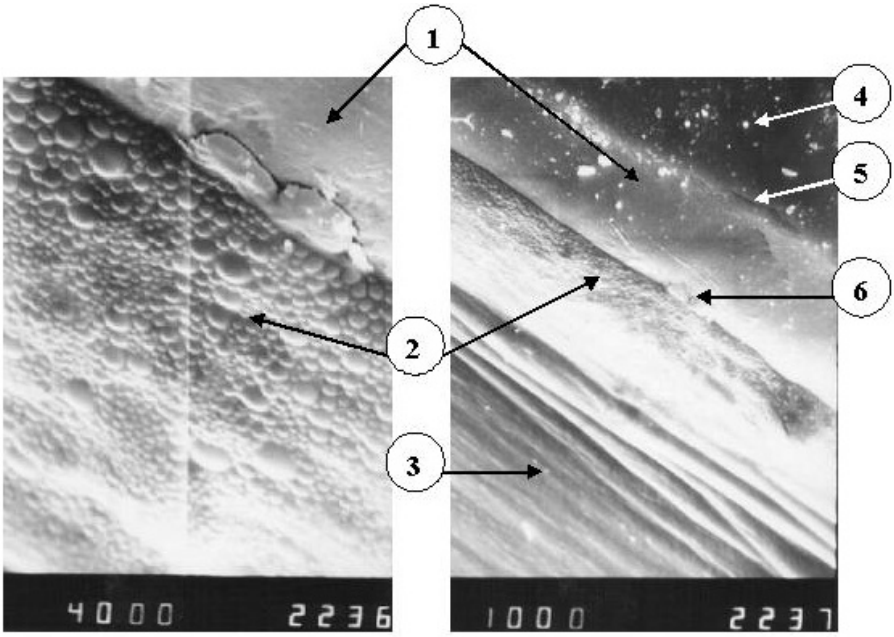


Figure 4. Cut of bilayer protective film (X 4000; X 1000):
1 - lateral surface of inner modified polyethylene film;
2 - formation of glue, 3 - lateral surface of the outer polyethylene terephtalate film, 4 – outlet of plasticizer and quasicrystall formations, 5 - cracks on the interface of amorphous and crystalline phases, 6 - crystal formation in polyethylene.

Source: own research.

The most active diffusion, gas and vapour convective processes of the same diffusing substances across the polymer coating occur in the hyperelastic state of polymeric material, also as during increasing of amorphous part in matrix and in structures with a small number of branches in the absence of spatial grid (Reytlynher S.A. 1974). Inhibitor introduction to the polymer matrix promotes the initial growth of branches, which increases the crystalline part of matrix and reduces the oxygene permeability. The quantity of methyl groups (CH3) in inhibited in a protective coating increases, which is revealed during the spectral studies by measuring the optical density of methyl band 1378 cm-1 (Domantsevych N. 2000). However, the aging of these films is at

a considerable intensification of crystallization, which in the specific formation of intermolecular bonds and amorphous matrix has small crystalline nature with a greater percentage of crystalline phases. The growth of defects along interface between amorphous and crystalline phases in these films is greater, compared with un-inhibited films, that most noticeably at high lifetime of exploitation.

Plasticization of polyethylene films un-inhibited necessarily leads to the stabilization of the amorphous state, increasing the mobility of polymer chains, which certainly is corrected with the increasing of oxygene permeability indexes. Adding of a small amount of plasticizer leads to the activation the gas transport processes across the films.

The simultaneous introduction of plasticizer and inhibitor in polymer matrix leads to the ambiguous changes in the mechanisms of the occurrence of diffusion processes, resulting in a possible decrease in initial permeability of polymers and stabilizes the time characteristics, which leads to an increase in the protective properties of polymer coatings.

A physical phase state and the orientation of the polymers dependent were found, such as flexibility and the nature of thermal motion of chain molecules, weakening intermolecular bonds, changes in intermolecular interactions, degree of crystallinity and orientation, on the permeability of polymer films (Uhartseva Y.Yu. et al 2003).

Research gas permeability of polymer modified material revealed that the initial values of gas permeability index correspond to the theoretical developments and practical research, which highlights the increasing level of diffusion process by weakening intermolecular bonds with the introduction of modifying component and increasing the flexibility of chain molecules. The inhibitor CHAB is an exception of such modifiers, that why contribute to the rapid increase of crystallinity of the polymer matrix at the initial stage.

The accelerated crystallisation, which takes place with aging inhibited films during 1 - 2 years contributes to the relative reduction of gas permeability. However, the destructive processes, which are activated on the border of the “amorphous - crystalline phase” at 3-4 year, lead to the growth matrix defects and thus gas permeability.

Introduction of a small amount of plasticizer to the polymer matrix increases the initial gas permeability due to increased mobility and flexibility of polymer chains. The gas permeability of these films is characterized by stable and relatively high during the period of aging.

Inhibited polymer coating with plasticizers has a good time characteristics of gas permeability for the whole period of aging, despite the higher initial index of diffusion. This is mainly due to the passage of two interacting, but opposite in direction of influence on to the polymer matrix the processes that is caused by the introduction of the inhibitor and plastisizer –

increased crystallinity during the initial stage of aging at entry inhibitor offset by the influence of plasticizer, which ultimately leads to the formation of small-crystal polymer matrix. Such interaction, with further aging, leads to the formation of metastable structures, which at limiting external factors (UV-irradiation, washing, etc.) have sufficiently low index of gas permeability.

In the bilayer polymer films additions of inhibitors and plasticizers in the inner layer positively affect both the inhibition of corrosion of metal, and inhibition of destructive processes of the coating. However, in such coatings growing quantity of small-crystal formations, helped increase the quantity of small-chain lateral branches. External layers of coatings, under the influence of inhibitor, stabilize its structure and physico-chemical properties which remain virtually unchanged for 3 - 5 years.

Conclusions

Thus, by selecting and applying appropriate components and compounds of multilayer coatings we can significantly appreciate the quality of the inhibitor-containing preservation-packing materials.

Acknowledgement

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CONSUMERS' OPINION ON SAFETY AND FUNCTIONALITY OF FOOD PRODUCTS PACKAGING

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Introduction

Food packages are subject of constant change. Manufacturers of packaging, in cooperation with food manufacturers introduce a number of innovations designed to improve the functionality of packaging and improving safety of packaged products (Cholewa-Wójcik, Kawecka 2013). Previous studies on packaging and purchasing preferences concerned mostly on the topic of the appearance of the packaging, or graphics, such as color, typography, shapes and images, and the packaging structure, or shape, size and materials for construction of the package (Underwood 2003) (Vila, Ampuero 2007), (Estiria et al. 2010). The food packaging are also equipped with many additional elements and construction solutions, which objective is to improve the functionality and safety, such as elements facilitating the use of the products (e.g. closures, dispensers), guarantees of inviolability and guarantees of originality of the product (Lee, Yam, Piergiovanni 2008), (Lisińska-Kuśnierz 2010), (Robertson 2013).

Material and methods

Conducted research aimed to identify the opinions of consumers about innovative solutions, used in various types of packaging, whose main objective is to improve the functionality or improve the safety of packaged foods and beverages. Consumers' survey concerning design solutions that improve functionality and safety of packaged products. The study was conducted by questionnaire to 100 respondents from the age group 20-35 years. The respondents were 62 women and38 men, most of whom were residents of large cities over 500 thousand (68% respondents). In the questionnaire used closed questions and a semi-open questions, also question with using a Likert scale (Sagan 2004).

Results and discussion

The results of the research on consumers' opinion about the various solutions that improve operational safety and functionality of packaging for food and beverage products are shown below. Respondents rated the importance of packaging attributes such as shape and size of the container, the type of packaging material, quality, aesthetics (color and design). Evaluated was also: the ability to re-close a previously opened package, easiness to open, easiness of product's use related to for example using dispensers), moreover, the possibility of re-use of packaging and recyclability of packaging. Above mentioned characteristics were evaluated by respondents in a scale of 1 to 5, where 1 meant that a feature is not important, 5 - very important feature. Figure 1 shows the results of evaluations.

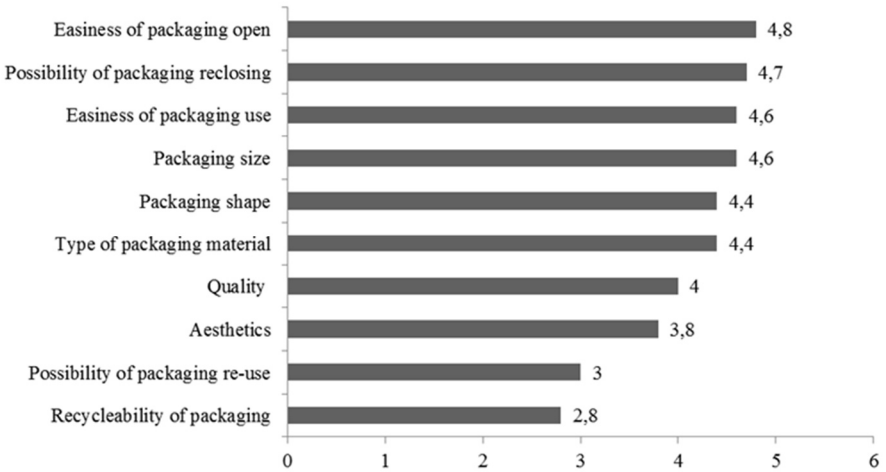

Figure 1. The importance of chosen packaging characteristics in the opinion of consumers

Source: own research.

Respondents recognized easiness of opening as the most important feature, which received 4,8 point in the assessment. Further pointed out that important to them is the ability to re-close of the packaged product, elements facilitate the use of the product and package size. Further down were: shape of the container and the type of packaging materials with the evaluation of 4,4 points. For important respondents considered the quality of the packaging. Ratings below "important", awarded such features as: aesthetics, the possibility of re-use and processing of packaging.

Examining respondents knowledge, they were asked to identify the answers, among those listed, best describing what guarantee of integrity of the

packaging is. The results are shown on figure 2. It was possible to make a multiple choice of answers such as:

- indicates that the product is hermetically sealed (fully sealed)
- indicates that the package may have been previously opened,
- indicates that the contents of the package can be dangerous,
- indicates that the product may be contaminated,
- indicates that the product could be stored in unsuitable conditions (e.g. temperature was too high),
- prevents reclosing,
- does not allow to open the package.

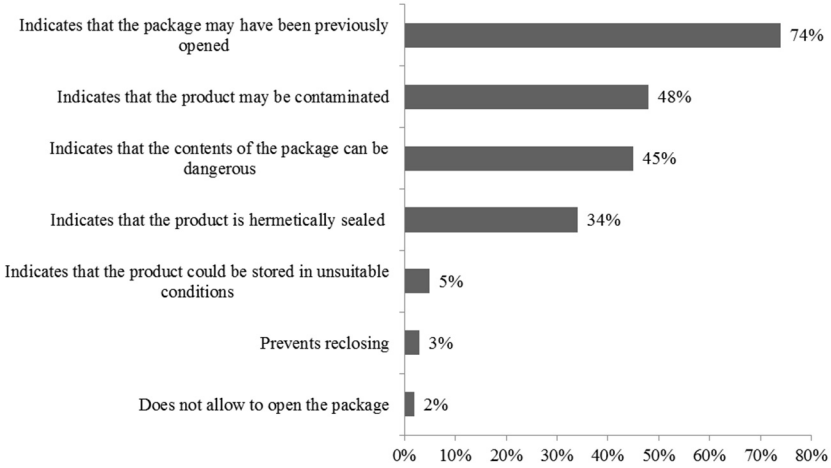

Figure 2. Respondents answers concerning the characteristic of guarantee of packaging integrity

Note: Answers do not sum up 100% due to the possibility of indicating respondent more than one answer by respondent.

Source: own research.

Analyzing the responses should be noted that up to 74% of the respondents correctly indicated that guarantee of the integrity indicates that the container could be opened earlier (Rosette 2009). In addition, respondents also predicted the possible consequences of such action involving the possibility of contamination of the food and the possibility of danger. As many as 34% of the respondents indicated that guarantee the integrity may also mean that the product is hermetically sealed. But this is not the correct answer. Between 5% and 2% of respondents indicated other responses about what is the guarantee of the integrity, according to them the guarantee indicate that the product has been stored under unsuitable conditions, is not allowed to re-close the packaging, or to open it.

In next question respondents were asked to indicate what factors / elements of the container affect the safety of the product. Respondents were selected from listed answers:

- no sharp edges,
- convenience package,
- the correctness of the package manufacturing (related to eg. tight seals),
- the information contained on the packaging,
- labelling in Brille alphabet,
- guarantees the integrity of the product,
- other (specify).

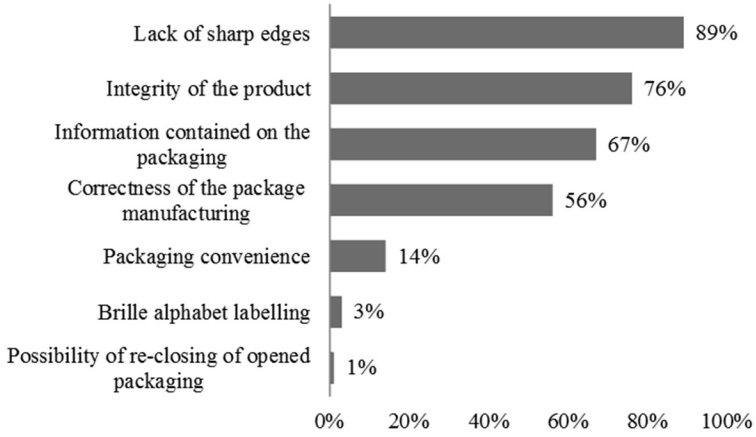

Figure 3. Respondents answers concerning factors / packaging elements affecting the safety use of a food product

Source: own research.

Most respondents indicated that the safe operation of the packaged foods is affected by the lack of sharp edges in the packaging, the presence of guarantees the integrity of the product, the information contained on the packaging and the correctness of the packaging manufacturing. In a much lesser extent, consumers noted that the safety may also be affected by the convenience of packing, labelling in Brille alphabet, which is important for the blind and visually impaired. One of the respondents chose the answer the other, indicating that the safety of use of the product concerns the ability to seal the opened package.

Later in the research was investigated consumers' opinion about:

- packaging used in package of liquid food and beverages such as bottles,
- multilayer materials packaging for liquid food and beverages,

– cans for solid food and beverage,
– packaging in the form of plastic bags or wraps.

In order to clearly identify what solutions were rated, to respondents photos or drawings of the evaluated solutions were presented. Respondents evaluated these elements indicating whether the solution according to them:

– effectively protects the packaged product,
– insufficiently protects the packaged product,
– is functional,
– is not functional.

The results of conducted research concerning the opinion of consumers in area of sufficiency of packaged liquid food products and beverages protection in bottles are presented on figure 4.

