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Intelligent food packaging: Concepts and innovations

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Abstract : Intelligent packaging systems are constantly changing to meet the growing challenges of themodern society. This article discusses the following issues: different currently available categories of intelligent packaging concepts, latest packaging research trends and innovations, and the growth perspectives of the intelligent packaging market. Intelligent packaging systems which monitor the condition of the packed food or its environment are in progress towards becoming more cost-effective, convenient and integrated in order to deliver innovative packaging solutions. Furthermore,the intelligent packaging market is promising with strong achievements for time–temperature indicator labels and progresses in intelligent concepts integration into packaging materials.
Keywords: Packaging;Intelligent; Shelf lif.

Introduction

Food packaging technology is constantly changing to meet the growing challenges of themodern society. Legislation, global markets, longer shelf-life, ease of consumption, safer and healthier food, environmental concerns, and food waste are the main current and future challenges of fast packaging of consumed goods[1].Food waste in Europe is estimated about 89 million tons[2]. For example, the corruption of raw meat in the food supply chain (manufacturers, retailers, consumers) is about 40%[3].Packaging optimization strategies such as different pack sizes which help the consumers purchase the right amount and various packaging designs which aim to preserve the quality of food and increase its shelf life have been suggested in order to reduce food waste[2].

Food safety is a global priority and is currently one of the main goals of food law. Furthermore, the growing consumers' demandsfor more natural, fresh and suitable food, and constant changes at industrial, retail and distribution levels related to globalization are creating major challenges for food safety and quality. This is a unique opportunity for the packaging industry to provide innovative solutions in order to handle the changing demands of the food industry and consumers[4].

Intelligent packaging is a good example of an innovation which provides information for the processor, retailer or consumer on the food or its surrounding environment for more consumer safety, while maintaining the quality of the packed food, beyond the traditional functions of packaging[1].

While protecting a product from contamination and damages, a packaging must at the same time[5]:

- increase product shelf life
- facilitate the distribution and presentation of a product (changes in the distribution, such as the globalization of the market)

- provide consumers with ease of consumption and time-saving.
- build a consumer relationship as a promotional tool
- lead to costs efficiency
- have the least environmental problems
- guarantee consumer health and safety

Concepts of Intelligent Packaging of Food:

Intelligent packaging is designed to monitor the condition of packed food or its surrounding environment[6]. An intelligent packaging system is able to detect, measure, record, track or exchange information on the quality or state of the product throughout the entire food chain[7]. In addition to providing product information (origin, expiration date, ingredients), packaging also provides information about the history of the product (storage conditions, headspace composition, microbial growth, etc.).Therefore, intelligent packaging represents a major step forward to avoid wasting food and food traceability. Intelligent performance can be achieved by the use of detectors, sensors or devices which are able to exchange information on the packaging system. Indicators inform the changes in the product or its environment (e.g. temperature and pH) using visual changes. Indicators used in the packaging of meat are time temperature indicators, oxygen and integrity indicators and freshness indicators. Biosensors are devices that are able to detect, record and transmit data on the biological reactions that occur in the packaging with high precision [7].

Indicators

Temperature is one of the most important environmental factors determining food preservation, because changes in temperature during foods storage may affect the safety and shelf life of perishable products.TTls are effective tools that are designed for constant monitoring of the time and temperature of chilled and frozen products across the food chain[8]. TTIs visually show the time passed from packaging and the process which is accelerated by temperature increase[9]. These indicators make constant monitoring on storage conditions (product storage) possible. Thus, they can report any breaks in the cold chain and the information can be used as indirect indicators of the product shelf life. Available TTIs indicators in the market are based on physical, chemical, or biological enzymatic processes[1].

3 M Monitor Mark®[10]device is a TTI dependent on the diffusion of fatty acid ester through a porous wick (filaments) made of a paper blotting with high quality. Measurable response is the distance diffusion of the substance from the point source. The useful range of temperature and the response life of the TTI are determined by the type and concentration of the ester. Another TTI sort from the same company is Fresh-Check® which is based on diffusion. This system uses a viscoelastic material that migrates into a diffusively light-reflective porous matrix at a temperature dependent manner which changes the porous matrix light and results in a visual response[10,1,11].

