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REVIEW ARTICLE

Advances in food packaging technology-A review

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ABSTRACT

Food packaging industry involve a number of actors which include producers, retailers, consumers and researchers. Each of the actors in the cycle has a legitimate priority to protect. The primary aim of all the players is to protect the food from degradation by environmental and human factors and also ensure delivery of food items to ultimate consumers in safe and sound condition. In addition to protection, food package also serves as means of communication between producer and consumer by carrying vital information about the content specification, producer's information, product handling tips and storage requirements. It requires that during containment the package should behave inert and prevent chemical migration between the package and the food. The materials that are commonly used in food packaging are glass, metals papers and plastics. Numerous laminates and coatings with different physical, chemical and barrier properties were developed from these traditional packaging materials. This paper reviews recent innovations in food packaging technology with emphases on principles and applications of active and intelligent packaging, nanotechnology, antimicrobial packaging, edible coatings and films and sustainable packaging.

Keywords: Advances, food, nanotechnology, packaging, sustainable

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INTRODUCTION

Packaging surrounds and protects food after manufacturing, defend its integrity through transportation, handling, storage and retailing, and ensure its wholesomeness during consumption. Packaging maintains the benefits of food processing after the process is complete, enabling foods to travel safely from point of origin to the point of consumption (Prasad and Kochhar, 2014). Food packaging has evolved from simply a container to hold food to something today that can play an active role in food quality. Many packages are still simply containers, but they have properties that have been developed to protect the food (Risch, 2009). Packaging today plays an important role in the quality of food products by providing protection from environmental, chemical, and physical challenges. This protection can be as simple as preventing breakage of the product to providing barriers to moisture, oxygen, carbon dioxide, and other gases as well as flavors and aromas. Packaging can block light to protect nutrients and colors in a product from deteriorating. In addition to providing passive protection, many packages today play an active role in the quality of a product by helping to maintain a desired atmosphere around the product (Risch, 2009; Pawar and Aachal, 2013). New trends in food packaging industry aimed at reducing food waste by improved preservation of food through prolonging it shelf-life (Tanja et al., 2016).

Changes in consumer preferences have led to innovations and developments in new packaging technologies (Dobrucka et al., 2015). Demand for quality food has driven packaging innovation (Risch, 2009), demand for convenience foods will also continue to be fueled by the aging of our population, the diminished cooking skills of the typical consumer and the reduced

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time available for home preparation of meals (Eilert, 2005). Increase in incomes in traditionally less economically developed countries has led to a rise in standards of living that includes a significantly higher consumption of packaged foods (Nitaigour, 2014). These developments led to improvement in food processing and packaging technologies.

Packaging has allowed us to have a wide variety of food year round that would not be possible without the protection of the package. Foods now have a longer shelf life, resulting in less loss due to spoilage. Packaging also provides for convenience with products that can be heated in the package and products that can be purchased as single-serve items (Dobrucka and Cierpiszewski, 2014). The dynamic nature of food packaging technology will be a continuous process with development of new packaging materials to reflect development in food technology, material and environmental sciences and consumers' preference (Dele, 2012; Dari et al., 2018)

In recent years packaging has developed well beyond its original function as merely a means of product protectio and now plays a key marketing role in developing on shelf appeal, providing product information, and establishing brand image and awareness (Kour et al*.,* 2013). Modified atmosphere, control atmosphere and intelligent packaging can extend shelf life and smart packaging can communicate quality indices of it is content (Marina et al., 2015). These development is a response to increase in consumer's demand on mildly preserved, fresh, testy and convenient food products with prolonged shelf-life and controlled quality (Dobrucka et al*.,* 2015). Packaging of the future is likely to be more than just a physical container that provides food with protection from the surrounding environment (Cushen et al*.,* 2012).