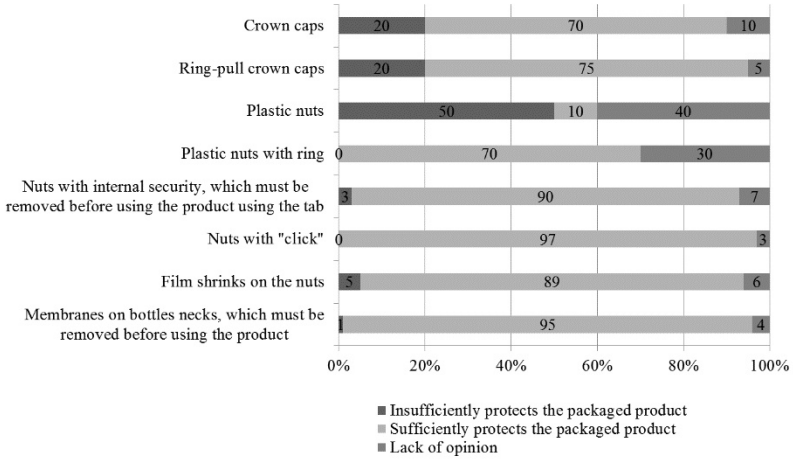

Figure 4. Consumers assessment of packaged product protection sufficiency of chosen bottle packaging elements

Source: own research.

As a solution to ensure the sufficient protection packed in bottles liquid food products and beverages, respondents most commonly indicated: "click" closures (97 % of respondents), the membrane on the necks of bottles (95 %), the nut with internal security (90% of responses) and wrap with shrank film on nuts (89% of respodents). For elements not giving security guarantees half of the respondents recognized the plastic nut without additional equipment such as rings, or shrink wrap.

Figure 5 presents opinion about functionality of chosen packaging construction elements in the same type of packaging.

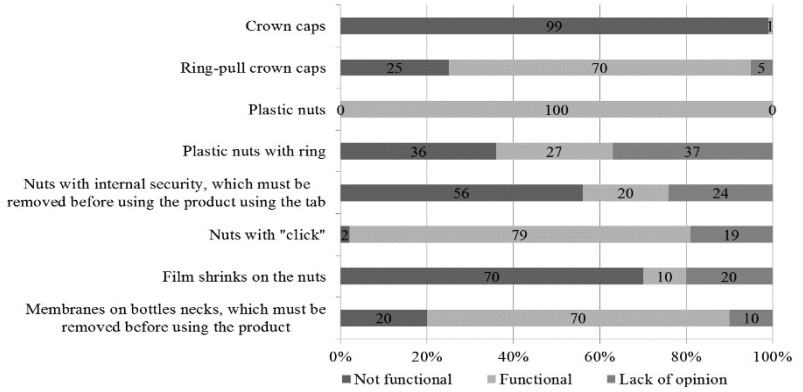

Figure 5. Consumers assessment of functionality of chosen bottle packaging elements

Source: own research.

Among presented solutions, the majority of consumers indicated that they are functional: plastic nuts (100 % of responses), lid with "click" when first opening (79% of respondents), ring-pull crown caps for easy removal of the cap and the membranes on the bottles necks, which must be removed before using the product (70 %). As non-functional respondents recognized: classic crown closures (99% of responses), the shrink-wrap film on the caps (70% of responses) and nuts with internal security element made from plastic, which must be removed before using products such as oil (56%).

Respondents also rated their relationship to the closures used in packaging in the form of boxes of multilayer laminates intended for food in liquid form and beverages. Consumers evaluated solutions closures boxes in a five-point scale, where 1 meant "definitely do not like this solution," and 5 means "I really like this solution." Assessed value for the following design solutions used in boxes of multilayer laminates:

- Solution 1 - box not fitted with any additional element regarded as the closure.
- Solution 2 - a box with an opening protected by the packaging material tube and allow direct consumption of the product from the box.
- Solution 3 - box fitted with flat plastic closure and additionally equipped with a piercing element into the interior of the packaging through pre-perforated packaging material.
- Solution 4 - box fitted with flat plastic closure of the flap of the depression into the interior of the package when opening it.

– Solution 5 - box equipped with a nut, underneath which there is an element of the packaging material to facilitate, providing hermetic package.
– Solution 6 - a box fitted with a nut which upon initial opening of the packaging material sticks to ensure the tightness of the packaging.

The assessment results are shown on figure 6 and 7.

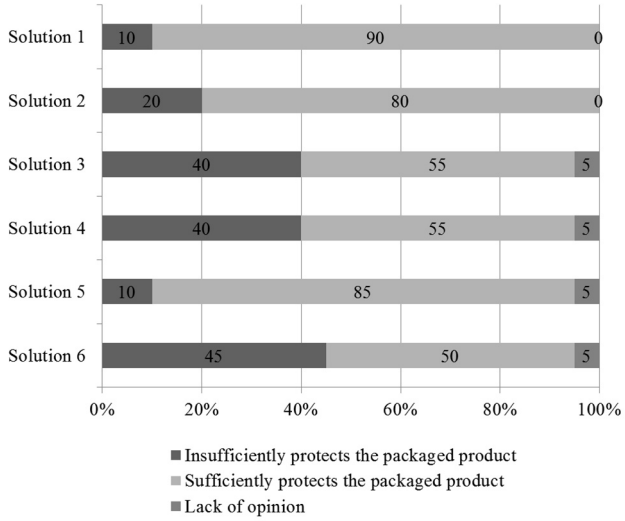

Figure 6. Respondents safety evaluation of different types of closures used in boxes from multilayer laminates

Source: own research.

In opinion of respondents most sufficiently protects solutions 1, 2 and 5 (box not fitted with any additional element regarded as the closure, a box with an opening protected by the packaging material tube and allow direct consumption of the product from the box, box equipped with a nut, underneath which there is an element of the packaging material to facilitate image providing hermetic package), every of this solution was pointed out by more than 80% of respondents. It must be stated that every solution was indicated as giving sufficient protection by majority of respondents. However noticeable is that every facilitation is considered as less protective that multilayer laminate box without any additional element.

In relation to functionality as the most useful very indicated solution 6 and 5 (a box fitted with a nut which upon initial opening of the packaging material sticks to ensure the tightness of the packaging and box equipped with a nut, underneath which there is an element of the packaging material to facilitate opening, providing hermetic package). Solution without any facilitation was considered as not functional by all respondents. Also functionality of solution

3 (box fitted with flat plastic closure and additionally equipped with a piercing element into the interior of the packaging through pre-perforated packaging material) was not indicated by most of the respondents.

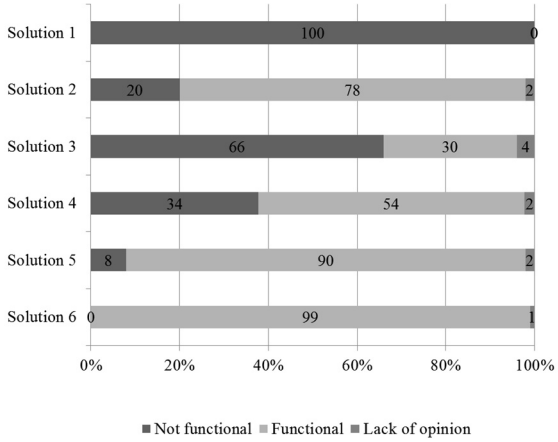

Figure 7. Respondents functionality evaluation of different types of closures used in boxes from multilayer laminates

Source: own research.

Figure 8 presents the results of assessments of the respondents in relation to the cans for beverages and food. Evaluated were: classic food cans, lids fitted with a pin for easy opening cans of food and a pin for easy opening aluminum cans for beverages.

All presented solutions were evaluated as giving a guarantee effective protection of the packaged product, all received 100% of responses. Classic food cans were rated as non-functional, due to the need to open them with additional equipment. Pins easy opening lids for food cans by 45% of respondents are judged to be awkward to use, and by 48 respondents as functional. Divided opinion of the respondents indicate a need for further improvements of this type of solution, in order to provide greater functionality cans of food. In the case of the pins used in the aluminum cans for beverages 47% of respondents rated the solution as non-functional, and only 20% as a convenient solution. In this case showing more clearly the need to improve or to develop a new solution for this type of package.

Surveyed consumer reviews on selected design solutions used in plastic packaging in the form of bags and wraps, during studies evaluated solutions were: closing stringed perforations for easy opening bags, foil strips for easy removal and welding plastic wraps vacuum packaging. Figure 9 displays the respondents opinions regarding these solutions safety of use.

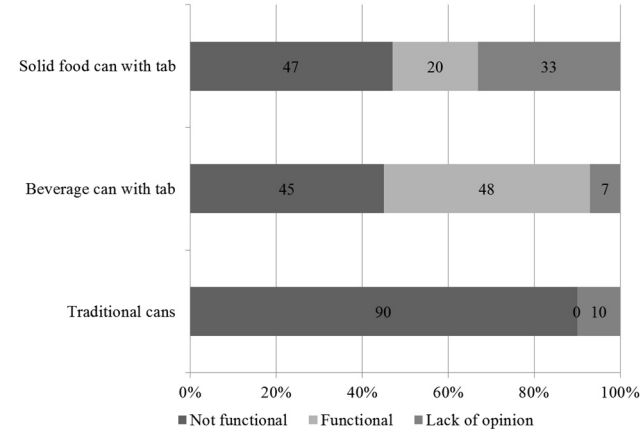

Figure 8 Respondents functionality evaluation of metal cans

Source: own research.

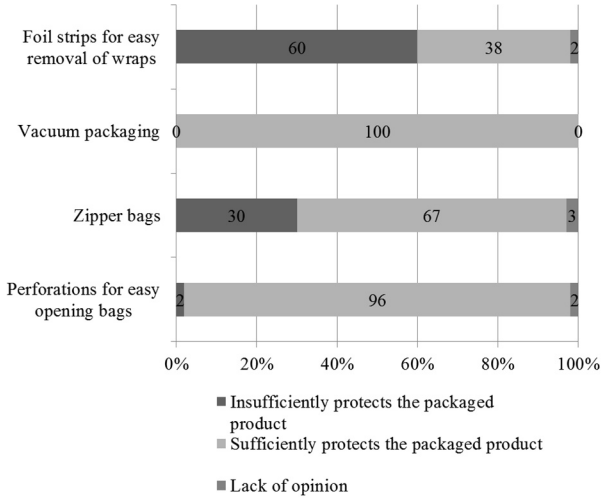

Figure 9. Respondents safety evaluation of solutions used in plastic packaging in the form of bags and wraps

Source: own research.

Consumers indicated that vacuum packaging (100% of respondents) and perforations for easy opening bags (96% of responses), this solution effectively protecting the product packed in plastic packaging in the form of bags and wraps. Figure 10 displays the respondents opinions regarding the functionality of solutions used in plastic packaging in the form of bags and wraps.

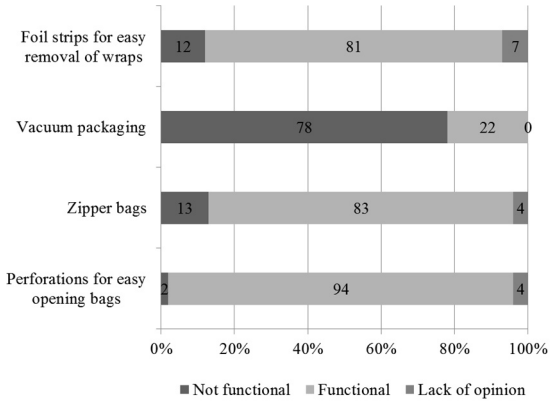

Figure 10. Respondents functionality evaluation of solutions used in plastic packaging in the form of bags and wraps

Source: own research

At the same time facilitates opening of the package perforations are functional as opposed to the vacuum packages that 78% of respondents found the non-functional. Closing strings and straps for easy removal of wraps by the majority of respondents were rated as functional, yielding respectively 83% and 81% of indications.

Conclusions

Young consumers deem the most important design solutions related to functional use of packaging food products such as ease of opening, the possibility of re-closing of the packaging or components to facilitate the use of the product. The results are consistent with the results obtained by other authors, including P. Silayoi and M. Speece (2005), J. Świda, A. Kulinski (2002), M. Klonowska-Matynia (2010), M. Lisińska-Kuśnierz (2011), M. Ankiel-Homa (2012), who found that most consumers are focused on convenience of packaging products. The remaining consumers may be numbered among the groups focused on exploration on the packaging information or looking at the packaging image, that confermed research conducted by G. Kuś (2011). On the market there are solutions that are also convenient for use by the user and giving a guarantee proper protection of the packaged product. In the opinion of the respondents is a nut issuing a distinctive "click" sound when first opened. At the same time it is necessary to provide consumers with adequate information on the type of collateral. It is noticeable that the solutions for improving the safety of the packaged products, such as shrink film wrapping on the nuts or nut with an internal plastic protection which must be removed before using the product, even

though the pins have additional help for their removal are inconvenient for consumers to use, and thus may discourage consumers from buying products that do not come. Some consumers have problems with an indication of what is the guarantee the integrity of the package, to improve knowledge in this area could cause a change in buying behavior.

The study confirmed the need to refine some of the solutions used in food packaging. Consumers clearly indicated that certain types of equipment such as pin cans, to improve the functionality of this type of packaging, still do not provide sufficient comfort in the use of the product. It was also confirmed that more consumers prefer the types of closures, which are known to traditional packaging. Among the closures boxes of multilayer laminates closures were the most preferred closure to the greatest extent reminiscent solutions used in traditional bottles for beverages.We conclude that the functionality of the packaging is now the key to success in the market for food products.

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FOOD PACKAGING AS NON-SATISFACTORY COMMUNICATION INSTRUMENT IN OPINION OF CONSUMERS

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Introduction

Fulfilling by the packaging its function (protection, utility and communication) must be satisfying for all the subjects who create the chain of supplies. The most important, in this chain, is a consumer as a purchaser and the user of the packaged products. The other subjects, that is companies connected to the whole life cycle of packaging are trying to make up to the expectations of all interested sides [Bix, Fuente&Lockart 2009; Lisińska-Kuśnierz 2011].

Business entities connected to the packaging branch, that is packaging producers, and the manufacturers of the packaged products try to improve their packaging [Korzeniowski 2012]. The World Packaging Organization, as well as the branch associations all over the world and the research centers connected to packaging, by their missions, promote innovative activities including social responsibility [Position Paper. Sustainable…2008]. It is recommended that social responsibility was an integrated part of a basic strategy of each subject in the branch and it should be reflected in the decision making process and included in the tasks realization. In order to define the scope of social responsibility, defining crucial issues and determining the priorities, the international standard ISO 26000:2010 can be useful. The guidelines included in this standard indicate seven key areas in the holistic aspect. There are also consumer aspects among them. The consumer aspects concern, among others, fair marketing practice, health protection and safety, balanced consumption, including the consumers' needs particularly sensitive and being in unfavorable social and educational position.