Lifelines Freshness Monitor® and Fresh-Check (Lifelines technology, USA) TTLs are based on temperature dependence polymerization reactions in which diacetylene crystals are polymerized into highly coloured polymers via 1,4 addition polymerization. The changes in reflectancecan be measured through scanning with a laser pen. In Fresh-Check indicator circular label that is used to make decisions about consumption in those circumstances, the color of the inner circle and outer circle color compared[1,12].

VITSAB®[13] is based on the color change caused by PH reduction due to a controlled enzymatic hydrolysis of lipid substrate. The indicator is made of two distinct compartments, one containing an aqueous solution of lipolytic enzymes and the other mainly containing triglycerides and a pH indicator. The TTI activation is through a wall break between the two compartments and might be carried out manually or through in-line automation. The substrate hydrolysis reduces pH and results in color change (from dark green to bright yellow) on the pH screen[9,13]. CheckPoint® labels are the latest labels designed by VITSB® in order to provide a better response for consumers and offer direct application to poultry and ground beef products. OnVu™ is a new TTI jointly developed by Ciba and Freshpoint™ which is designed based on a photochemical reaction.OnVu™ indicators contain a pigment called benzopyridines that changes color over time at temperature dependant rates. It is activated by exposure to UV light to turn into dark blue and the color disappears over time. This system can be used as a label or directly printed onto the package[14,15].

Another approach of microbiological TTIs application like the one developed by TRACEO has been developed. TopCryo™ is a time–temperature indicator system based on Carnobacterium maltaromaticum and a color change indicator, and acid fuchsin. Microorganism, indicator and a nutritious medium gel are placed in a multilayer plastic bag glued on the outer layer of the food package.[16,17]

Eventually, we find TTIs like FreshCode™ (Varcode Ltd.) and Tempix® (Tempix AB) labels based on barcodes printed with inks which disappear because of the change of temperature.[18,19]

Integrity Indicators

Integrity indicators are the simplest indicators of the integrity of the packaging which provide information about how long a product has been opened. This tag is activated at the time of consumption, when the seal is opened; a timer is activated and the color changes over time. Some commercial examples are ®Timestrip (Timestrip Ltd.), Novas® embedded labels (Insignia Technologies Ltd.) and ™ Best-by (FreshPoint lab) or bulk.[20,21,22]

Gas indicators are the mostly used integrity indicators for meat packaging. They act as leak indicators and provide information on the integrity of packaging throughout the supply chain.Among the various types of gas indicators, oxygen indicators are the most common ones used for MAP packaging[7]. Except MAP packaging which contains high levels of oxygen for fresh meat (to improve color), most of the foods are packaged with lower oxygen levels (0-2%). In these cases, leaks considerably increase the oxygen concentration. Dye based colourimetric redox indicators are the most common O_2 indicators consisting of a redox dye like methylene blue, and a strong reducing agent like glucose in an alkaline medium[23]. Reversibility is a disadvantage of these indicators. If the concentration of oxygen is reduced, it will return to its original form. The entering oxygen might be consumed due to microbial growth[24]. The primary use of these indicators is in combination with O_2 containment systems[11]. The combination will prevent the O_2 indicatorfrom reacting with the residual O_2 in the packaging. Ageless Eye® tablets (Mitsubishi Gas Chemical Co.) are reversible oxygen indicators used in combination with AGELESS O_2 absorbers. The color of the tablets turns to pink at $O_2 \leq 0.1\%$, and to blue at $O_2 \geq 0.5\%$ based on the temperature[25,26]. More recently, EMCO packaging has developed irreversible oxygen indicator labels[27].FreshPoint Lab has provided O_2Sense™ as a luminescence O_2 indicator label for detecting leakages in MAP packages[28].