ACTIVE AND INTELLIGENT/SMART PACKAGING

Changes in life style with little time for household preparation of foods revolutionised food packaging industry with invention of active and intelligent packaging which involve intentional interaction with the food or it is surrounding. Innovation of active and intelligent packaging, also known as novel packaging, resulted from consumers desire's to convenient, ready to eat and minimally processed food products (Ishrat et al*.*, 2016). Active and intelligent packaging materials and articles were firstly introduced in the market of Japan in the mid 70s, but only in the mid 90s they raised the attention of the industry in Europe and in the USA (Dainelli et al*.,* 2008). 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 (Dobrucka and Cierpiszewski, 2014). Developing smart packaging to optimize product shelf life using nanotechnologies has been the goal of many companies. Such packaging systems would be able to repair small holes/tears, respond to environmental conditions such as temperature and moisture changes and alert the customer if the food is contaminated (Alfadul and lneshwy, 2010). Unlike traditional packaging, which must be totally inert, active packaging is designed to interact with the contents and/or the surrounding environment (Prasad and Kochhar, 2014). The packaging material interacts with the food to confer longer shelf-life, also improve hygiene safety and organoleptic properties, minimise food losses and increase regularity of the food (Nitaigour, 2014; Dobrucka et al*.,* 2015; Amra et al*.,* 2015).

Active packaging is a packaging system that changes the condition of the packaging and maintains these conditions throughout the storage period to extend shelf-life or to improve safety or sensory properties while maintaining the quality of packaged food (Ozdemir and Floros, 2004; Dainelli et al*.,* 2008). Intelligent packaging, sometimes referred as smart packaging, senses some properties of the food it encloses or the environment in which it is kept and informs the manufacturer, retailer and consumer of the state of these properties and conditions during transport and storage (Ravishankar, 2016). Active packaging materials are designed to actively maintain or improve the condition of the food either by eliminating unwanted components from the package headspace and/or from the food itself or by releasing active components into the food or its surroundings (Kour et al*.* 2013).

The advancement in novel food packaging technologies involves retardation in oxidation, hindered respiratory process, prevention of microbial attack, prevention of moisture infusion, use of CO_2 scavengers/emitters, ethylene scavengers, aroma emitters, time-temperature sensors, ripeness indicators, biosensors and sustained release of antioxidants during storage (Ishrat et al*.*, 2016). Intelligent packaging devices include sensors, time-temperature indicators, gas sensing dyes, microbial growth indicators, physical shock indicators, freshness indicators etc. (Dobrucka et al*.,* 2015), self-heating or self-cooling containers integrated with electronic displays indicating important information on nutritional qualities and expiry dates (Sani and Abdulaziz, 2013). Also includes some microwave packaging as well as packaging that has absorbers built in to remove oxygen from the atmosphere surrounding the product or to provide antimicrobials to the surface of the food (Risch, 2009). The action of indicators used in smart packaging should be able perceive and understand without the use of any external apparatus (Mills, 2005).

NANO TECHNOLOGY IN FOOD PACKAGING

Nanotechnologies involve the manipulation of matter at a very small scale e generally between 1 and 100 nanometres. Many large international food companies are exploring the potential of nanotechnologies for applications in the food sector. Recent research has highlighted the potential for nanotechnologies' use in wide ranging food applications, including novel food packaging (Cushen et al*.,* 2012). Application of nono-science and technology in food packaging is predicted to be increasing in the next two decades (Peelman et al*.*, 2013). Potential benefits were reported particularly in food-package interaction and monitoring of quality and freshness (Amal, 2015).

Nanosensor are extremely small device than can bind to whatever is wanted to be detected and send back a signal. These tiny sensors are capable of detecting and responding to physicochemical (sensors) and biological signal (biosensors), transferring that response into a signal or output that can be used by humans. Various nanosensors were developed for detection of internal and external conditions in food packaging (Omanović-Mikličanin and Maksimović, 2016). Nanosensors can be used to determine microbes, contaminants, pollutants, and ultimately the freshness of the food (Joyner and Kumar, 2015). Nanoparticles can reduce the amount of material used and improve packaging function. It can also increase tensile strength up to forty percent, and this decreases the amount of film used in pouch producing. Nanoparticles can increase thermal stability up to 350 percent, and that keeps food fresh and can be reheated it in its original packaging. It can enhance barrier properties against gas permeations such as oxygen and carbon dioxide, ultraviolet permeation, moisture, and volatile compounds, develope active antimicrobial surfaces, and creates nano-biodegradable packaging materials (Mahmoud, 2005; Abeer and Choudhary, 2013). Food contact materials have been developed with improved flexibility, gas barrier properties, temperature control and moisture stability due to the inclusion of nanoscale fillers. The effect a nanopackaging has on a food depends on the composition of the nanomaterial that involved. (Cushen et al*.,* 2012). In addition to protection, nanofillers reduces the use of plastics as packaging materials, and also required less energy for their production and biodegradation, these make them more friendly to environment (Sozer and Kokini, 2009). Nanomaterials and nanoparticles may include any of the following nano forms: nanoparticles, nanotubes, fullerenes, nanofibres, nanowhiskers, nanosheets (Cushen et al*.,* 2012).