Business entities, which supply the packaged products have certain duties regarding the purchasers. The duties include above all education and honest information, the use of fair, clear and useful marketing information, promoting

balanced consumption and designing products, which can be bought by everyone so the packaging must be universal .

The above duties, according to this concept, must also be done by the subjects creating the packaging chain, in recommendations and activities however, offered in the discussed international standard, the attention was paid to the crucial role of packaging, among others as the crucial tool of a communication transfer [ISO 26000].

The packaging branch and the needs to improve the packaging

The packaging branch and the world packaging market and packed products, including food, dynamically develop. The global packaging market stood at $ 799 billion in 2012, increasing by 1% over 2011. The sales are expected to increase by 3% in real terms from 2013 to $ 824 billion. Smithers Pira forecasts annual growth of 4% per year to 2018 in the world packaging market, with sales to reach over 1 trillion US dollars by 2018 [The Future… 2013].

Social and market trends play the most important role in the packaging market development in the regions of economic wealth [Position Paper. Market…2008].

According to the report results, in 2012 all sectors of the packaging users noted down the growth. Medium-range forecast of growth for the food packaging is estimated on 3,4% every year to 2018 year, when it reaches the value of about 284 billion dollars. The use of packaging for drinks in the same period should grow in the average annual pace of 3,3% and reach the value of 102 billion dollars to 2018 year [The Future…2013].

The research concerning conditionings of the packaging market development and the packaged products is systematically conducted. The research also includes the influence of packaging on the consumers behaviour while doing shopping and how the packaging influences the consumers satisfaction. This research concerns all subjects which create the packaging chain and include the developed and the developing countries as far as the packaging is concerned [Position Paper. Market…2008].

The research conducted in Europe and the USA in 2012 among 500 main producers and fast moving consumer goods suppliers and the packaging branch representatives, allowed to identify the actual conditionings and the packaging development trends.

The respondents say that the cost is the top factor driving the industry today (59%) but they predict it will fall significantly in 10 years (dropping 28%) below factors like sustainability (51%) and food safety/security (37%). Though rarely selected as “top” trend convenience factors are identified as

very important today – and that importance is expected to be maintained in 10 years (30% each in both time periods).

The respondents see: packaging will play a more important role in a product's success in 10 year (81%) and regulations will have a greater influence one packaging design in 10 years [Survey…2012].

The research conducted in the analogical period among consumers from different countries concerned the effect of packaging on the buying decisions and its influence on satisfaction from the products and creating loyalty in regard to brands. The research results presented in the "Packaging Matters" report, showed that packaging play an important role in purchasing behavior. 57% of the researched Germans and 64% Britons admitted that they tested a new product, because they were attracted by an interesting packaging distinguishing a product on the shelf in a shop. 41% of the respondents at different markets, mentioned the packaging as a factor, which encouraged them to come back and buy the product again. However, 36% of the consumers altogether changed the brand of a product because of the negative experience with the packaging. Only 11% of the researched people claimed that they do not have any objections to present packaging, including less than 20% from the USA and 7% from Germany and Great Britain. The results show that the influence of the packaging on general consumer satisfaction with products is much bigger in case of developing countries (54%) than the developed ones (20%) [Packaging Matters…2013].

The crucial demographical factor influencing the packaging branch is inhabitants` ageing, especially in the highly developed countries. The conducted research mainly concerns the society ageing trend as well as the life behaviour, including purchasing behaviour and the needs concerning the products and their packaging. The elderly people are becoming the most important segment of the packaged products` buyers.

We can identify five major trends: birth rates are falling, people live and stay healthy longer, they are wealthier and work longer [Walker, Mesnard 2011; Demograficzne…2012].

In 1950, 200 million people were in the "over-60" group, by the year 2000 the number had risen to 600 million, last year to 800 million, and by 2050 the number will have reached 2 billion. Globally, this older population is increasing at a rate of 2,6 percent per year, considerably faster than the current 1,2 percent annual growth in the population as a whole. Further, the 80 year old and an older group is increasing at 4 percent per year. By 2030, 36 percent of Germans, 30 percent of French and 22 percent of Americans will be older than 60 [Walker, Mesnard 2011].

Polish society will analogically age. Long term demographical forecasts for our country are that people over 60 years old will make 27% of the population in 2030[Prognoza…2008]. The research done in 2011 among

consumers 60 plus from 23 countries in the world, allowed to elaborate the document "Global Maturing Consumer".

Senior shoppers often find product packaging hard to open and labels, prices and usage directions difficult to read. Fifty-two percent of the study's participants aged from 60 to 70; 58% of the age group from 70-to-80; and 66% of the shoppers over 80 said they could not read labels properly, even when they were wearing their glasses or contact lenses [Oaks 2012; Mininni 2012].

The research conducted among seniors in seven European countries (not including Poland) showed that one out of five older consumers is fully satisfied with the packaging, which are being used at present, 81% is satisfied to some extent or completely dissatisfied. The consumers mainly complained about missing or illegible information concerning the components, quality and attributes of a product and badly visible expiry date. At the same time, the consumers didn`t like too much unimportant information, for example texts in a few languages or misleading signs and symbols. The reason why products are criticized was often usefulness – too complicated opening mechanisms, difficult to close again. Finally, the respondents claimed, that the design of the packaging was often unattractive or inadequate to the product [Dalgleish, Maron 2006].

The results of the surveys allow to say that the growth of consumer satisfaction, including the seniors from quality of the used products, does not go with the dynamics of world development of packaging and the food packed.

The research mentioned above did not include the assessment of Polish consumers, that is why the survey concerning the elderly people's needs has been done. It has been conducted in the scope of packaging improvement, among others communication transfer by labelling them.

New legal regulations concerning transferring information to consumers by food packaging

In order to guarantee high level of consumers protection in the scope of information about food, including perception from consumers and their informational needs, Regulation (EU) No 1169/2011 of the European Parliament and of the Council has been recently passed.

According to the legal requirements, information about food must be accurate, clear and easy to understand, so that it could be helpful for consumers, who want to make more aware choices concerning food and diet [Śmiechowska 2013]. The research show that good legibility is an important element of increasing probability that information on packaging will influence their purchasers and the unlegibility is one of the main reasons of consumers`

dissatisfaction from food labelling [Ankiel-Homa 2012; Tomaszewska-Pielacha, Ozimek 2011]. According to this, the Regulation (EU) No 1169/2011 of the European Parliament and of the Council a comprehensive approach is necessary in order to include all aspects concerning legibility. Legibility means the physical appearance of information, by means of which the information is visually accessible to the general population and which is determined by various elements, inter alia, font size, letter spacing, spacing between lines, stroke width, type colour, typeface, width-height ratio of the letters, the surface of the material and significant contrast between the print and the background [Regulation (EU) No 1169/2011…].

According to the author, visibility of information is also connected to legibility of information, which can be defined by physical appearance of information, which decides about seeing and finding the content by the general population. It can be assumed that the level of visibility is analogically defined by elements of information like in case of legibility. Information must be clear and understandable. Understandability should be defined by physical appearance of information, which decides about the order, consistency and perception of the message, according to the sender`s intention. It can be assumed that the level of understandability will depend on appearance of such elements like for example Latin names, combinations of numbers and letters, complicated expressions, too long sentences, information in many languages at the same time, words division, etc.

Communication transfer by food labelling, that is by any words, particulars, trade marks, brand name, pictorial matter or symbol relating to the products and put on every packaging, label, banderol or a cover, should not only be consistent to the regulations of law but also satisfying for all subjects who create the supply packaging chain, including consumers [Lisińska-Kuśnierz 2012; Śmiechowska 2013].

Empirical studies

The aim of the research was to know the opinion of the senior consumers about the meaning of packaging for them as a market communication tool and indication of reasons why they are dissatisfied with labelling and making packaging unfriendly.

The research was done in the group of 100 elderly people at the age above 60 with the use of the direct survey interviews technique, according to the requirements included in the literature on the subject [Maison 2001].

The scope of research concerned the consumers opinion about:

– the meaning of packaging among various purchasing determinants of the chosen food groups,

- the importance of particular food packaging features, including appropriate labelling,
- the hierarchy of importance of the chosen information connected to the protection of consumers` health put on the packaging including the kind of food group,
- the scope of reading information put on the packaging of the analyzed food groups,
- the reasons of low satisfaction from information transfer of food packaging labelling.

In the research concerning the above issues, consumers opinions about food products packaging of frequent purchase such as milk, bread and smoked meat, have been taken into consideration. Such example elaboration was supposed to help the respondents to understand the problem.

In the research concerning the meaning of packaging among various determinants of purchase of the chosen food groups, four factors like: a price, producer, relatively brand, custom to the product features and its quality and promotion, have also been included apart from the packaging. So, the most important products purchase determinants analyzed in the literature and included in the marketing research have been included [Ankiel-Homa 2012].

In the research concerning the importance of proper labelling of food packaging among other features, seven characteristics like: microbiological cleanness of packaging, no interactions of packaging with packaged product, proper organoleptic features (including lack of other smell), proper construction in the scope of robustness, barrier of the packaging (towards smell, water steam), usefulness, usage safety and lack of disadvantages (such as moisture, possibility to tear), have been taken into consideration.

Consumers defined the level of importance of the analyzed determinant, relatively features, by choosing such terms like: unimportant, not very important, important, very important.

In the research concerning determination of importance hierarchy of the chosen information connected to consumers health protection, information put according to the law requirements on the packaging of the analyzed food groups, has been taken into consideration. The senior consumers defined the importance of particular information by choosing numbers from 0 to 3 points, and they meant in order: unimportant, not very important, important and very important.

Opinions about the scope of reading information on the packaging of the analyzed often bought food groups, consumers expressed by such expressions: I read all information, I only read the most important information, I don`t read any information.

However, defining the reasons of not reading information put on the packaging of the above food groups concerned indication, by the consumer, of the order of reasons like: little understanding of information, little legibility of information and a small visibility of information.

The terms like understanding, legibility and visibility, have already been explained to the consumers by the interviewer, according to the accepted definitions. What is more, consumers were asked to show the elements of packaging and labelling, which influence the level of satisfaction of information transfer.

Results and discussion

The achieved results concerning the importance of a product packaging among typical determinants of purchasing decisions like often bought food groups including milk, bread and smoked meat in consumers assessment has been arranged in the table 1.

Table 1. The hierarchy of the importance of particular purchase determinants of the chosen food groups in the customer's assessment

Position	Purchase determinants factors	Factors importance (% indications)			
		Unimportant	Not very important	Important	Very important
Milk					
1	The unit price of the product	0	0	6	94
2	Custom to the product features and its quality	2	16	20	62
3	Promotion	0	26	67	6
4	Brand or producer	0	38	56	6
5	Packaging	5	54	37	4
Bread					
1	The unit price of the product	0	2	45	53
2	Custom to the product features and its quality	0	3	53	44
3	Brand or producer	0	15	47	38
4	Promotion	0	16	72	9
5	Packaging	8	76	16	0
Smoked meat					
1	The unit price of the product	0	2	12	86
2	Brand or producer	0	20	72	8
3	Custom to the product features and its quality	1	26	38	35
4	Promotion	0	25	73	2
5	Packaging	2	42	54	2

Source: own research

The research showed that only the product price as the most important and the packaging as the least important determinants while purchasing a product, placed in the importance hierarchy independently from the kind of products group. The retail price of milk for 100% of the respondents was important or very important. However, in case of bread and smoked meat the determinant was important or very important and was 98%. The second position among the decision making determinants custom (as far as features and quality are concerned) traditionally took place. In case of the analyzed food groups definitely the biggest meaning has this factor in case of bread, which indicates as important and very important 97%. In case of smoked meat seniors put brand or the product manufacturer higher than custom (in total 80%). Similar position in the determinants ranking have brand/producer and promotion. Packaging, including its type, outside appearance and properties, is important for consumers, however, as a purchasing determinant has a lower, in comparison to the rest of the factors, influence on food purchasing decisions. Only in case of smoked meat, for over half of the consumers the packaging was important or very important while buying. The bread packaging is definitely the least important factor while making purchasing decision. The above proves that the presented attitudes and traditions of seniors concerning buying even unwrapped bread.

The results concerning the importance hierarchy for consumers of certain packaging properties of the analyzed food groups presents the table nr 2. The order of importance includes in total, the percent of indications as important and very important feature.

While analyzing the meaning for consumers of proper labelling among the rest, equally important properties of the packaging, it can be stated that it is dependent on the type of a product. In case of milk, proper labelling takes the first position of importance along with such properties as: proper construction as far as validity is concerned, barrier of the packaging, usefulness and the usage safety. 98% of the senior consumers showed that the packaging features are important to them, relatively very important. In case of bread and smoked meat, proper labelling takes the fourth or fifth position of importance, and of course in case of smoked meat it is equivalent to the proper construction, usefulness and the usage safety (indicators important or very important 75% and 80%). Regardless of the type of product, the most important property of packaging was microbiological cleanness. In case of such groups of products like milk and smoked meat, none of the packaging feature was not recognized by consumer as unimportant. On the other hand, considering the construction forms of packaging used to packaged bread, indicators of lack of importance concerned such features as proper construction in the scope of robustness, lack of disadvantages, usefulness and usage safety.

Table 2. The hierarchy of the importance of features packaging of the chosen food groups in the customers` assessment

Position	Packaging features	Features importance (% indications)			
		Unimportant	Not very important	Important	Very important
Milk					
1	Paper labeling on the packaging	0	2	82	16
1	Proper construction	0	2	54	44
1	Barrier of the packaging	0	2	12	86
1	Usefulness and usage safety	0	2	52	45
2	Microbiological cleanness of packaging	0	3	22	75
3	Lack of disadvantages	0	4	54	42
4	Proper organoleptic features	0	10	51	39
5	No interaction of packaging with packad product	0	12	66	22
Bread					
1	Microbiological cleanness of packaging	0	0	5	95
2	Proper organoleptic features	0	4	12	84
3	No interaction of packaging with packad product	0	10	50	40
4	Barrier of the packaging	0	24	28	46
5	Proper labeling on the packaging	0	25	70	5
6	Lack of disadvantages	13	14	48	25
7	Proper construction	2	78	15	5
8	Usefulness and usage safety	14	84	2	0
Smoked meat					
1	Barrier of the packaging	0	0	6	94
1	Microbiological cleanness of packaging	0	4	0	96
2	Proper organoleptic features	0	2	36	62
3	Lack of disadvantages	0	16	24	60
4	Proper labeling on the packaging	0	20	37	43
4	Proper construction	0	20	10	70
4	Usefulness and usage safety	0	20	41	39
5	No interaction of packaging with packad product	0	21	24	55

Source: own research

The achieved results concerning the hierarchy of information importance connected to consumers health protection, put on the packaging of the chosen food groups are presented in the table 3, as the set of average assessment of importance in points and % of information indicators which are important and very important.