Freshness Indicators and Sensors

Freshness indicators monitor the quality of the packed food through reacting to the changes caused by microbial growth or metabolism. Thus, they provide direct information about product quality[29]. Changes in the concentration of metabolites like glucose, carbon dioxide, organic acids (e.g. L-lactic acid), ethanol, nitrogen compounds, biogenic amines, volatile sulfuric compounds during storageshow the microbial growth which makes it possible to use them as indicators of freshness for meat products[30]. Intelligent packaging systems which are considered as freshness indicators for monitoring food freshness act based on indirect identification of metabolites through color markers (for example, pH) or based on direct detection of target metabolites using biosensors. Although several developments have been presented by packaging companies, in many cases, successful commercialization has not been achieved yet.

In 1999, COX Technologies (Plainfield, IL) offered Fresh Tag®-a colorimetric indicator- which provides information on volatile amines in fish products, but its production was stopped in 2004[31]. In 2007, DSM[32] NV developed SensorQ™ in cooperation with Food Quality Sensor International Co. which is a pH-sensing technology based on anthocyanins with ability to give information on microbiological originated biogenic amines in meat and poultry packaging[32,33] .VTT Technical Research Centre of Finland in collaboration with UPM Raflatac presented a freshness indicator for meat and poultry on the basis of a nano-silver layer reacting with hydrogen sulfide (a decomposition product of cysteine). The color of this indicator is opaque light brown at the time of packaging, but when the silver sulfide is formed, itbecomes transparent[29,34]. However, SensorQ™ and Raflatac indicators were not commercially available until the publication time of this article.Biosensors are intelligent systems which are able to detect target metabolites included in food packaging. They are capable of monitoring food freshness more precisely than freshness indicators. They are also able to detect the formation of bad products and can be designed according to the type of packaged product.Biosensor is a compact analytical tool capable of detecting, recording and transmitting information about biochemical reactions. This smart device has two primary components: a bioreceptor which detects the target and a biochemical signal converter which converts biochemical signals into a measurable electrical response. Bioreceptor is an organic or biological material such as an enzyme, antigen, bacteria, hormones or nucleic acid. Transformers are available in various forms (such as electrochemical, optical, and voice) based on measurable parameters[35].

There are currently two commercially available biosensor systems: ToxinGuard ™ developed by Toxin Alert (Canada) a visual detection system that combines antibodies in plastic packaging based on polyethylene composition and is able to detect Salmonella, Campylobacter E.coli 0517 and Listeria species. Food Sentinel System™ (SIRA Technologies, California, United States) is a biosensor system with the ability of constant detection of infection by immunological reactions occurred in part of a barcode. The barcode is unreadable in the presence of contaminant bacteria[1].

Thermochromic Inks

Thermochromic ink is a special dynamic ink that changes with exposure to different temperatures. Ink color change is either irreversible or reversible. Thermochromic Ink is irreversible and invisible, until exposed to high temperature which develops into an intense color when exposed to a certain temperature. This color progress will remain constant or the color change will stay permanent when there is a temperature change. Reversible thermochromic inks change color if heated and return to original state with temperature reduction[36]. Cold-activated thermochromic ink is used on the packaging labels to create a color change when cooled. Touch-activated thermochromic ink reveals an image or another color printed beneath once rubbed or touched. Touch activated liquid crystal ink- when rubbed or touched- changes color within the visible spectrum. High temperature thermochromic ink changes color just below the pain threshold alerting consumers about a safety hazard.

RFID:

Radio Frequency Identification Tag, in fact, is a wireless identification system that is capable of transferring stored data in the tag section to a reader using electronic and electromagnetic signals[37].

Generally, there are three types of tags including passive, semi-active and active.Passive tags have no internal power source and obtain their energy from the antenna and through the signals received from the reader. In semi-active tags, a small battery is embedded to provide energy. Active tags have an internal power source and the ability to transmit information over long distances[38].