Application of nanosensors in food packaging will assist consumers in purchasing fresh and tasty products and also improve food safety (Omanović-Mikličanin and Maksimović, 2016). Consumers rely on expiry date in food package provided by producers which is based on the assumption of the required storage and processing conditions. When either of these requirements is abused the product may likely deteriorate and this may not be known to consumer unless the food package is open. Nanosensors can offer solutions to this problem when apply to food package because they can detect presence of gasses, aromas, chemical contaminants, pathogens, and even changes in environmental conditions (Cushen et al*.,* 2012; Joyner and Kumar 2015). Advancement in food packaging requires development of toxic free and degradable or edible packaging materials that are safe for human and environment (Kour et al*.* 2013).

Despite the tremendous benefits of nanoparticles in food industry, there is great public concern regarding toxicity in human and the environment (Mahmoud, 2005). Lack of knowledge about the effectiveness and impact of nanoparticles on the environment and on human health is of great concern due to potential risk resulted from migration of nanoparticles into the food (Amra et al*.,* 2015). The migrants may likely react with oxygen and produce toxic substance (Abeer and Choudhary, 2013). There is a growing scientific evidence, which indicates that some free nanoparticles may cause harm to biological systems because of their ability to penetrate cellular barriers, and induce oxyradical generation that may cause oxidative damage to the cell (Chaudhry et al*.* 2008). There is an urgent need for regulation of nanomaterials before their incorporation into food processing, packaging, and food contact (Alfadul and Ineshwy, 2010). Before releasing any new product with the nanotechnology in food system, manufacturers must thoroughly assess its risk on human, animal and environmental health (Abeer and Choudhary, 2013).

ANTIMICROBIAL PACKAGING

Antimicrobial packaging involves combination of food-packaging materials with antimicrobial substances such as the incorporation of antibacterial nanoparticles into polymer films to control microbial surface contamination of foods (Dele, 2012). Antimicrobial food packaging systems have received considerable attention since they help control the growth of pathogenic and spoilage microorganisms on food surfaces (Amra et al*.,* 2015). Development of antimicrobial packaging requires multidisciplinary approach in the fields of food and material sciences. There are different studies on different nanoparticles incorporated into various polymeric matrices, and results are indicating a great potential of antimicrobial nanocomposite system for prolonging the shelf-life and preservation of different food stuff. However, it is clear that this part of active packaging solution is still in the developing phase, because there are not so many studies on the real food systems (Tanja et al*.,* 2016). Nano-silver antimicrobial food packaging application is a novel approach toward the preservation of foods and the extension of their shelf-life (Amal, 2015). Intensive contact between the food product and packaging material is required in antimicrobial packaging, therefore, potential food applications include vacuum or skin-packaged products, e.g. vacuum-packaged meat, fish, poultry or cheese (Dele, 2012).

The three basic categories of antimicrobial packaging systems include incorporation of antimicrobial substances into a sachet connected to the package from which the volatile bioactive substance is released during further storage; direct incorporation of antimicrobial agent into the packaging film; coating of packaging with a matrix that acts as a carrier for the antimicrobial agent (Sunil, 2012). Tinja et al*.* (2016) summarised (Table 1) antimicrobial effects of different nanoparticles used in different antimicrobial packaging system.

EDIBLE COATINGS AND FILMS

Edible films and coatings are thin layer of material which can be consumed and provides a barrier to moisture, oxygen and solute movement for the food (Bourtoom, 2008). Edible films coatings form an integral part of the food product, and hence should not interfere with sensory characteristics (Guilbert, 1997).