Table 3. The hierarchy of the importance of the chosen information connected to consumers` health protection, put on the packaging of the chosen food groups in the customers` assessment

Information connected to consumers healt protection	Average of assessment importance (in points)	Information about big and very big importance (% of indications)
Milk		
Date of minimum durability	3,0	100
Storage conditions	2,28	98
Name of the product	2,24	96
Amount of fat	2,20	98
Period and conditions of storage after opening	2,17	95
List of ingredients causing allergies	2,12	94
Name or business name and address of the food business operator	2,08	88
Way of strengthrning	2,04	84
List of ingredients	1,48	48
Nutrition declaration	1,24	20
Serial number	0,28	14
Bread		
Date of minimum durability	2,80	100
Name of the product	2,68	96
List of ingredients	2,40	82
Storage conditions	2,16	83
List of ingredients causing allergies	2,08	82
Information “bread produced from deep frozen dough” (eventually)	1,40	56
Name or business name and address of the food business operator	1,15	31
Nutrition declaration	1,12	26
Serial number	0,92	8
Smoked meat		
Date of minimum durability	3,0	100
List of ingredients	2,72	94
List of ingredients causing allergies	2,40	80
Name of the product	2,30	80
Storage conditions	2,16	70
Veterinary identification number of a manufacturing plant	1,90	50
Name or business name and address of the food business operator	1,85	65
Information concerning technological processing	1,58	42
Serial number	0,95	10

Source: own research

The average of assessment of information importance connected to health safety of a product, regardless of the product, reached the highest level in case of date of minimum durability, of course for milk and smoked meat all consumers assessed that it is a very important information, giving the mark on the level of 3 points. For the elderly respondents important information on the milk packaging was also: storage conditions, name of a product, amount of fat, period and storage conditions after opening. However information which was the least important was: nutrition declaration and the serial number. In consumers opinion, important information is also: the name of the product, list of ingredients, storage conditions and the list of ingredients causing allergies. Information which is the least important was the same as in case of the milk. As far as smoked meat is concerned, according to the consumers, important information put on the packaging is: list of ingredients, the list of ingredients causing allergies and the name of a product. The least important, according to the respondents, are: a serial number and information concerning technological processing.

The analysis of the achieved properties allows to claim that there is a certain analogy in the information importance hierarchy, concerning the elderly consumers health protection and other age groups of consumers presented in the literature on the subject [Lisinska-Kuśnierz 2012; Tomaszewska-Pielacha, Ozimek 2011].

Except the consumers declaration about the importance of information put on the packaging, the scope of reading them is crucial. The results achieved in this range are presented in table 4.

Table 4. The scope of reading information put on the packaging of chosen food groups by the customers

Food groups	Scope of reading information (% of indications)		
	All information	Most important information	Any information
Milk	0	69	31
Bread	0	22	78
Smoked meat	0	82	18

Source: own research

The results are not surprising that none of the respondents, taking part in the research, declared that they read all information, but the results concerning percentage, not reading any information. Information put on the packaging of smoked meat is not read by 18% of the respondents, put on the milk packaging by over 30%, and in case of information about bread by 78% of the people who took part in the survey.

Taking into consideration the above, the declaration of senior consumers concerning the reasons of not reading the above information is crucial. The results are presented in table 5.

Table 5. The reasons of not reading information put on the packaging of the chosen food groups by the customers

Food groups	Reasons of not reading information (% of indications)		
	Small understandability	Small legibility	Small visibility
Milk	23	49	28
Bread	10	59	31
Smoked meat	12	48	40

Source: own research

The achieved data proved the general diagnosis about non-satisfactory legibility of information put on food packaging, regardless of the type of food group analyzed. Small visibility is also a crucial reason of not reading the information. Little understanding of information, which is third in order, was more often enumerated in case of information put on the milk packaging than on the packaging of the rest of the analyzed food groups. In the average, almost half of the respondents claimed that the appearance of information put on the packaging allows visual access to a small extent. The crucial problem for older consumers, even for the ones who wear glasses, is seeing and finding communication content, that is small visibility. Consumers see the problem in small visibility and legibility, most of all in the use of: improper size, kind and colour of the font, too small spaces between the lines, small contrast of the colour of the font and background. Moreover, according to the customers, the graphical elements put on the packaging diminish legibility and visibility of the searched information. It often causes frustration, anger and resignation of the product purchase. Small understanding of information, according to the respondents, which is expressed in the fact that the full sense of the message does not reach to them, caused by the use of: combination of letters and numbers, complicated expressions, too long sentences and information in a

few languages. The hindrance is also the coverage of the text by colorful graphical elements put on the packaging.

According to the consumers, the packaging itself, its construction form, shape and size influence the degree of legibility, visibility and understandability of information put on the packaging.

According to the customers, who took part in the research, the packaging used to pack food is not as friendly for the elderly as they expected. In their opinion, there is a big problem with the limited possibility of the comfort use of packaging and the use of labelling put on the packaging and labels.

Conclusion

The research conducted among the subjects of the packaging chain supplies, including consumers who function on developed and developing markets indicate the need to improve the packaging. The role of the packaging as a marketing strategy element is meaningful at present and according to the forecasts for the nearest 10 years, the packaging will influence the success of a product on the market even more. The meaning of packaging, as an important communication tool, was emphasized in recommendations and activities concerning consumer issues in the international standard, defining the guidelines of social responsibility.

The problem of the need of the packaging improvement is not local, regional, national but global. Consumers, from different regions of the world, at various ages are not satisfied with the quality of the used packaging. Polish respondents, who took part in the presented survey concerning, among others, informativeness of food packaging, also claimed that they are dissatisfied with the packaging. The researched seniors paid attention to the necessity of the often bought food packaging change, that is milk, bread or smoked meat. Too small legibility, visibility and understandability of information in the way of labelling does not allow them to make fully aware purchasing decision.

That is why it is also very crucial to obey the law in the scope of food labelling, which is an element of ensuring health safety and consumers` lives (all age groups) by the subjects introducing the goods to the market. Doing the research is also very important, in order to improve the products informativeness.

Except the quantity and quality marketing methods of the consumers` opinion research about the degree of satisfaction from food packaging, neuromarketing complimentary methods should be used with the use of, for example eye tracking to survey the visual layer of packaging from the point of view of receiving information transfer. By using the eye tracking in order to research informativeness of packaging, the elements of visual layer, which have been noticed and understood by a consumer, can be distinguished

[Świda, Kabaja 2013]. The results of such surveys should define certain dependencies of the informativeness of level assessment from the elements of visual layer of the packaging including the needs of different consumer groups, as well as seniors.

Taking actions which improve packaging in order to optimize them should be done by every subject of supplying packaging chain of the social responsibility concept. The vision of the future of packaging presented by Federal Senior Company Organization in Germany "Optimal packaging should be friendly, practical and comfortable suitable for young and old, just for all" [Ruzicka, Caisowa 2007] seems to be right and promotion worthy.

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NORMATIVE REGULATION REQUIREMENTS FOR QUALITY PACKING PAPER IN UKRAINE

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Introduction

In recent years the problem of goods quality has been gaining utmost importance in all economic sectors. Especially it concerns food products. Under such circumstances one of the most important things is the preservation of products' quality in the products distribution process. The latter is provided by means of modern wrapping materials and packaging.

Packaging quality must meet set up requirements and must be strictly controlled. Instead the importance of packaging is underestimated by Ukrainian producers as well as by consumers.

Results and discussion

Paper packaging materials attract our attention the most in this research. These materials remain the safest for food packaging in terms of low levels of harmful substances migration. However they can be the safest only if qualitative raw materials are used to produce such materials, and if the manufacturing process is carried out in accordance with all the requirements.

The requirements to the quality of paper packaging materials for food products are determined by their function and objective exploitation factors. All the factors that influence food products together with their packaging in the process of exploitation can be relatively divided into external and internal.

External factors can vary in nature:

– mechanical (different kinds of load);
– climatic (temperature, air humidity and their sharp fluctuations);
– biological (microorganism and insect influence).
– Internal factors are the following:
– chemical resistance of materials;

– internal pressure;
– loss of packaging quality under the influence of products packed.

Taking into consideration all these factors it is possible to point out general indicators that characterize paper packaging materials for all food products. Other specific indicators with regard to the goods packed can also be determined (fig.1).

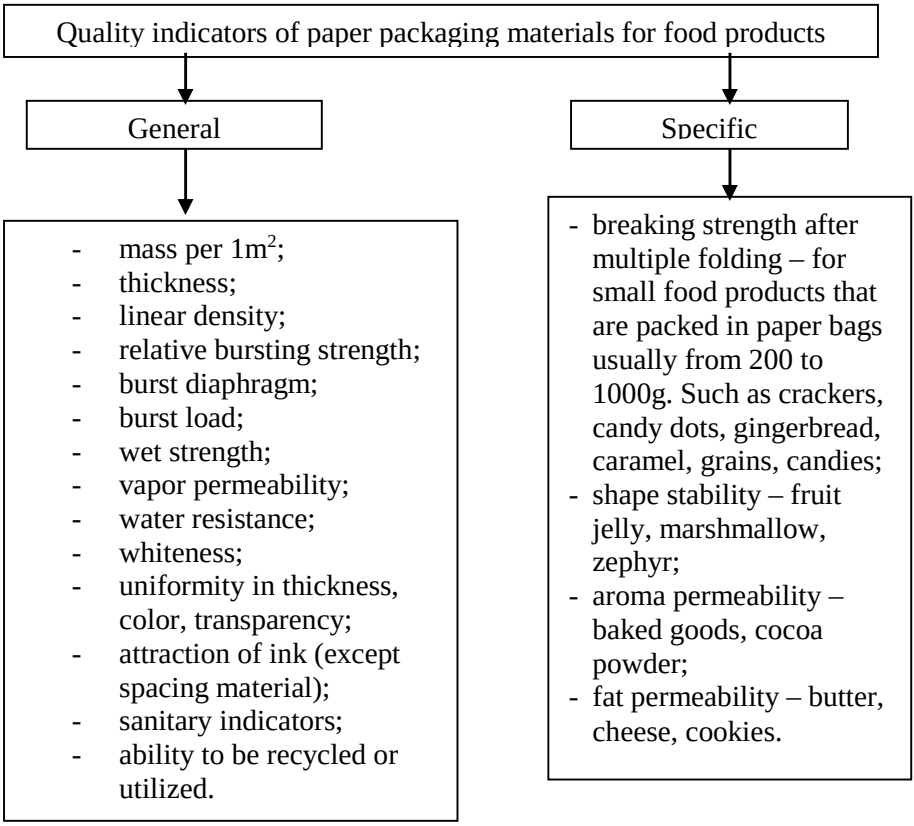

Figure 1. Indicators of wrapping paper quality

Source: own research.

The quality of packaging materials for food products is regulated by the following documents in Ukraine:

– All Union State standard 1341-97. Vegetable parchment. Technical requirements;
– All Union State standard 1760-86. Artificial parchment. Technical requirements;

- All Union State standard 8273-75. Pack paper. Technical requirements;
- All Union State standard 9569-79. Paraffin paper. Technical requirements;
- SanRaN 42-123-4240-86 “Permissible migration quantities of chemical substances, which are produced from polymer and other materials, and which contact food products, as well as the methods to define these quantities”

These statuary documents define the requirements to the indicators by means of which the realization of packaging material function is utilized. The main function is in the product’s protection from the destroying factors. For this purpose wrapping paper should have high barrier properties such as: sufficient mechanical strength, chemical resistance, optimum permeability indicators (concerning gases, water and its vapors, fat and other environments including aggressive ones) (ГОСТ 1341-97, ГОСТ 1760-86, ГОСТ 8273-75, ГОСТ 9569-79).

Mechanical resistance indicators depend on the paper packaging material content, its mass, thickness, linear density, and humidity. It can also be characterized with the help of such characteristics as breaking strength, burst load resistance, shape stability under different load influence. The figures for the indicators must be defined by taking food products peculiarities into consideration. Therefore, breaking strength indicator value must be the maximum one, but at the same time breaking strength high figures should not prevent a consumer from opening the packaging. Especially when it comes to the products that can easily lose shape even under minimal load (fruit jelly, marshmallow, zephyr, sugar cookies) as well as cocoa powder, which can be scattered while being opened.

Relative burst load resistance must be increased in proportion to the product’s firmness. For example, it is necessary to create the conditions under which pressure will be impossible when it comes to such product as fruit jelly. Taking it into account such characteristic is burst load resistance is of no importance at all. On the other hand such product as caramel is often stored in big group packages and can burst the wrapping with its edges. It is also possible to spoil an image on a wrapping if there is certain burst load put on chocolate packaging.

Paper bags that are yielded to the constant change of shape and folding during transportation must have such a characteristic as breaking strength after multiple folding. Such bags are usually used for candies, caramel, candy dots, butter scotch or cocoa powder with weight range from 100 to 500g. Paper packaging materials that are used to wrap fruit jelly, zephyr and marshmallow must have shape stability, because the surface form of these products can be easily damaged.

Physical and mechanical indicators of wrapping paper are defined according to the standard methodologies. The statuary documents stipulate the requirements to the relative burst load resistance, parchment and wrapping paper breaking length and their breaking strength after multiple folding.

Exceptional attention is paid to the chemical resistance indicators as well as to food products packaging material permeability. Chemical resistance in the given environment is understood as the absence of paper material soaking in the contact environment. Also chemical resistance is defined as a material's stability under the influence of the given environment. The change in physical, chemical and mechanical properties of a material in an aggressive environment can lead to the packaging destruction, bursting or to the shape stability loss. It means that packaging material loses its quality before time. The main paper packaging material chemical resistance characteristic is wet strength, which is defined as a correlation between the strength value of dry and wet paper stretching under certain conditions. There are set norms concerning the latter indicator. Though, they are used only in connection with wet and fat resistant type of artificial parchment. The norms are 25% and 23% for the highest category and the first category respectively.

Permeability is a transfer of chemical substances from the external environment or the product components through the packaging material sides. Permeability is determined by paper's structure and density depending on these two factors it can vary greatly. The main indicators that characterize paper packaging material permeability are gas, vapor, fat, aroma permeability and wet strength.

Vapor permeability is defined by the quantity of water vapor, which penetrates material through unit of area per unit of time at designed temperature and difference in pressure on both sides of a sample. Packaging material aroma permeability on product's side is defined organoleptically or chromatographically. The levels of vapor permeability and aroma permeability are not restricted by any norms for any kind of paper. Though, these indicators are essential, especially for baked products, cocoa powder, mixtures that have cocoa powder as one of its constituents. These products easily absorb different scents from the external environment. It leads to worse organoleptic characteristics.