Stored Information by this type of label includes product code, production, storage and maintenance place, consumption history, ingredients and transportation. Therefore, Radio Frequency Identification tag has a variety of applications in identifying, tracking and expediting the product.The main advantages of RFID over barcodes are that they enable a remote control, can be monitored simultaneously on several cases, and have the capacity to store various information (origin, processing parameters, business information etc.) and allows unique identification of product-formation[11].These tags have many advantages such as the ability to read many tags simultaneously, high capacity to track and store information and the ability to be re-read. And the disadvantages of RFID are high cost, the possibility of interference in two ways, tags interference (when several tags placed in a small container.), readers interference (interference in signals from multiple reader devices), and increase in the possibility of stealing if the tag is activated after purchase.

In recent years, significant progresses have been made in the field of RFID technology allowing the use of RFID in the food supply chain[39]. RFID tags have had the potential benefits in meat production, distribution and improving traceability in retail chains, inventory management and automation facilitation[40].There are some RFID suppliers such as EPISILIA (Canada), RFID Enabled solutions Inc. (America) and HRAFN Inc. (Sweden) which have been working with meat and fish industries on the implementation of RFID systems[41,42,43]. More developed RFID systems have provided the merging and acquisition of other applications such as time-temperature indicators or biosensors, monitoring and notification of the temperature history of the product and the quality of information in RFID tags[39]. There have been more progresses in the application of RFID, merging TT sensor into RFID device. TT sensor tags are installed on the surface of boxes or pallets which makes temperature tracking possible during the transportation of food in the food chain. The combination of RFID and sensor technology used in cold chainimproves the effectiveness of supply chain management and increases savings due to less produced waste. Some reusable examples of TT sensor labels such as Easy2Log "© (CAEN

RFID Srl), CS8304 sensor tag (Convergent Systems) and TempTRIP label sensor (TempTRIP LLC) are designed to provide a temperature history of the product throughout the cold chain processes[44,45]. Some packaging companies use RFID systems in their food boxes. Mondi Plc. has provided its intelligent box, an RFID-activated corrugated case, equipped with an RFID tag at case-level, enabling it to be tracked throughout the supply chain[46]. Finally, smart radio-frequency labels with sensors capable of measuring temperature, humidity and the presence of volatile amine compounds,were used to estimate cod fish freshness[47]. In line with the new European Union's rule which requires fish labeling to ensure complete traceability of fish, the Craemer Group Company has designed a smart fish box.Patent pending intelligent fish box possess a RFID transponder, (transmitter) providing the capability to identify, track and trace information on fish, fishing grounds and the quality and size of the fish taken[48].

Intelligent Packaging Systems Perspective

The global market for advanced systems which includes active packaging, controlled, intelligent, and other advanced-packaging parts was about $31.4 billion in 2011 and $33.3 billion in 2012 (Fig.1). The market growth was promising and the overall market value is estimated to be about $44.3 billion in 2017, following 5.8% increase at compound annual growth rate (CAGR)[49]. In 2011, the market was dominated by controlled packaging. Active packaging stood in the second place in the market with almost $ 8.8 billion in sales; it is expected to rise to $ 11.9 billion in 2017. Smart packaging sales was about $ 3.8 billion in 2011 and could reach $ 5.3 billion in 2017[50].

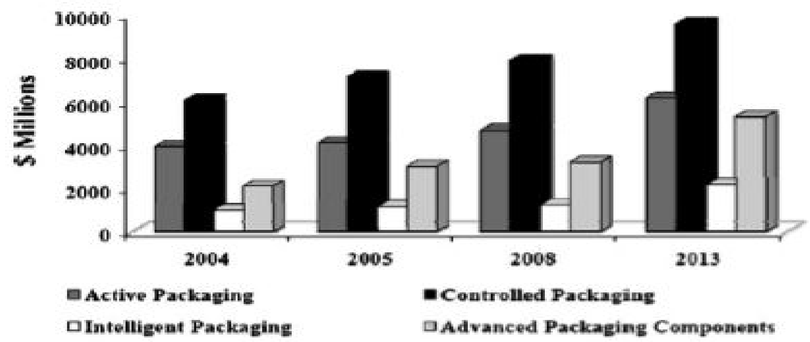

Fig. 1. Growth of active, controlled, and intelligent packaging for the food and beverage industry 2004–2013 ($ millions).