Table 1. Summary of antimicrobial packaging systems with different nanoparticles

Nanoparticles	Polymer matrix	Tested microorganisms	Reference
Ag/Chitosan	PLA[1]	*Staphylococcus aureus* (ATCC6538) *Escherichia coli* (DSMZ 30083)	Turalija et al. (2016)
Ag	Agar banana powder	*Escherichia coli* *Lysteria monocytogenes*	Orsuwan et al. (2016)
TiO2/Ag/Cu	PVC[2]	Mixed microorganism culture media	Krehula et al. (2016)
ZnO/Ag/Cu	PLA[1]/PEG[3]	*Lysteria monocytogenes* *Salmonella typhimurium*	Ahmed et al. (2016)
Ag	PE[4]	*Escherichia coli*	Eslami et al. (2016)
Ag/Cu	Guar Gum	*Lysteria monocytogenes* *Salmonella typhimurium*	Arfat et al. (2017a)
Ag/TiO2	PE	*Aspergillus flavus*	Li et al. (2017)
Ag/Cu	Fish skin Gelatin	*Lysteria monocytogenes* *Salmonella enterica* sv Typhimurium	Arfat et al. (2017b)
Ag	Starch/PVA[5]	*Lysteria inocua; Escherichia coli Aspergillus niger; Penicillium, expansum*	Cano et al. (2016)
Ag/SiO2/TiO2	LDPE[6]	*Escherichia coli*	Becaro et al. (2016)
Ag	PHBV3[7]	*Salmonella enterica* *Lysteria monocytogenes*	Castro-Mayorga et al. (2017)
SiO2	PBAT8	*Escherichia coli;* *Staphylococcus aureus*	Venkatesan and Rajeswari (2016)
ZnO	LDPE	*Bacillus subtilis; Enterobacter aerogenes*	Esmailzadeh et al. (2016)
ZnO	MC[9]	*Staphylococcus aureus; Lysteria monocytogenes*	Espitia et al. (2012)
Nanoclay (NaMMT, OrgMMT)	PVOH/chitosan	*Escherichia coli*	Giannakas et al. (2016)

[1]Polylactic acid; [2]Polyvinylchloride; [3]Polyethylene glycol; [4]Polyethylene; [5]Polyvinyl alcohol; [6]Low density polyethylene; [7]poly(3-hdroxybutyrate-co-3mol%-3-hydroxyvalerate); [8]poly(butylene adipate co-terephatalate; [9]Methyl cellulose **Source: Tinja et al. (2016)**

Edible films and coatings must be chosen for food packaging purpose according to specific applications, the types of food products, and the major mechanisms of quality deterioration (Danijela et al*.,* 2015). Components used for the preparation of edible films can be classified into three categories: hydrocolloids (such as proteins, polysaccharides, and alginate), lipids (such as fatty acids, acylglycerol, waxes) and composites (Donhowe and Fennema, 1993). Edible films can be produced from materials with film forming ability. During manufacturing, film materials must be dispersed and dissolved in a solvent such as water, alcohol or mixture of water and alcohol or a mixture of other solvents. Plasticizers, antimicrobial agents, colors or flavors can be added in this process. In food applications, film solutions could be applied to food by several methods such as dipping, spraying, brushing and panning followed by drying (Bourtoom, 2008).

Edible polymeric packaging materials can be made from polysaccharides, proteins and lipids as wrapping materials, stand-alone films, or can be fabricated into pouches and bags for subsequent packaging use. Can also be applied directly to the food product in a liquid form and then allowed to dry on the substrate. Edible films and coatings are generally used to improve the mechanical properties of the food, minimize respiration in fruits and vegetables, limit the movement of moisture and other gases, provide antimicrobial or antioxidant capabilities to the product, enhance the sensory properties, and extend the shelf life of the product. In some cases, blended films and coating are made by combining different ingredients. This is usually done to harness the advantages of the individual components to produce a material with superior properties (Pascall and Lin, 2013). Combination of different materials improve mechanical properties and demonstrate higher permeability than the single-component films (Elena et al*.,* 2014).

Edible coatings and films can serve as a carrier for antimicrobial and antioxidant compounds in order to keep high concentration of preservatives on the food surfaces. Their presence could avoid moisture loss during storage, reduce the rate of rancidity causing lipid oxidation and brown coloration, reduce the load of spoilage and pathogen microorganism on the surface of foods and also, restricting the volatile flavor loss (Pérez-Pérez et al*.,* 2016). They can also serves as carrier to food ingredients, improve the mechanical integrity and make product handling easier (Krochta and Mulde-Johnson, 1997; Danijela et al*.,* 2015).