Packaging material fat permeability is characterized by the duration of oil or fat penetration all the way through the sample at designed temperature. For a lot of materials this indicator is defined as a time period between putting painted fat composition on packaging material's surface and painted fat stain creation or the creation of certain amounts of holes that will let fat through per unit of square. For parchment this indicator must be no more than 100 holes the size of 0,1mm per 1m2. Artificial parchment with surface treatment fat permeability must be no less than 600 mg for the paper mass of 40 g/m2 no more than 28 mg for artificial parchment without surface treatment (ГОСТ

1341-97, ГОСТ 1760-86). Fat permeability indicator value should be taken into consideration depending on the content of fat when packing chocolate products, placing pastry and cakes as well as other products that have fat as their constituent. Fat permeability prevention is achieved by means of combining paper with aluminum leaf.

Water resistance is determined by the time during which water goes from one side of a packaging material sample to the other one under designed conditions. This indicator is very important for pastry items packing, because the majority of these products is hydroscopic. They lose their nutritional qualities even if there is little water penetration. Especially, it concerns caramel products, cookies, and fruit jelly. However, there are no requirements set for paper packaging material water resistance.

Packaging material adaptability to streamlined manufacturing provides an opportunity to produce packaging and to fill it in with products using high-yielding methods at low labor cost using effective automated packing equipment. However, the value of main indicators that make packaging adaptable to streamlined manufacturing, which are strength and firmness, must be set taking into consideration the preservation of goods themselves as the most important issue, and only then the convenience of the packing must be taken into account. Packaging paper as well as paper used for any other purpose should attract ink easily, have uniformity in thickness, color, and transparency. Whiteness indicator value is set up for each kind of paper. In each case crude material peculiarities and methods of production are taken into consideration.

Used packaging utilization is an essential requirement nowadays. When choosing packaging material a producer should always take into account the ability of the packaging to be recycled to prevent environmental pollution. There exist different ways to solve this issue: to decrease packaging mass, to recycle, to burn wastes while utilizing its energy, to disintegrate by heat, to bury wastes. Paper packaging materials can be utilized by means of all the above mentioned processes. Packaging paper materials remain the safest packaging materials. Therefore, their usage should grow in a wide range.

The comparison of requirements to packaging paper set by statuary documents in Ukraine are stated in a table 1.

The analysis of the above mentioned data shows that existing Ukrainian standards set up requirements only to very few packaging material quality indicators. In addition, there is no congruency between different types of materials. Also the existing requirements are general and do not take into consideration the peculiarities of each food product type packaging materials are used for. In its turn, it leads to certain difficulties while choosing packaging material. It also doesn’t give an opportunity to foresee probable changes in goods quality while storing and distributing them.

Nevertheless, packaging materials that used for food products have the strictest requirements set up among all other kinds of packaging materials. First of all, the necessary level of sanitary and hygienic indicators must be provided. The most important requirement for the usage of packaging materials for food products must be sanitary and epidemiological conclusions, that proves materials to be safe for a human.

Table 1. Statuary documents requirements to packaging paper quality

Indicator	Parchment	Artificial parchment	Wrapping paper	Paraffin paper
Mass, g/m^2	48-68	48-55	20 -160	not defined
Breaking length, m, no less than: in machine direction in cross direction	 6000-7700 3000-4100	 not defined not defined	 1600- 5200 1600-5200	 not defined
Relative burst strength resistance, kPa, no less than: dry wet	 270-310 110-130	 250-300 not defined	 170-290	 not defined
Fat permeability: mg, no less than mg, no more than the number of holes per 1 m^2, no more: the size of less 0,1mm or 0,1mm the size of more than 0,1 mm	 50-100 should be absent	 900-1800 8-30	 not defined	 not defined
Vapor permeability, g/m^2, no more than	not defined	not defined	not defined	not defined
Whiteness %	70	65-75	not defined	not defined
Humidity %	7,0-9,0	7-9	10	not defined
Moisture resistance, %, no less than	not defined	23-25	not defined	not defined

Source: own research.

Sanitary and epidemiological expertise has a complex of hygienic research as its basis. Then the decision about the safety of the objects of expertise is made according to the expertise results. If expertise objects are pastry paper packaging materials then it should be taken into consideration that the biggest number of requirements is set to the materials with polymer coating. Paper packaging material, which contact food products, must meet the following requirements (*Герасимова, Дишіневич, Головащенко 2010)*:

- the absence of substances migration that can worsen organoleptic qualities;
- the absence of packaging material chemical substances emission of such concentration that can do harm to health;
- packaging materials shouldn't stimulate microorganisms' development in food products;
- packaging materials should not change nutritional value of food products, and their external appearance should not change while contacting.

Chemical contaminant quantity in created environments must not be higher than it is established by SanRaN 42-123-4240-86 "Permissible migration quantities of chemical substances, that are produced from polymer and other materials, and which contact food products as well as the methods to determine them".

The harmful substances migration level of paper packaging materials, even those that are compositional is lower in comparison with polymer materials. Furthermore, substances' migration, which can happen in paper is easier to find. Therefore, paper packaging materials are not only safer to use for food products, but also easier to test during sanitary and hygienic expertise.

Conclusions

To sum up, statuary regulation requirements to packaging paper in Ukraine do not set up norms to all indicators that characterize packaging paper quality and its safety for food products. The same requirements, which are set according to the standards, are general and are not agreed for different types of materials. The usage of packaging materials with a wide range of constituents requires the determination of optimal conditions for distribution of each paper packaging material as well as strict control over it.

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COMPUTER-AIDED LIFE CYCLE ANALYSIS FOR A METAL CONTAINER

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Introduction

The processes accompanying the production of metal packaging involve some specified environmental impacts. The aim of this study is to identify differences in impacts related to metal container manufacture at present and ten years ago. For this purpose a life cycle analysis method covering the entire period of product life cycle from the conception up to disposal. It is assumed that the life cycle of a product begins as early as with its conceptual phase, thus in principle when a need for creating a given product arises, including feasibility study, product design and manufacturing technology, that is the pre-production phase (Adamczyk 2004). Life Cycle Assessment carried out within the framework of sustainable development and in accordance with governmental policy programs is based also on the ISO 14040 standard series (PN-EN ISO 14040, 2006). Once environmental impacts are analyzed in detail, it is possible to make product environmental optimization to choose a model with least environmental impact. When assessing product impact it is possible to make also an evaluation of potential environmental improvement, for example to verify and select a corrective action scenario. The life cycle analysis methodology takes into account economic, organizational, technical, ecological, motivative, psychosocial as well as legal factors (PN-EN ISO 14041, 2002)**.** Such LCA features imply specific uses. This method is successfully used in environmental impact assessment for a given product or process to modify or optimize the design, product or technology. Such analyses are especially useful in developing strategies for logistics of products and its packaging and become a component of *evaluation of ecological options*. Also for environmental policy evaluation by using environmental assessment methods, so called ecological profiles can be created to qualify raw materials, materials or technologies. The presented life cycle assessment method as an investigation of interactions between humans and the environment in the period of dynamic civilizational and

technical development allows knowledge of mutual interactions to be gained in quite accurate way, thus enabling proper, conscientious and responsible influences on the environment that have an immediate effect, among other things, on the quality of human life. However, life cycle assessment is often not a simple and univocal task. Despite of its undoubtful advantages, the life cycle assessment methods have also weak points. In many cases it is difficult to interpret the results of analysis, but they give a good ground for further comparative studies and optimization. However, it could be found that labour expenditures necessary for a full life cycle analysis of a single product is too high compared to the expected outputs. This why a computer-aided LCA is used along with initial databases containing environmental impact data for most common raw materials and processes. Such data can be used as components of further analyses (Goedkoop, An De Schryver, Oele, Durksz, Douwe de Roest, 2008). Such approach to *LCA* enables many-fold reduction in necessary labour expenditures and simplifies highly time-consuming comparative analyses for optimized solutions. It is possible to get a full and clear product image that can give a ground for determining its environmental performance in a more comprehensive approach than labelling commonly used by manufacturers and indicating, for example only product-related energy consumption during use of a product. Thus, when undertaking actions to improve ecological properties of products it could be advisable, especially for big polluting companies to extend their analyses by *LCA* to get more comprehensive and long-term results. Such actions should cause an improvement in the quality of life by environmental enhancement having a direct effect on human life.

Material and methods

This study deals with comparison of environmental impacts related to current manufacture of metal containers in the form of aluminium cans. The results of investigations of the aluminium can production effects presented by Adamczyk in "Ekologia wyrobów", 2004. Environmental impacts of aluminium can life cycle were examined by using so called screening life cycle analysis (Goedkoop, An De Schryver, Oele, Durksz, Douwe de Roest 2008), while the presented comparisons apply to the can production phase. The comparison of the mentioned results of two studies enables the directions of aluminium can production changes over last 10 years in Poland to be determined. This allows also verification and comparison of solutions and technologies used in the terms of emissions released. Life cycle assessment was carried out by using the Eco-indicator 99 method that converts impacts caused by the existence of a product from the design to final disposal into values in impact categories expressed in Eco-points (Goedkoop, Effting,

Collignon, 2000). The impact categories being used in the eco-indicator method are expressed by damage they caused and its seriousness is indicated by Eco-points. The eco-indicator method was developed in the Netherlands and Switzerland simultaneously. The method was oriented to different types of damage existing in the environment. The following damage categories were indicated: damage to human health, damage to ecosystem quality and damage to natural resources. *Disability Adjusted Life Years (DALY)* is used as a quantitative index describing the seriousness of adverse effects to human health and is used also by the WHO. Damage to Ecosystem Quality is expressed as the percentage loss of species over a certain area, during a certain period of time due to an environmental impact (the unit used is *PDF – Potentially Disappeared Fraction*). The consumption of raw materials in the sense of irreversible resource use measured as expenditures needed for future extraction of raw materials, and *MJ* is the unit. To provide an uniform and comparable assessment these three different types of damage are converted into one common units called Eco-points. The Eco-indicator 99 assumptions allows also its score to be calculated by weighting of these three damage categories. Individual weights were established by a panel of experts at the level of 40% for damage to human health, 40% for damage to ecosystem quality and 20% for damage to natural raw materials. The Eco-indicator method is thought rather as a method of product comparison than a way to provide full eco-balance due its specificity and difficulties in interpretation of results. The result conversion can be combined with damage costs in particular impact groups. Thus, it could be possible to make a cost analysis related to adverse effects within individual damage groups. Such valuation could consist in cost estimation pertaining to restoring the category to previous state, thus requiring an extensive methodological base to developed.

To demonstrate a LCA procedure an example of eco-indicator determination for life cycle of a common beverage container, namely aluminium can is presented. The factors inducing selection of this product is highly arduous process of raw material extraction and more and more increasing recycling. The functional unit is 1 kg of aluminium cans, that is 53 cans of 0.5 liter or 63 cans of 0.33 liter in capacity and this is intended to facilitate comparison with reference to production volume. The analysis covers the aluminium manufacturing process beginning from bauxite extraction and rafination to the electrometallurgical process, smelting and final can casting. Also the sheet rolling and can manufacturing processes are taken into account. Due to its relatively minute share in overall environmental loading the filling, use and transport processes were neglected. The data from software databases as well from previous analyses and papers and information

derived directly from practice were used for *LCA* purposes. Environmental impacts during life cycle were presented by using the *Eco-indicator 99* method. The *Eco-indicator 99* method includes three steps. The first step is a *LCA* standard procedure in life cycle assessment, that is gathering information about all significant emissions, extraction of natural raw materials, land use at all processes involved in product life cycle. The next step is the calculation of damages to human health, ecosystem quality and natural resources. The final step is to estimate environmental loadings in the three damage categories (eco-indicator assignment).

The simplified aluminium can production structure is presented in the form of network diagram in Figure 1. Besides structure simplification also components with environmental impacts not exceeding 0.125% share in the final result were omitted. The whole production system can be divided into three stages: manufacture of cups, manufacture of lids and a part of enterprise operation and production organization, that because of its low environmental share has not been specified in figure 1. Each system component in the diagram has so called thermometer determining its environmental impact compared to the overall impact caused by aluminium can production.

The aluminium can manufacturing process uses cold rolled sheet metal inn coils delivered by an outside supplier. When preparing the material for production the sheet metal is uncoiled and coated with oils at the same time. Then after further processing the pressing and forming processes are performed. Depending on the component being produced, shallow cups or can lids are formed and the aluminium scrap is left over from these operations. The formed parts got to a series of pressure washers where oil residues and other deposits are removed. The washing is carried out by using solvents and significant amounts of tap water, while in other processes also demineralised water is used for cooling machines and devices. After thorough washing the can components are transported to a paint shop where become coated with appropriate paints and varnishes. Afterwards the can parts are dried in an oven (drier) by using thermal energy from combustion of natural gas in a furnace. The presented simplified product path applies both to the aluminium cup (can body) and can lid. When assembling the can as a whole a sealing material is used to obtain an appropriate joint of the lid and the can. Also water is used to verify the final product leak-tightness. The most important impacts of the whole manufacturing process are indicated in Figure 1 with process thermometers, and also by appropriately thickened process flows in Figure 2. Not all processes mentioned above are shown in Figure 2, as some of them were omitted due to its environmental impact below 0.125% as expressed in eco-points.