It is expected that ongoing advances in biotechnology, analytical chemistry, microelectronics and materials science develop new solutions to help smart packaging. However, the price and the integration of the smart concepts are still the main limitations to packaging materials. Biosensors integration with RFID system to inform and provide real-time information about the status of the product is a high potential for intelligent packaging which results in improved safety, quality and inventory management and reduction in the waste.Enhancements are necessary to reduce costs for better integration of intelligent systems in packaging materials. Published and used advances help to integrate the intelligent systems with the material packaging in electronics to create a wide range of electrical devices on various platforms by providing layers of conductive ink. Progresses in ink technology such as grapheme ink application with a unique mixture of properties like mechanical flexibility, high electrical conductivity and chemical stability, make it ideal for the next generation of electronics[51].

References

1. Kerry, J.P., M.N. O'Grady and S.A. Hogan. (2006). *Past, current and potential utilisation of active and intelligent packaging systems for meat and muscle-based products: A review*. Meat Science. *74*:113-130.
2. European Commission (2012a). Regulation (EU) No 528/2012 of the European Parliament and of the Council of 22 May 2012 concerning the making available on the market and use of biocidal products. Official Journal of the European Union, L 167, 1–123.

3. Sperber, W. H. (2010). *Introduction to the microbial spoilage of foods and beverages*. In W. H. Sperber, & M. P. Doyle (Eds.), Compendium of the microbial spoilage of foods and beverages (pp. 1–40). N.Y.: Springer
4. Han, J. H. (2014). *A review of food packaging technologies and innovations*. In J. H. Han (Ed.), Innovations in food packaging (pp. 3–12). San Diego, USA: Academic Press.
5. Mike Vanderroosta,*,Peter Ragaerta,b,c, Frank Devliegherea,c andBruno De Meulenaerb,c , *Intelligent food packaging: The next generation* , Trends in Food Science & Technology 39 (2014) 47e62 .
6. European Commission (2009). Commission Regulation (EC) No 450/2009 of 29 May 2009 on active and intelligent materials and articles intended to come into contact with food. Official Journal of the European Union, L 135, 1–11.
7. Yam, K. L., Takhistov, P. T., & Miltz, J. (2005*). Intelligent packaging : Concepts and applications*.Journal of Food Science, *70*(1), R1–R10.
8. Lee, S. J., & Rahman, A. T. M. M. (2014). *Intelligent packaging for food products*. In J. H. Han (Ed.), Innovations in food packaging (pp. 171–209) (2nd ed.). San Diego, USA:Academic Press.
9. Galagan, Y., & Su,W. F. (2008). *Fadable ink for time–temperature control of food freshness*:*Novel new time–temperature indicator*. Food Research International, *41*(6), 653–657.