There is a growing interest in edible coatings due to factors such as environmental concerns, new storage techniques and markets development for under utilized agricultural commodities (Pérez-Pérez et al*.,* 2016). Edible coating and films are eco-friendly, because biopolymers do not cause environmental problems as packaging materials derived from non-renewable energy sources do (Danijela et al*.,* 2015). Edible films and coatings can improve the recyclability of packaging materials, compared to the more traditional non-environmental friendly packaging materials, and may be able to substitute such synthetic polymer films (Bourtoom, 2008). Food graded antimicrobial packaging films are promising food packaging materials because their biodegradability provides sustainable development for modern community (Vodnar et al*.,* 2015).

SUSTAINABLE PACKAGING

Sustainable and green protocols recommend the use of biodegradable and environmentally friendly materials for food packaging as many packaging materials generates waste. There is renewed focus on creating sustainable packaging and some of the examples of those materials are polylactide acid (PLA) plastics, sugar cane pulp, fiber composite, starch-based films, and so on (Nitaigour, 2014). Biopolymers have been around for billions of years longer than synthetic polymers like plastics. They are generated from renewable natural sources, are often biodegradable, and not toxic to produce. They can be produced by biological systems (i.e. micro-organisms, plants and animals), or chemically synthesized from biological starting materials (e.g. sugars, starch, natural fats or oils, etc.) (Pawar and Aachal, 2013). Sustainable packaging is a complex idea which must be applied with a systematic approach and critical thinking. Three important issues to be consider in evaluation of packaging sustainability are: (1) entire lifecycle of the package from raw materials through to ultimate disposal to avoid problems being transferred from one part of the lifecycle t another (2) interactions between the package and the product it contains so that the environmental impacts of the product-packaging system as a whole are minimised (3) there is also needs to consider 'triple bottom line' impacts of packaging: on the business, on people and on the natural environment. Four principles of sustainable packaging were originally identified by Sustainable Packaging Alliance under the headings of 'effective', 'efficient', 'cyclic' and 'clean' (Helen et al*.,* 2007).

The Sustainable Packaging Coalition, an international consortium of more than 200 industry members, offers the most acceptable definition of sustainable package as:

1. It is beneficial, safe, and healthy for individuals and communities throughout its life cycle.
2. It meets market criteria for performance and cost.
3. It is sourced, manufactured, transported, and recycled using renewable energy.
4. It maximizes the use of renewable or recycled source materials.
5. It is manufactured using clean production technologies and best practices.
6. It is made from materials healthy in all probable end-of-life scenarios.
7. It is designed to optimize materials and energy.
8. It is recovered effectively and used in biological and/or industrial cradle-to-cradle cycles (SPC 2011).

Both biobased and biodegradable materials are being investigated as potential substitutes for petroleum-based plastics (Risch, 2009). Replacing the oil-based packaging materials with biobased films and containers might give not only a competitive advantage due to more sustainable greener image, but also some improved technical properties (Vartiainen, 2014). Biodegradable polymers can fulfill all the functions of food packaging without causing any threat to the environment. The belief is that biodegradable polymer materials will reduce the need for synthetic polymer production (thus reducing pollution) at a low cost, thereby producing a positive effect both environmentally and economically (Pawar and Aachal, 2013). Development of biopolymers containing natural antimicrobial agents and their effective commercialization will be a great step towards attaining sustainability in food packaging applications (Sunil, 2012, Abdul Rahaman and Bishop, 2013).

The primary factors driving development of the biodegradable packaging market include the increase in crude oil prices, consumer's demand; the proliferation of convenience packaging; development of new applications for bioplastics, and development of the composting infrastructure for optimal disposal of bioplastic products. Also consumer demand for products that are environmentally friendly, safer and nontoxic. Besides their biodegradability, biopolymers have other characteristics as air permeability, low temperature sealability, availability and low price (Pawar and Aachal, 2013). Number of Biopolymers are use in food packaging, this includes pectin, starch, chitosan, xylan, galactoglucomannan, Lignin, Cellulose nanofibrils (CNF), also referred to as nanocellulose (Vartiainen et al., 2014).