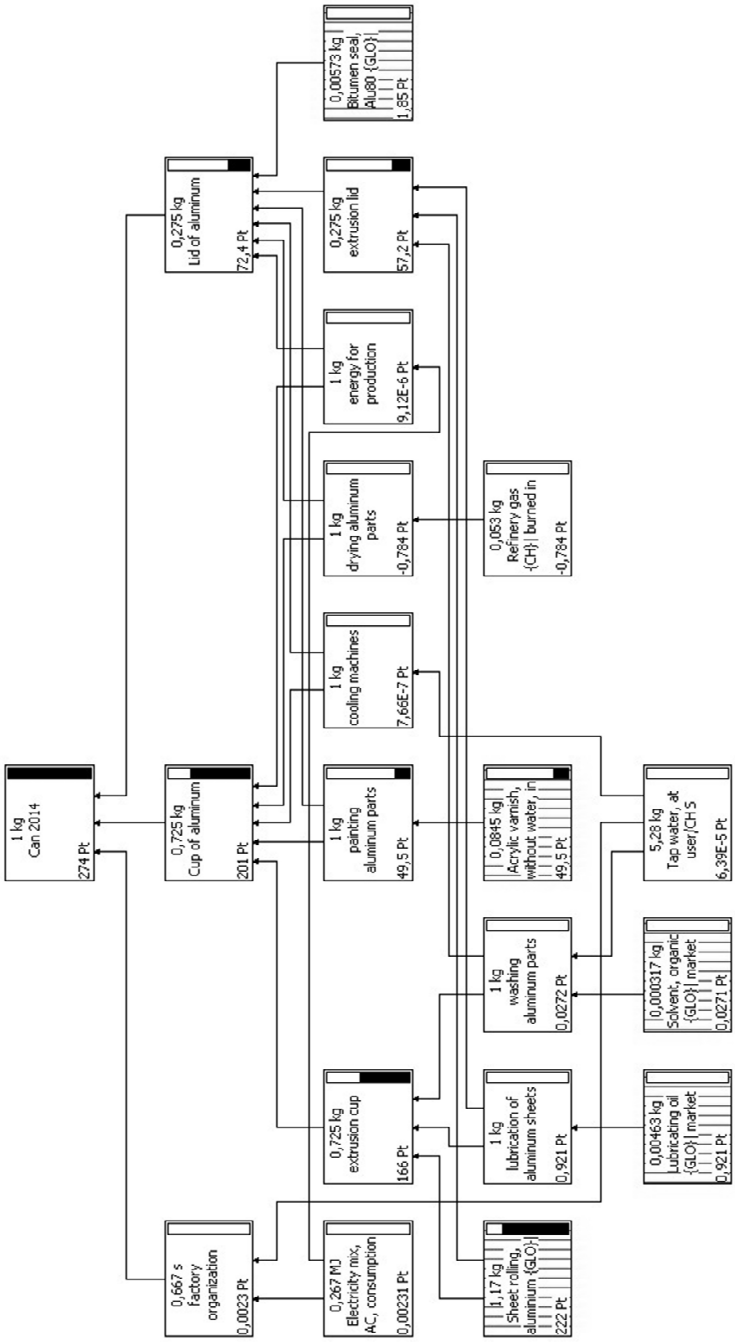

Figure 1. Network diagram for simplified aluminium can production system based on the 2014 data.

Source: own research by using the SimaPro software

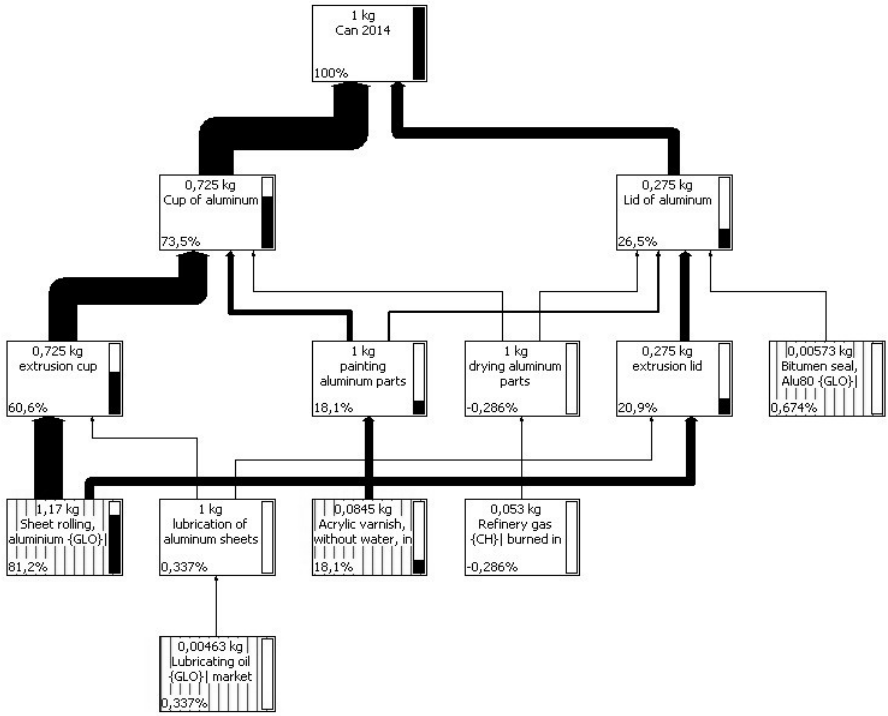

Figure 2. Network diagram of process flows for aluminium can manufacturing from the 2014 data

Source: own research by using the SimaPro software

Results and discussion

As follows from the latest data the aluminium sheet manufacturing process, including the extraction of raw material, getting aluminium bars and rolling into sheet metal, has the highest environmental impact reaching up to 81.2 % of the impact of the whole production impact (see Figure 2). This refers both to the aluminium cup and can lid in proportion to their weights. However, the second highest impact has painting, namely the use of acrylic paints and varnishes that causes 18.1% of the overall impact. Also for the 2004 data the process of aluminium production and preparation demonstrates the highest degree of environmental intervention. However, at the present stage of investigation it is impossible to decide unequivocally which stage of aluminium preparation is of utmost importance. It follows from the data related to can manufacturing ten years ago (Figure 3) that the highest share in the total score can be most likely assigned to the natural resource consumption and processing.

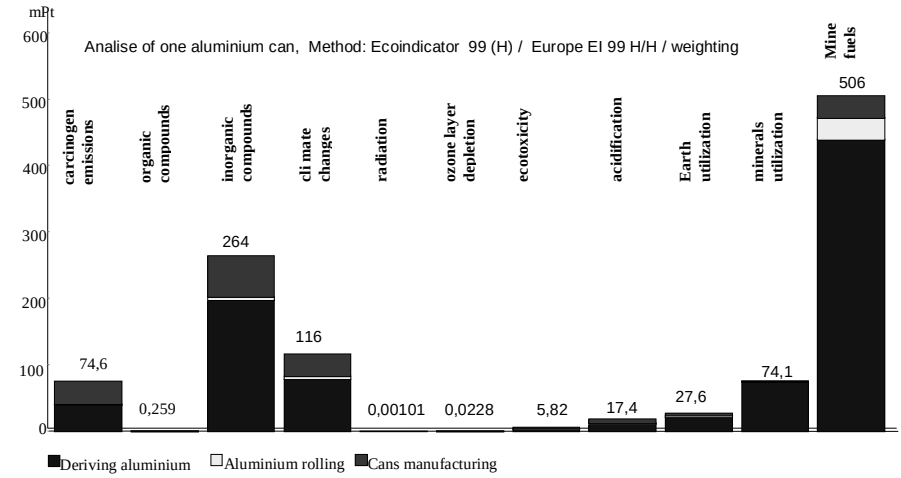

Figure 3. Damage categories for aluminium can manufacturing based on the 2014 data

Source: (Adamczyk 2004).

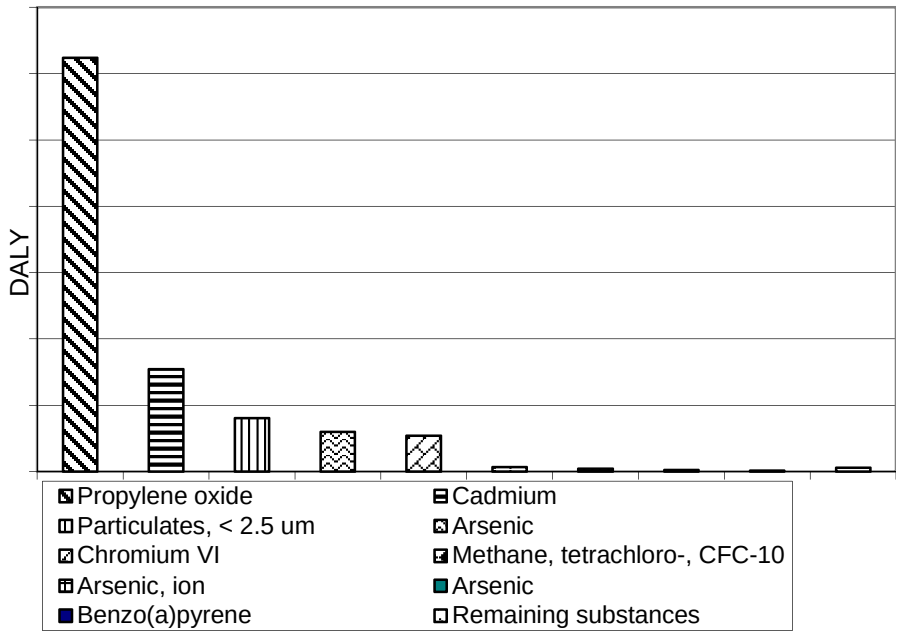

Figure 4. Characteristics of carcinogenic emissions baed on 2014 data

Source: own research by using the SimaPro software

Due to various software versions used in Eco-indicator conversion and probably because of different system of eco-point calculation it is impossible to make direct comparison of these two results, however a comparison of their structure may be attempted.

Based on Figure 3 presenting the categories and values of adverse impacts of the can production system from just ten years ago, the life cycle stages can arranges according to the seriousness of these impacts. In each category the processes related to deriving aluminium from primary raw materials have the most adverse environmental effect. The second most serious impact is assigned to the can manufacturing stage, while the effect of sheet metal rolling is minimal. Such result pattern was subjected to normalization, that is the category indicators were divided by environmental impact per capita, for example per European resident, yearly, i.e. so called normal impact. Thus the comparison involves dimensionless values and normalization allows the share of individual environmental impact categories in the total impact of product life cycle to be determined. The highest values of the indicator are reached by such categories as fossil fuels, inorganic compounds and climate changes (Adamczyk 2004). For fossil fuels a high value of the indicator related to aluminium rod manufacturing is connected at first place with depletion of fossil fuel resources and, as specified by the Eco-indicator, the surplus energy needed in future to extract these resources. The second strongly highlighted impact related to the raw material preparation is the emission of inorganic compounds caused in part by the can manufacturing process itself. Also emissions of carcinogenic compounds of Eco-score at the level of 74.6 mPt is dangerous to human health. In addition, carbon dioxide emissions causing the greenhouse effect is noticeable.

The 2014 data presented in Figure 4 indicates a slightly different impact structure. While the impacts connected with human health deterioration still prevail and such dominance is very strong over the other results, the use of natural resources was reduced significantly. This may result from the use of recycled materials in sheet metal production by the aluminium supplier. Also the structure of energy generation needed for the manufacturing process has been changed. The processes causing adverse effects to human health include the manufacture of can body (cup) and aluminium lid, i.e. those can components that require aluminium to be derived from primary raw materials and processed. The prevailing assessment component are NMVOC (*NMVOC – Non-methane Volatile Organic Compounds, unspecified origin*) emissions to the atmosphere. In addition, carcinogenic emission as well as the consumption of energy sources characteristic of the country where energy is generated, i.e. hard coal, natural gas and methane, and oils, are observed.

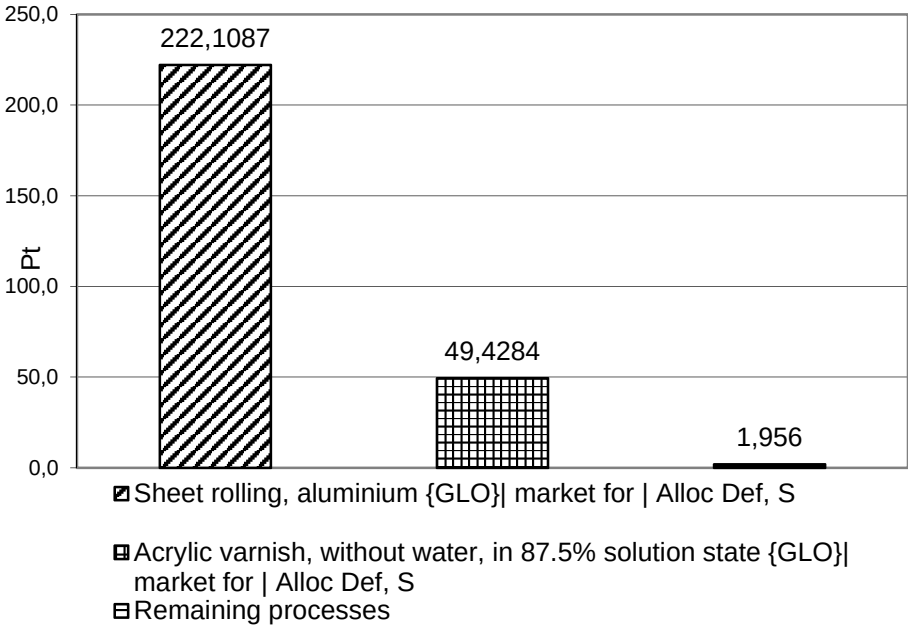

Figure 5. Processes of highest environmental impact based on the 2014 data

Source: own research by using the SimaPro software

Harmful emissions concentrate around a few manufacturing processes (Figure 5). The processes with the share higher than 1% of the overall environmental impact are shown in this figure.

The older manufacturing technology showed similar characteristics of environmental impacts. The highest arduousness corresponds to the aluminium production process (864 mPt), aluminium can manufacturing (176 mPt), and only 46 mPt for aluminium rolling processes. For environmental impacts in the aluminium production process the following effects can be ordered in descending sequence of importance: use of fossil fuels, inorganic compounds, climate changes, ozone layer depletion and carcinogenic emissions. The use of fossil fuels had a higher share in environmental damage than the present value. This is undoubtedly connected with the characteristics of electricity and heat generation. Also the emission of inorganic compounds to the atmosphere, particularly harmful to human health, seems to be high. The next high emission to the atmosphere are greenhouse gases causing accelerated climate change.

Similarly, the use of fossil fuels has the highest significance in the aluminium rolling process, while in aluminium can production the emission

of inorganic compounds, carcinogenic emissions, use of fossil fuels and climate change are of highest significance in descending order. Aluminium production is the most arduous life cycle stage that to large extent affects raw material resources and human health. Therefore the can production process creates a serious hazard to human health and the two main problems connected with the product are to be solved: to decrease arduousness of the aluminium manufacturing process and to reduce harmful effect of aluminium can production process to human health. In the former case the simplest solution is to increase the can recycling rate, and then to start work on the aluminium production process. Harmful effect of aluminium can production to human health can be reduced by liquidating emissions of hazardous substances, e.g. by changing methods of coating application. When selecting appropriate solution the LCA method aided by relevant software can be used.

When determining an overall environmental impact of a process or product, the calculated damage indicators are grouped into three categories: human health, ecosystem quality and natural resources. This allows the prevailing category to be identified and the cause of this situation to be pointed out, while normalisation indicates relative values of these impacts and to represent its significance, weighting is required. Weighting consists in converting the results by using weighting factors corresponding to the significance of impacts (PN-EN ISO 14042: 2002). Typically, the normalisation procedure has some subjective features. In the software used the factors specified in the Eco-indicator 99 method are employed.

Because of the comparison with another production system and compliance with the ISO standard on the interpretation of results (PN-EN ISO 14043:2002), weighting will not be considered in this paper. Skipping the stage allows the comparison of results to be not dominated by subjective weighting factors.

To obtain the cumulative impact indicator the indicators are summed. For the functional unit under consideration the summed impact is 1.09 Pt (eco-point). The eco-point values corresponding to individual life cycle stages by impact categories.