10. 3M (2014). 3 M™ MonitorMark™ time temperature indicators. http://solutions.3m.com/wps /portal/3M/en_US /Microbiology/ FoodSafety/ product- information/ productcatalog/ ?PC_Z7_RJH9U523003DC523023S523007P523092O523003O87000000_nid =NFNLL87000005PG 87000088beX87000002 JZNTZSLTgl (Last accessed: 02/03/2014).
11. Kuswandi, B., Wicaksono, Y., Abdullah, A., Jayus, Heng, L. Y., & Ahmad, M. (2011). *Smart packaging: sensors for monitoring of food quality and safety*. Sensing and Instrumentation for Food Quality and Safety, *5*, 137–146.
12. Temptime Corp. (2014). Reading Fresh-Check® time temperature indicators. http://www.fresh-check.com/reading.asp (Last accessed: 02/03/2014)
13. VITSAB (2013). Seafood TTI labels. http://vitsab.com/?page_id=1983 (Last accessed 02/03/2014)
14. Freshpoint (2011c). Time temperature indicator consumer brand. http://www.freshpoint-tti.com/links/default.aspx (Last accessed: 02/03/2014
15. O'Grady, M. N., & Kerry, J. P. (2008). Smart packaging technologies and their application in conventional meat packaging systems. In F. Toldrá (Ed.), Meat Biotechnology (pp. 425–451). New York, USA: Springer Science and Business Media.
16. EFSA (2013*). Scientific opinion on the safety evaluation of a time–temperature indicator system, based on Carnobacterium maltaromaticum and acid fuchsin for use in food contact materials*. EFSA Journal, *11*(7), 3307.
17. raceo (2014). Applications. http://www.traceo.com/en/food/food industry/applications.html (Last accessed: 02/03/2014)
18. Varcode (2014). FreshCode™label. http://www.varcode.com/?CategoryID=158&ArticleID=178 (Last accessed: 02/03/2014)
19. Tempix (2014). *The Tempix temperature indicator*. http://tempix.com/ (Last accessed:02/03/2014)
20. Freshpoint (2011a). BestBy. http://www.freshpoint-tti.com/product/BestBy.aspx (Last accessed: 15/03/2014)
21. Insignia Technologies (2014). Novas: Embedded label. http://insignia.mtcserver11.com/ portfolio-view/novas-embedded-label/ (Last accessed 15/03/2014)
22. Timestrip (2012). Timestrip® cold chain products for food. http://www.timestrip.com/coldchain_food.php (Last accessed: 15/03/2014)
23. Mills, A. (2005). *Oxygen indicators and intelligent inks for packaging food*. Chemical Society Reviews, 34, 1003–1011.
24. Hurme, E. (2003). *Detecting leaks in modified atmosphere packgaging*. In R. Ahvenainen (Ed.), Novel food packaging techniques (pp. 276–286). Cambridge, UK: Woodhead Publishing Ltd.
25. Mitsubishi Gas Chemical (2014). AGELESS EYE oxygen indicator. http://www.mgc.co.jp/ eng/products/abc/ageless/eye.html (Last accessed: 15/03/2014)
26. Sorbent Systems (2014). *Oxygen indicators tablets (Tell-Tab*). http://www. sorbentsystems.com/tell-tab.html (Last accessed: 15/03/2014)
27. Emco Packaging (2013). *Oxygen indicator labels*. http://www.emcopackaging.com/index. php/products/oxygen-indicator-labels (Last accessed: 15/03/2014)