CONCLUSION

Changes in consumer's preferences, demand for convenience and quality, diminish in cooking skill, limited time available for home preparation of meal, needs to develop environmental friendly packages and competition between producers in developing shelf appealing packages led to technological advancement in food packaging technology. These forces will be driving the dynamic nature of packaging industry and result in further innovations in food packaging. Number of techniques were developed to tackle these challenges, these include active and smart packaging technology, application of nanotechnology in food packaging, antimicrobial packaging, food packaging using edible films and coating and sustainable packaging and more innovations are expected in near future. It is always important to assess and quantify the potential risk of new technologies in order to avoid damage to food, consumers and the environment.

REFERENCES

Abeer A. and Choudhary R. 2013. Current practices in bread packaging and possibility of improving bread shelf life by nanotechnology. International Journal of Food Science and Nutrition Engineering, 3(4): 55-60.

Abdul Rahaman, A. and Bishop, C. 2013. Evaluating the Effects of Biodegradable and Conventional Modified Atmosphere Packaging on the Shelf Life of Organic Cavendish Bananas. Journal of Postharvest Technology, 1 (1): 29-35.

Alfadul S. M. and lneshwy A. A. 2010. Use of nanotechnology in food processing, packaging and safety – Review. African Journal of Food, Agriculture, Nutrition and Development, 10(6):2719-2739.

Amal M. M. 2015. Effects of nanocomposite based nano-silver and nano-titanium dioxideon food packaging materials. International Journal of Applied Science and Technology, 5(2):26-35.

Amra B., Amra O. S. and Ćatić, I. Š. 2015. Application of polymer nanocomposite materials in food packaging. Croat. J. Food Sci. Technol, 7(2):86-94.

Bourtoom T. 2008. Edible films and coatings: characteristics and properties. International Food Research Journal, 15(3): 237-248.

Chaudhry Q., Castle L., Bradley E., Blackburn J., Aitken R. and Boxall A. 2008. Assessment of current and projected applications of nanotechnology for food contact materials in relation to consumer safety and regulatory implications. Food Standard Agency report, project A03063

Cushen M., Kerry J., Morris M., Cruz-Romero M. and Cummins E. 2012. Nanotechnologiesin the food industry- Recent developments, risks and regulation. Trends in Food Science & Technology, 24:30-46.

Dainelli D., Nathalie G., Dimitrios S., Esther Z. B. and Paul T. 2008. Active and intelligent food packaging: legal aspects and safety concerns. Trends in Food Science & Technology 19:103-112.

Danijela Z. S. Vera L. L., Senka Z. P. and Nevena M. H. 2015. Edible films and coatings – sources, properties and application. Food and Feed Research, 42 (1):11-22.

Dari, L., Nenguwo, N. and Afari-Sefa, V. 2018. Evaluation of packaging liners in wooden and plastic crates for handling tomatoes. Journal of Postharvest Technology, 6(1): 36-40.

Dele R. 2012. Application of plastics and paper as food packaging materials – An overview. Emir. J. Food Agric. 25(3):177-188.

Dobrucka R. and Cierpiszewski R. 2014. Active and intelligent packaging food – research and development – A Review. Pol. J. Food Nutr. Sci., 64(1):7-15.

Dobrucka R., Cierpiszewski R. And Korzeniowski A. 2015. Intelligent food packaging - research and development. LogForum 11(1):7-14.

Donhowe, I. G. and Fennema, O. R. 1993. The effects of plasticizers on crystallinity, permeability, and mechanical properties of methylcellulose films. Journal of Food Processing and Preservation 17: 247-257.

Eilert S. J. 2005. New packaging technologies for the 21st century. Meat Science, 71:122–127.

Elena P., Roi R., Shani D., Batia H. and Victor R. 2014. Gelatin-chitosan composite films and edible coatings to enhance the quality of food products: Layer-by-Layer vs. blended formulations. Food Bioprocess Technol, 14(1):1-9.

Guilbert S., Cuq, B. and Gontard, N. 1997. Recent innovations in edible and/or biodegradable packaging materials. Food

Additives and Contaminants 14:741-751.

Helen L., Leanne F., Karli V., Kees S. and Robert J. 2007. Sustainable Packaging Redefined. A publication of Sustainable Packaging Alliance. Available from: http://nbis.org/nbisresources/packaging/sustainable_packaging_guidelines.pdf Accessed September 11, 2017.