Table 1. Environmental damage categories to the 2004 production.

Damage category	Unit	Sum	Aluminium rods	Aluminium rolling	Can production
Sum	Pt	1.09	0.864	0.046	0.176
Human Health	Pt	0.455	0.315	0.0105	0.129
Ecosystem Quality	Pt	0.0508	0.0357	0.00221	0.0129
Natural resources	Pt	0.58	0.513	0.0332	0.0338

Source: Own research based on Adamczyk 2004.

Table 2. Environmental damage categories to the 2014 production.

Damage category	Unit	Total	Aluminium can production organisation	Aluminium cup (body)	Aluminium lid
Total	Pt	178.9817	5.27E-06	177.4482	1.533421
Human Health	Pt	178.8537	2.9E-06	177.3285	1.525125
Ecosystem Quality	Pt	0.121035	6.77E-07	0.119601	0.001433
Resources	Pt	0.00696	1.69E-06	9.46E-05	0.006863

Source: Own research

Due to different system of eco-point calculation, instead of their values, only the structure within impact categories will be compared in this paper. In raw material use category where at least residual recycling has been implemented, some improvement can be noticed. Probably such improvement was supported by more refined manufacturing technology minimising amount of waste. The hazard to ecosystem was also reduced over last ten years. However, the indicators related to threats to human health, thus the category of utmost importance to humans, still have strong negative overtones. The emissions of organic and carcinogenic compounds from the aluminium manufacturing and painting processes are so distinguishable enough from other results that further steps are required to reduce them. Thus better solutions should be found to allow the processing of mentioned raw materials and manufacturing processes to be carried out in a safe and healthy manner.

To reduce negative emissions from aluminium production it is possible to attempt increase gradually the share of recycled raw material. An effect of recycling rate on harmfulness of aluminium can life cycle based on the 2004 data and performed scenario analyses can be presented as follows:

Scenario where no recovery was assumed (0% recycling rate) causes a slight increase in harmful impacts resulting from directing the waste stream into landfill. Scenario in which 40% recovery of used containers is foreseen, brings significant effect and eliminates about 30% of life cycle harmful impacts. As regards to the ozone hole category and organic compound emissions, harmful impacts are eliminated completely (in 100%). This results from abandoning aluminium production from primary raw materials in favour of recycled metal. Also in other categories significant effects were achieved: eco-toxicity (64% reduction), mineral extraction (39% reduction).

The effect of complete replacement of aluminium produced from primary raw materials by recycled metal is 80% reduction in harmful impacts. Such effect is of special importance particularly in the categories of raw materials and human health.

Conclusions

The contemporary aluminium can manufacturing methods compared to those used ten years ago certainly bring a functional improvement by reducing some of adverse environmental impacts. This results not only from factors related to modernisation of can manufacturing technologies, but also all co-working and contributing processes. Among other things, the electricity generating method for production powering has been improved. The use of natural gas reduced the carbon dioxide emission compared to hard coal or coke firing. Also transport of raw materials decreased its share in environmental pollution by fulfilling the more and more stringent exhaust cleanliness standards as well due to lesser life cycle environmental harmfulness. Thus, general conditions for a number of co-working processes have been improved not only on the side of the manufacturing plant , but also in its nearer and farther environs. However, despite of improvements in raw material use parameters and ecosystem quality, there is still a significant negative impact of atmospheric emissions of gases harmful to human health. Thus, it is necessary to focus on cleaning emitted gases from harmful substances. An increase in contribution of recycled raw material could also bring positive effects in several categories. As mentioned above in previous section 100% replacement of primary aluminium by recycled raw material causes 80% reduction in gas emissions. In the case under consideration such emissions are especially harmful activities because of its immediate impact on threats to human health and life. Thus it would reasonable to perform also further analysis of enterprise activity and to identify an exact process or resource directly responsible for individual emissions of unfavourable substances to the atmosphere and to eliminate or replace it in the production system. Obviously, when making such a change it will be necessary to perform a new life cycle assessment for aluminium cans and to determine new obtainable functional parameters, while verifying new dangerous emissions that may arise.

To make an assessment of environmental impact caused by enterprise activity the *LCA* method enabling the relations between the environment and a product and manufacturing process with reference to product ecology tools, is the most adequate, available and widely renown. Therefore, LCA is recommended to analyse enterprise functioning, especially large manufacturing plants being large pollutant emitters. Such actions could enable enterprise operation to be optimised in terms of harmful substance emissions, thus could contribute in improving the quality of human life. This could improve environmental quality and have an advantageous effect on human health, while enhancing the quality of life.

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PN-EN ISO 14043:2002, *Zarządzanie środowiskowe – Ocena cyklu życia – Interpretacja cyklu życia*.

RFID TECHNOLOGY IN SUPPLY CHAIN OPERATIONS

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Introduction

Presented paper concentrate on using RFID (Radio Frequency Identification) technology in supply chain management. Supply chain management is the management of material, information and finance through a network of organizations (i.e. suppliers, manufacturers, logistic providers, wholesales distributors and retailers) that aims to produce and deliver products or services for the consumers (Blos et all 2009). It includes the coordination and collaboration of processes and activities across different functions such as marketing, sales, production, product design, procurement, logistics, finance, and information technology within the network of organizations. The desire to cut supply chain costs has pushed radio frequency identification. Technology, an e-tagging technology that can be used to provide electronic identity to any object. RFID is not a new technology. It was first used in the Second World War to identify aircraft. But the application of this technology (described in the paper) in supply chain management is new.

The history of technology

The service sector has been using barcode technology since the mid-1970s. Barcodes appear on almost every purchase, from soft drinks to automobiles. The code itself is made up od the series of wide and narrow parallel lines and spaces and can store as many as 20-30 characters per inch of coded informations. Research and development in barcoding technology das led to the development of the new two-dimensional code which contains a stack of as many as 90 one-dimensional barcodes each just three-hundredths of an inch high. New developed barcodes allows user to maintain a large block of information about each product – manufacturer, cost price, order size, weight, etc. High-speed laser scanners read the new barcode quickly and retrieve the information for continual monitoring (Jones & Christopher 2007).

But not in all cases this technology was the best solution. Sometimes the barcodes a unreadable and we can't use scanner. Because of that there is a new technology – RFID – radio frequency identification. This technology originated in the 1940 when the US government used transponders to distinguish friendly aircraft from enemy aircraft (Attaran 2007; Finkenzeller 2010). Also, in the 1950s, other technical developments in radio and radar along with the IFF exploration of long range transponder systems for identification was conducted. These development also led to future patents for RFID technology (Jones & Christopher 2007).

Through the 1970s, the federal government primarily used the systems for tracking livestock and nuclear material. Radio tags have been used commercially in so-called closed loop systems for delivering packages, handling luggage, tracking food in supermarkets and monitoring highway tolls in the 1980s and 1990s. In 1997 Mobil installed an RFID system called "Speedpass" the lets you wave tag in front of the gas pump to record your transaction and debit your credit card.

In 1980 the Bay Area Rapid Transit (BART) installed RFID system to provide equal access to the system for disabled individuals. Under the new system disable people were issued an I|D tag at no charge. To operate the system, the disabled person holds the tag close to the reader to activate station elevators (Attaran 2007).

In 1999 with the help of scientist at the Massachusetts Institute of technology a consortium companies formed center for continued research into the nature and use of radio frequency identification. The consortium had a new idea about how organizations could identify and track their assets. The new vision underlying automatic identification of objects. Today the RFID technology can not only be enterprise assets, but also the movement of products, containers, vehicles and other assets across vast geographical areas. (Sweeney 2010). Between 1999 and 2003, the Centre gained industry acceptance of the passive RFID tagging system with the support of more than one hundred large end-user companies. The industry support is evidenced in the fact that some of the biggest retailers in the world – Albertsons, Metro, Targret, Tesco, Wal-Mart and U.S. department of defense have initiated plans to use this technology to track goods in their supply chain (Jones & Christopher 2007; Finkenzeller 2010).

The use of technology

Barcoding technology has become very important to all industries including manufacturing and services. But there were some problems witch this technology. Some situations have environmental condition, such as temperature, dirt or hazardous contamination, that make optically scanning

the barcodes on a label ineffective. In those cases a different technology, called radio frequency identification (RFID), is often preferred. RFID does not require the tag or label to be seen to read its stored data.

For a nominal price a RIFD tag is attached to the product in the initial stages of manufacturing that follows the product down the supply chain all the way to a retail setting, and finally into the hands of the customer. There, it can again be scanned while in a box or crate, saving labor. In a retail setting, the tag can serve as the price tag count on the tag for warranty information after purchase.

Consumers can RFID does not require the tag or label to be seen to read its stored data. RFID uses radio waves to capture data from tag, rather than optically scanning the barcodes on a label. RFID systems have three primary components:

- the tag or transponder,
- the reader,
- the computer.

An important promise of RFID technology is to cut costs and deliver a wealth of information that helps firms more effectively understand, predict, and respond to customer demand. RFID not always is the best solution. It is an enabler that allows firms to change their supply chain processes for the better.

RFID technology is used in a range of applications. More specifically, it has useful applications in the following industries (table 1):

- shipping and distribution,
- retail industry,
- manufacturing sector,
- agriculture, cattle and food production,
- health care,
- pharmaceutical,
- government,
- gaming industry,
- security industry.
- Signaling between the reader and the tag is done in several different incompatible ways, depending on the frequency band used by the tag. Tags operating on LF and HF bands are, in terms of radio wavelength, very close to the reader antenna because they are only a small percentage of a wavelength away. In this near field region, the tag is closely coupled electrically with the transmitter in the reader. The tag can modulate the field produced by the reader by changing

the electrical loading the tag represents. By switching between lower and higher relative loads, the tag produces a change that the reader can detect. At UHF and higher frequencies, the tag is more than one radio wavelength away from the reader, requiring a different approach. The tag can backscatter a signal. Active tags may contain functionally separated transmitters and receivers, and the tag need not respond on a frequency related to the reader's interrogation signal (Daniel &Dobkin 2008).

Table 1. The use of RFID technology in various industries

Industry	The use of technology
Shipping and distribution	In this industry, RFID technology enables suppliers to accurately determine the location of a pallet, to track its journey through the supply chain, and to make instantaneous routing decisions. At a major trucking and logistics provider company, RFID tags are embedded in the fleet of 2600 trucks. At the service center, the tag automatically determines what loading/ unloading activities are needed and assigns an appropriate crew to service the truck.
Retail industry	RFID technology offers a very significant advantage over bar coding. Wal-Mart's initiative and move in using the technology was heralded as the most important tech development for retailers since the barcode. RFID tags continually gather information as products move from shelves to the checkout counter. The technology not only helps the retailer to reduce labor and manual costs, it also curbs shoplifting and boosts store.
Manufacturing sector	This sector has been finding different ways to derive value out of this technology. For example, manufacturers are using RFID product tracking mechanisms to ensure accuracy. Parts can be individually tagged and tracked throughout the manufacturing proces while on the production line. Parts received from the production plant can be tracked throughout the assembly process. This certainly helps manufacturers with their carefully scheduled just-in-time (JIT) assembly lines. Tags containing equipment specifications can be attached to enable easy upgrading. Similarly, tags can be used to keep track of usage, availability, location, and maintenance of material handling equipment. Procter & Gamble (P&G), for example, believes that RFID technology can help thecompany to track where every item is in themanufacturing process and supply chain..
Agriculture, cattle and food production	Increased government regulation about food traceability in the USA and a mandate from the European Union (EU) for tightened traceability requirements beginning in 2005 has pushed RFID technology into food sourcing. RFID can help these traceability requirements at a reasonable cost. The technology should also reduce recall costs by increasing the ability of the manufacturers to identify and recall only the affected items. Similarly, RFID technology is used to secure the identification of cattle by means of inserting a tag into the stomach of an animal, enabling accurate records for automated farm management.

Health care	RFID technology can be used in health-care industries to improve quality and reliability. In the US Navy, RFID tags, embedded in wristbands, are used to identify patients and update their status automatically. A British firm is using RFID tags to match blood samples to patients.
Pharmaceutical	The drug industry uses RFID technology to self-police in the fight against thieves and counterfeiters. For example, Purdu Pharma, the manufacturer of the popular painkiller OXYContin, is using RFID tags to track shipment of its theft-prone drug. Pfizer is planning to put the radio tags on bottles of its widely counterfeited Viagra drug by the end of 2005. With RFID tags, pharmacists will be able to identify counterfeit drugs and law enforcement officers also will be able to quickly check whether bottles they recover have been reported stolen.
Government	This sector is another emerging application area for RFID. Government agencies are using RFID technology for supply chain management, inventory, security, and military strategies. The Army uses tags on supply containers for detecting shock and variances in temperature. These tags have a range of up to a mile to enhance supply management capabilities. The Navy, on the other hand, uses RFID tags for weapon management, with a range of less than six inches to protect sensitive data. Weaponry data collected by RFID tags reveal anything from materials to capabilities and mission details.
Gaming industry	This industry has been finding otherways to derive value out of this technology. For example, the Wynn Las Vegas Casino is using radio tags on Betting chips to deter counterfeiting, card-counting and other illegal behavior. Casino executives envision RFID transforming the way they operate table games. Thecasino is installing RFID readers and PCs at game tables. Dealers can take a quick inventory of chips that have been wagered. In addition to monitoring wagers, the technology will let dealers or cashiers see when the value of the chips in front of them does not match the scanners' tally. The casino industry is also planning to use the technology to help casinos keep tabs on how much players bet and how long or often they play for incentive programs.
Security industry	Giant retailers and manufacturers aren't the only adopters of RFID technology. RFID seems to be moving quietly into the people-tracking realm, especially in the area of monitoring children. Lauren Scott of California, the $2 million-a-year apparel company, will launch a line of pajamas with RFID tags sewn into the hems. RFID readers installed at various points throughout a house will be able to scan the tags within a 30-foot radius, and will trigger an alarm when boundaries arebreached.

Source: Own work on basis (Attaran 2007).

An Electronic Product Code (EPC) is one common type of data stored in a tag. When written into the tag by an RFID printer, the tag contains a 96-bit string of data. The first eight bits are a header which identifies the version of the protocol. The next 28 bits identify the organization that manages the data for this tag; the organization number is assigned by the EPCGlobal consortium. The next 24 bits are an object class, identifying the kind of product; the last 36 bits are a unique serial number for a particular tag. These

last two fields are set by the organization that issued the tag. Rather like a URL, the total electronic product code number can be used as a key into a global database to uniquely identify a particular product (John 2009).