28. Freshpoint (2011b).Oxygen sensors technology. http://www.freshpoint-tti.com/technology/default.aspx (Last accessed: 15/03/2014)
29. Smolander, M. (2008). *Freshness indicators for food packaging*. In J. F. Kerry, & F. Butler (Eds.), Smart packaging technologies for fast moving consumer goods (pp. 111–128).West Sussex, England: John Wiley and Sons Ltd.
30. Arvanitoyannis, I. S., & Stratakos, A. C. (2012). *Application of modified atmosphere packaging and active/smart technologies to red meat and poultry: A review*. Food and Bioprocess Technology, *5*(5), 1423–1446
31. Kerry, J. P. (2014). *New packaging technologies, materials and formats for fast-moving consumer products*. In J. H. Han (Ed.), Innovations in food packaging (pp. 549–584)(2nd ed.). San Diego, USA: Academic Press.
32. DSM (2007). DSM invests in food freshness device company. https://www.dsm.com/ corporate/media/informationcenter-news/2007/2008/2051-2007-DSM-invests-infood- freshness-device-company.html (Last accessed: 07/03/2014)
33. -Williams, J., Myers, K., Owens, M., & Bonne, M. (2006). Food quality indicator. In: Google Patents
34. UPM (2007). *UPM Shelf Life Guard keeping an eye on packaged foods*. http://www.upm.com/EN/MEDIA/All-news/Pages/UPM-Shelf-Life-Guard-Keeping-an-Eye-on-Packaged-Foods-001-to-010-helmi-2011-2019-2014.aspx (Last accessed: 07/03/2014)
35. Mohan, C.O., C.N. Ravishankar, T.K. Srinivasa Gopal and K. Ashok Kumar. 2009. *Nucleotide breakdown products of seer fish (Scomberomorus commerson) steaks stored in O2 scavenger packs during chilled storage*. Innovative Food Science and Emerging Technologies. 10: 272–278.
36. Sarley,A.(2011). Implications of thermochromic ink.Graphic Communication Department; California Polytechnic State University.
37. Lopez-Rubio, Amparo., Lagaron, Jose Maria and Jose Ocio, Maria., Active polymer packaging of Non-Meat food products. In: Smart packaging technologies for fast moving consumer goods. Kerry, Joseph and butler, Paul (eds)., John Wiley & Sons Ltd. 2008.
38. Otles, Semih., Yalcin, Buket., “Smart food packaging”, Journal of LogForum. Vol. 4, issue. 3, NO. 4, 2008.
39. Guillory, M., & Standhardt, G. (2012). NVC world review on supply chai applications ofRFID and sensors in packaging. http://www.nvc.nl/nl/pasteur-sensor-enabled-rfid/files_content/NVC%20World%20Review%20on%20Supply%20Chain%20Applications%20of%20RFID%20and%20Sensors%20in%20Packaging.pdf (Last accessed: 27/02/2014)
40. Mousavi, A., Sarhadi, M., Lenk, A., & Fawcett, S. (2002). Tracking and traceability in themeat processing industry. British Food Journal, 104(1), 7–19.
41. Swedberg, C. (2011). Norwegian group tracks super-chilled meat. RFID Journal (http://www.rfidjournal.com/articles/view?9022, Last accessed: 06/03/2014).
42. Swedberg, C. (2012). Bereket Doner Tracks Its Meat Products Via RFID. RFID Journal(http://www.rfidjournal.com/articles/view?10246, Last accessed: 06/03/12014).
43. Wasserman, E. (2010). Canadian beef processor deploys RFID for food safety. RFID Journal(https://www.rfidjournal.com/purchase-access?type=Article&id=7331&r=%7332Farticles%7332Fview%7333F7331%7332F7206/7303/2014, Last accessed: 06/03/2014).
44. CAEN RFID (2014). CAEN RFID easy2log© RT0005. http://www.caenrfid.it/en/CaenProd. jsp?mypage=3&parent=65&idmod=780 (Last accessed: 14/02/2014)
45. CSL (2013). CS8304 cold chain temperature logging tag. http://www.convergence.com.hk/products/rfid/rfid-tags/cs8304/ (Last accessed: 11/02/2014)
46. Mondi (2014). Intelligent box. http://www.mondigroup.com/products/desktopdefault. aspx/tabid-1784/ (Last accessed: 12/02/2014)
47. Smits, E., Schram, J., Nagelkerke, M., Kusters, R., Heck, G. v, Acht, V. v, Koetse, M., Brand, J.v. d, Gelinck, G., & Schoo, H. (2012). Development of printed RFID sensor tags for smart food packaging. 14th International Meeting on Chemical Sensors (pp. 403–406) (Nuremberg, Germany).
48. Craemer (2014). New RFID supported fish box enables seamless tracking & tracing.http://www.craemer.com/en/service-portal/news/detail/article/craemer-grouppresents-product-innovation-for-the-fishing-industry/. Last accessed: 12/02/2014.
49. BCC Research (2013 Aprila). The advanced packaging solutions market value for 2017 is projected to be nearly $44.3 billion. http://www.bccresearch.com/pressroom/fod/ advanced-packaging-solutions-market-value-projected-nearly-$44.43-billion-2017(Last accessed: 01/03/2014)

50. BCC Research (2013, Mayb). *Active, controlled, and intelligent packaging for foods andBeverages.*http://www.bccresearch.com/market-research/food-and-beverage/foodbeverage-packaging-fod038c.html (Last accessed: 01/03/2014)
51. AIPIA (2013c). Improved graphene inks for inkjet application. http://www.aipworldcongress.org/news_218_improved-graphene-inks-for-inkjet-application.php (Last accessed: 04/02/2014)

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