Ishrat M., Gulzar A. N., Shuaib M. D. and Vikas N. 2016. Novel food packaging technologies: Innovations and future prospective. Journal of the Saudi Society of Agricultural Sciences, http://dx.doi.org/10.1016/j.jssas.2016.11.003.

Joyner J. R. and Kumar D. V. 2015. Nanosensors and their applications in food analysis: A review. The International Journal of Science & Technoledge, 3(4):80-90.

Kour H., Naseer A. T., Anisa M., Rajkumari K., Harmeet C., Gupta P., Anju B. and Jagmohan S. 2013. Advances in food packaging – a review. Stewart Postharvest Review, 4(7):1-7.

Krochta, J M and De Mulder-Johnston, C. 1997. Edible and biodegradable polymer films - Challenges and opportunities. Food Technology 51:61-74.

Mahmoud M. B. 2005. Nanotechnology in food industry; advances in food processing, packaging and food safety. Int. J. Curr. Microbiol. App. Sci. 4(5):345-357.

Marina R., Arantzazu V., Ana C. M. and María C. G. 2015. New trends in beverage packaging systems- a review. Journal of Beverages 1(1):248-272.

Mills A. 2005. Oxygen indicators and intelligent inks for packaging food, Chem Soc. Rev., 34:1003-1010.

Nitaigour P. M. 2014. Advances in packaging methods, processes and systems. Challenges 5:374-389.

Omanović-Mikličanin E. and Maksimović M. 2016. Nanosensors applications in agriculture and food industry. Bulletin of the Chemists and Technologists of Bosnia and Herzegovina, 47:59-70.

Ozdemir, M., Floros, J. D., 2004. Active food packaging technologies. Critical Reviews in Food Science and Nutrition 44:185–193.

Pascall M. A. and Lin S. J. 2013. The application of edible polymeric films and coatings in the food industry. J Food Process Technol 4(2):1-2.

Pawar P. A. and Aachal H. P. 2013. Bioderadable polymers in food packaging. American Journal of Engineering Research 2(5):151-164.

Peelman N., Ragaert P., De Meulenaer B., Adons D., Peeters R., Cardon L., Impe, F.V. and Devlieghere F. 2013. Application of bioplastics for food packaging.Trends in Food Science & Technology, 32(2):128-141.

Pérez-Pérez C., Regalado-González C., Rodríguez-Rodríguez C. A., Barbosa-Rodríguez J. R. and Villaseñor-Ortega F. 2016. Incorporation of antimicrobial agents in food packaging films and coatings. Research Signpost 37(2):193-216.

Prasad P. and Kochhar A. 2014. Active Packaging in food industry-a review. Journal of Environmental Science, Toxicology and Food Technology 8(5):01-07.

Ravishankar C. N. 2016. Recent advances in processing and packaging of fishery products: a review. Aquatic Procedia 7(1):201–213.

Risch S. J. (2009). Food packaging history and innovations. J. Agric. Food Chem. 57:8089–8092

Sani M. S. and Abdul Aziz F. 2013. Advanced manufacturing systems in food processing and packaging industry. In: Proceedings of Iinstitute of Physics Conference Series; Material Science and Engineering (IOP-2013), March 9-10, 2013, Grand Hyatt, Bandung, Indonesia. Pp 1-9.

Sozer, N., & Kokini, J. L. 2009. Nanotechnology and its applications in the food sector. Trends in Biotechnology, 27(2):82-89.

Sunil M. (2012) Antimicrobial food packaging to enhance food safety: current developments and future challenges. J Food Process Technol 3(5):12.

Sustainable Packaging Coalition 2011. Definition of Sustainable Packaging. Available from: https://sustainablepackaging.org/uploads/Documents/Definition%20of%20Sustainable%20Packaging.pdf. Accessed September 11, 2017.

Tanja I. R., Ivan S. R., Branka M. P. and Aleksandra R. N. 2016. Antimicrobial nanomaterials for food packaging applications. Food and Feed Research, 43(2):119-126.

Vartiainen J., Vähä-Nissi M., Harlin A. 2014. Biopolymer films and coatings in packaging applications—a review of recent developments. Materials Sciences and Applications, 5:708-718.

Vodnar D. C., Pop O. L., Dulf F. V. and Socaciu C. 2015. Antimicrobial efficiency of edible films in food industry. Not Bot Horti Agrobo, 43(2):302-312.