Often more than one tag will respond to a tag reader, for example, many individual products with tags may be shipped in a common box or on a common pallet. Collision detection is important to allow reading of data. Two different types of protocols are used to "singulate" a particular tag, allowing its data to be read in the midst of many similar tags. In a slotted Aloha system, the reader broadcasts an initialization command and a parameter that the tags individually use to pseudo-randomly delay their responses. When using an "adaptive binary tree" protocol, the reader sends an initialization symbol and then transmits one bit of ID data at a time; only tags with matching bits respond, and eventually only one tag matches the complete ID string (Glover & Bhatt 2006). Both methods have drawbacks when used with many tags or with multiple overlapping readers. Bulk reading is a strategy for interrogating multiple tags at the same time, but lacks sufficient precision for inventory control.

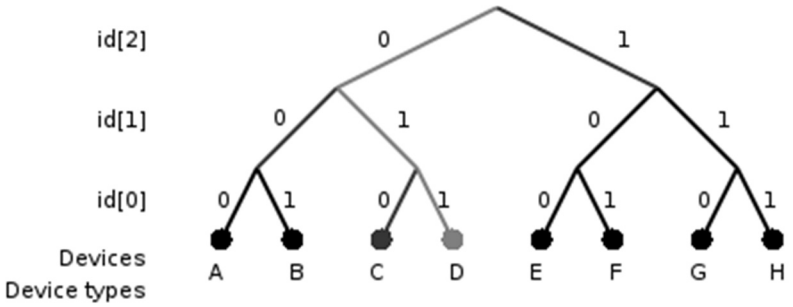

Figure 1. An example of a binary tree method of identifying an RFID tag
Source (Piramuthu 2008).

RFIDs are easy to conceal or incorporate in other items. For example, in 2009 researchers at Bristol University successfully glued RFID micro-transponders to live ants in order to study their behavior (Ants 2013). This trend towards increasingly miniaturized RFIDs is likely to continue as technology advances. Hitachi holds the record for the smallest RFID chip, at 0.05mm × 0.05mm. This is 1/64th the size of the previous record holder, the mu-chip. Manufacture is enabled by using the silicon-on-insulator (SOI) process. These dust-sized chips can store 38-digit numbers using 128-bit Read Only Memory (ROM) (TFOT 2007). A major challenge is the attachment of antennas, thus limiting read range to only millimeters.

Results and discussion - Benefits of technology

Organizations who take the time to understand the technology's capabilities and limitations can increase their revenue growth, lower costs, reduce inventory, better utilize fixed assets and gain favor with retailers. The main benefit of using RFID technology is reducing human intervention. Because of that the benefit of having fewer humans hands involved is reduced errors, which produces reduced costs, faster throughput, and reduced damage and returns. The overall implication of reduced human intervention, given the high cost of salaries, benefits and the cost of management associated with crews of human workers, is a dramatic reduction in operating costs. Automated toll systems are a prime example of how the lack of human intervention saves both time and money (Sweeney 2010).

Some of the most important benefits that business is able to gain by using this technology are (Attaran 2007, Robbins 2005):

- enhanced visibility into customer needs;
- enhanced visibility along the supply chain;
- accurate and timely asset tracking;
- smart product recycling;
- streamlined or better managed business processes within the company;
- improved productivity by generating the fastest and lowest
- cost method of acquiring the data;
- improved velocity by responding to demand signals faster;
- better utilization of fixed assets, resulting in lowered
- capital asset requirements;
- reliable and accurate order forecasts;
- reduction in inventory costs including stock-out and
- holding costs;
- improved technology return on investment;
- improved accuracy by reducing the opportunity for human error;
- increased productivity and dramatically reduced operating costs;
- improved product quality and reliability including traceability;
- improved supply chain management by better tracking transportation and warehousing channels;
- improved counterfeiting identification, theft prediction, and faster recalls; and
- gaining favor with retailers to better position products on shelves.

The advantages of RFID vs. barcode technology (Advantages):

- no line of sight requirement.
- the tag can stand a harsh environment.

– long read range.
– portable database
– multiple tag read/write.
– tracking people, items, and equipment in realtime.

There are a few important social and ethical risks that must be realized, especially in regard to the healthcare environment. Monahan and Fisher researched the ethical and social risks of RFID devices being implanted into humans via observational studies and staff interviews in twenty-three United States hospitals using RFID technology The first risk they identified in their study was that patients who opted to receive the RFID tag were receiving expedited care. Secondly, Monahan and Fisher found that doctors tended to trust the information obtained from the RFID tags over the information the patients themselves provided. This raises a large concern pertaining to the accuracy of the information on the tags. If the information on a patient's tag were to be incorrect, it is possible that the care administered to the patient could be doing him or her harm. The third and final risk discovered in this study was that patients who do not know the extent of the capabilities of the RFID tags may actually be endangering themselves. A patient's ignorance of the chip's capabilities may cause them to assume that the chip can do things that it cannot, leading to a very false sense of security (Monahan & Fisher, 2010).

Conclusions

Nowadays the RFID technology is increasingly using in various industry as: shipping and distribution, retail, manufacturing, agriculture, health care, pharmaceutical, government, gamin, security, timber, library etc. in supply chain management process. Many benefits described in the paper causes the possibility of wide use of this technology. Because of benefit of having fewer humans errors it can lead to reduced costs and faster throughput. Also reduced damage and returns are important problems from logistic and also quality management point of view. On this basis we can say that the RFID technology will develop and will be implemented to other industries. But there are some concern regarded to RFID relevant to cost of the technology and also social and ethical risks' that must be realized.

Acknowledgments

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MARKET ANALYSIS OF POLYETHYLENE PACKAGING IN UKRAINE AND NEW REQUIREMENTS FOR QUALITY CONTROL OF POLYMERIC PACKAGING MATERIALS

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Introduction

The growth of the global market of packaging materials, changing in directions of its development, increasing requirements in terms of safety protection products and packaging materials, which connected with environment, have found unprepared of Ukrainian enterprises to the introduction of new technological schemes. Flexible packaging materials market in Ukraine range to 209 million dollars in 2011 and expected his increasing on 4.9%, which is approximately 266 million dollars in 2016 year (Jvanko 2012, Olinkovsky 2013, Data of researches Smithers PIRA 2013).

Characterization of the manufacter

The main materials for the produce of flexible polymer packaging are polyolefin's, their copolymers and derivatives, which are inexpensive and have good enough consumable characteristics. Foremost, there are polyethylene, polypropylene, polystyrene, polyvinyl chloride and polyethyleneterephtalate - materials whose production in Ukraine are limited, that why polymer market is characterized by significant dependence on imports. The total volume of polyethylene imports was evaluated by 334.1 thousand tons during 2012 year, which is more higher compared to 300.49 thousand tons in 2011 year. However, the part of manufacturers in the structure of imports amounted to 169.9 thousand tons (51% of total value) in 2012 and 144.7 thousand tons from them enter for the needs of the packaging industry (fig. 1).

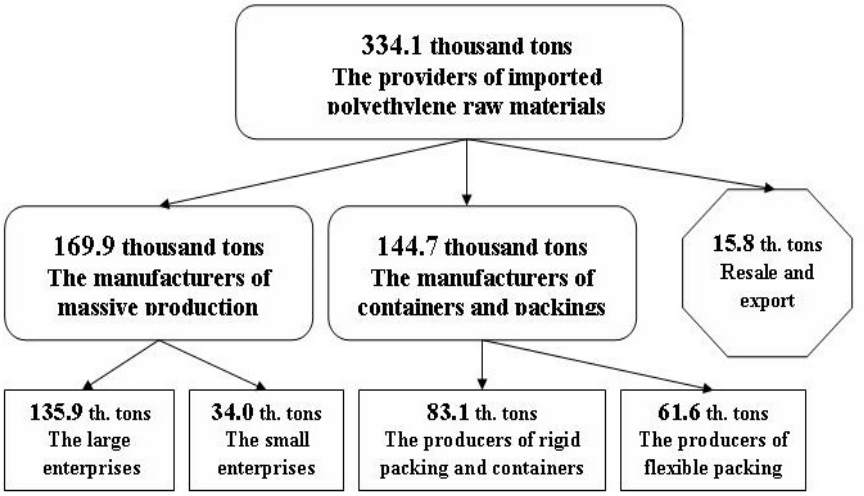

Figure 1. Distribution of import polyethylene raw materials on manufactures in Ukraine

Source: own research

Polyethylene market in 2013 was tended to increase both the quantity and in value definition. Moreover, the increasing in value determination is preventive by increase in prices of polymer raw materials.

- The main providers of polymers are divided into four groups:
- Russian enterprises;
- Central Asian and South Korean companies;
- European manufacturers;
- Home enterprises.

The Russian providers are mostly powerful petrochemical enterprises with obsolete equipment, which makes impossible production polymers in a wide range of assortment and quality. The high-density polyethylene, whose share in total consumption is steadily declining, is dominated in structure of manufactured products. Overall competitive position of all these companies is based on a low competitive price, which is formed due to cheaper energy hydrocarbon resoures, which are the main raw material for the production of large amount polymers. The entire niche imports of polyethylene in Ukraine in 2012 from Russia are divided between the four providers – Kazan'orgsintez (39 %), TNHZ (34 %), Polimir (15 %) and Sumgait (12 %) (Borisova 2013).

The Central Asian producers formed separate group, who, due to very cheap resources, can dumping on the market, but only low quality of the product has not allowed fully capture Ukrainian markets. The South Korean manufacturers represent a wide range of quality products at high prices.

The manufacturers from Eastern Europe such as concerns TVK, Basell, Slovnaft and Chemopetrol created a powerful production, which provide a fairly wide choise and excellent quality products. These producers are export-oriented, because the level of consumption in the countries, where they are located, is very low compared to production quantity.The Western Europe enterprises formed other separate subgroup. For the most part they have very powerful manufacturer; working on the latest production technologies polymers, provide a complete product range and high quality of products. In the structure of their polymers the latest high-tech brands were dominated. These productions by narrow specialization and the higher rating customer satisfaction were characterized. European imports were represented by special marks, copolymer with BA, MA and compounds (Borealis, Exxon, DOW).

The native manufacters of of the primary polymers could significantly work on the country territory, but because of suboptimal commodity structure of production has led to the forced export that exists as a result of the overproduction for separate group consumer goods. Overall, more than 40 % of exports creates low-pressure polyethylene of one brand (HXF 4810), which is produced in Kalush of Ivano-Frankivsk region, in the company that owns the group “Lukoil”. In fact, exports cover more than 99 % of the company products. This situation has arisen because the company is working on imported raw materials and does not want to pay the tax on added value for the sale of goods on the domestic market. However, it should be noted that about 40.0 tons per year of products of this company re-exported by non-residents on the territory of Ukraine. Moreover, the consumption of this product is increasing at the expense of its quality and price competitor’s advantages.

The major Ukrainian companies – plastic processors are Hartsyzsk Pipe Plant, OAO “Ukrplastik” and next companies “Hekro-Trade”, “Sirius Extrusion” and “Eurotrubplast” using up to 80% of imported granulated polyethylene.

Large amounts of polyethylene (115.6 thousand tons) traders are buying for the purpose of separating large parties and resale to domestic consumer. Share stuff that eventually goes to the production of flexible packaging is 33.2 thousand tons. Generally, Ukraine uses about 61.6 thousand tons of polyethylene for the manufacture of flexible packaging.

Constantly changing proportion of imports by type of product – most require in past years was low pressure polyethylene (LPPE or HDPE), high pressure polyethylene (HPPE or LDPE) and linear polyethylene (LLDPE or LPE), which are gradually being replaced by other types (fig 2). However, this tendency to change the type concerns over of producers “massive” polyethylene production rather than manufacturers of flexible packaging, where growth among manufacturers of products from HDPE – by 7%, LDPE – 15 %, LPE – 45% is observed.

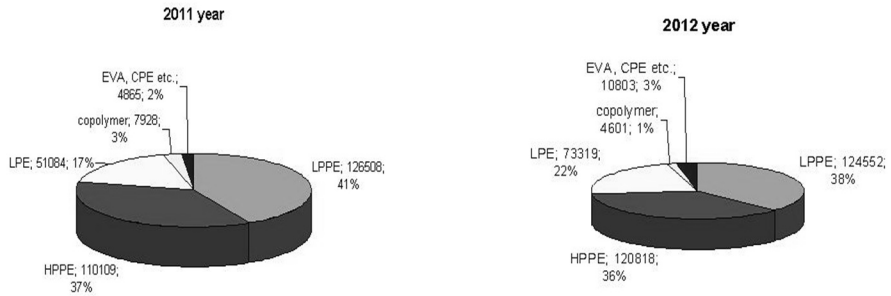

Figure 2. Polyethylene imports by type of product

Source: own research

The substantial reorientations of consumers of polyethylene products, which are used as packaging, are observed. If in 2011, the main consumers of flexible polyethylene packaging was light (легка промисловість) and food industry (including manufacturers of agricultural products), then to 2012-2013 leaders were engineering and construction industry, which increased the number of packing materials. Consumption of polyethylene products is ongoing, but throughout the year there are seasonal consumptional fluctuations observed throughout the year, which have arisen due to seasonality of production in some sectors of the national economy. In addition, the consumer requires new types of flexible polymer packaging, which would differ not only by lower cost and higher mechanical properties, but also had properties that are necessary for storage and transportation products and goods, also after expluitation haven't any problems for utilization. Using different types of fillers, applications, ingredients can solve these problems and opens up prospects for new polymer products with a wide range of densities (such as bimodal line polyethylene LLDPE Borstar ™), the decomposed film with different additions, modifiers (UV-stabilizers, antimicrobial, lights modifiers), fillers (chalk, black carbon or aluminum powder), recycled materials, inhibitors of various processes occurring on the surface of the packing product etc (Kobzev 2009, Gen'kin 2009, Moroz 2011).

Necessity of carrying out of researches

The structural, spectroscopic, thermogravimetric, polarographic studies and differential thermal analysis of the polymers are neseccery for ensure high performance on quality polyethylene films for packaging. The molecular structure of the polymer matrix and its properties are defined more precisely according to results of these investigations. However, the use of modifiers, inhibitors, plasticizers and fillers differently affects the consumer properties of protective polyethylene films, that why can lead to a decreasing in terms of

protection or to lossing of safety properties. This requires additional studies that should be performed in a short time. Such investigations are carried out in three directions (Domatsevich 2003, Domantsevich 2000):

- the study of changes in the surface during excited environment action;
- aging in closed warehouses and open areas;
- the accelerated researches in artificial weather camera.

It should provide for the holding of periodic control structure and physico- chemical properties of the films. One can detect at the early stage of research trends in the changes of material properties, using such modern methods for studying surface morphology, and foresee the conditions and terms of pakaging materials using.

Conclusions

The packaging industry of Ukraine is characterised by the big dependence on import. Manufacturers of polymeric raw materials because of not optimum commodity structure and tax oversights pursue a policy of the compelled export and have essential influence on formations of balance of the market.

The heterogeneity of a raw-material base and versatile suppliers has led to requirement of use additional physical-chemical researches.

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