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NOVEL TRENDS IN MEAT PACKAGING: ACTIVE PACKAGING ON MICROBIOLOGICAL ATTRIBUTES OF DIFFERENT TYPES OF FRESH MEAT AND MEAT PRODUCTS

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Abstract: *The investigation of different types of active meat packaging, such as vacuum, modified atmosphere packaging, antimicrobial in various packaging materials and their influence on the microbiological quality of packed fresh meat has become increasingly popular over the last decade. Meat represents cellular, biochemically and structurally complex system, susceptible to many undesirable changes, such as microbial growth, lipid oxidation and sensorial change. This is directly related to consumer's acceptance. Meat packaging objective is to control and optimise meat quality, to confirm meat hygiene and safety, to extend its storage stability, and directly result in lower the utilisation of preservatives throughout the storage. Active packaging (AP) system provides such functionalities to facilitate these demands and offers role beyond the traditional protection and inert barrier to the external environment. This article reviews the main advantage of AP system for fresh meat or meat products. Also, in this review information about some dominant microorganisms in fresh meat or meat products, such as aerobic mesophilic bacteria (AMB), aerobic psychotropic bacteria (APB), lactic acid bacteria (LAB) and pseudomonas counts are provided.*

Keywords: *Active Meat Packaging, Aerobic Mesophilic Bacteria (AMB), Aerobic Psychotropic Bacteria (APB), Lactic Acid Bacteria (LAB), Meat, Pseudomonas Counts, Shelf-Life.*

INTRODUCTION

The key influencer that can cause undesirable meat changes, oxidation and nutrient deterioration in meat of meat products is the oxygen. Meat is a food product that is sensitive of the oxygen level in the packaging and it is proven that if the oxygen permeability is too high, despite the protein and lipid oxidation, microorganisms present in the meat can start growing (Sothornvit, R., & Pitak, N., 2007). Despite the fact that oxygen is highly preferable in red meat, some types of meat or meat products are prone to rapid oxidation which causes changes in the nutritional value of meat, development of undesirable flavours and odours, as well as changes in the meat colour (Fang, Z., Zhao, Y., Warner, R. D., & Johnson, S.K., 2017). Nowadays, in order to take off the accumulated oxygen from the packaging, it is highly recommended the utilisation of oxygen absorbers that aims to optimise the meat quality and prolonge its shelf life (Galić, K., Ščetar, M., & Kurek, M., 2019).

Presently, food-packaging sector plays an important role in optimizing the food quality and safety, decreasing the number of bacteria in food, and have a significant portion of the total plastic waste that is generated and has numerous environmental implications (Kanatt, R. S., & Makwana, H. S., 2019). Meat packaging have a crucial role in the eradication of spoilage microorganisms and meat deterioration ensuring the meat quality and safety, rising its shelf life and decreasing the utilization of food preservatives (Daniloski, D., Petkoska, A. T., Galić, K., Ščetar, M., Kurek, M., Vaskoska, R., Kalevska, T., & Nedelkoska, D. N., 2019).

The selection of optimal packaging for different types of fresh meat and meat products depends of number of criteria (Siracusa, 2002). The sensory and microbiological quality of the fresh meat or meat products are managed by the novel techniques and procedures of meat packaging (Ivanovic, J., Janjic, J., Dorddević, V., Dokmanović, M., Bošković, M., Marković, R., & Baltić, M., 2015). Therefore, diverse methods and technologies have been used in the last decades in order increasing the meat shelf life, such as vacuum packaging in flexible films and developing new methods like vacuum-skin packaging and modified atmospheres (Della Rosa, 2019). In contarst, the active packaging methods and biodegradable polymers were examined, resulting a development of sustainable solutions toward a more environmentally friendly meat value chain (McMillin, 2017).

Nowadays, the food scientists work towards application of active packaging technologies, which have been developed and applied to increase the meat quality (Wrona, M., Nerín, C., Alfonso, M. J., & Caballero, M. Á, 2017). Some studies have illustrated the active film application for storage of high moisture meat products (Fang, Z., Zhao, Y., Warner, R. D., & Johnson, S. K., 2017). The active packaging has two important modes of action including emitters that release desired antioxidants into the food and environment surrounding the food or scavengers that absorb undesirable compounds (oxygen, food-derived chemicals, radical oxidative species, etc.) from the food or the environment (Horita, C. N., Baptista, R. C., Caturla, M. Y. R., Lorenzo, J. M., Barba, F. J., & Sant'Ana, A. S., 2018). To be safe and inactivate meat oxidation, active compounds can be incorporated into the packaging material or in separate devices (López-Cervantes, L., Sánchez-Machado, D. I., Pastorelli, S., Rijk, R., & Paseiro-Losada, P., 2003).

There are two common systems to reach the goal of AP. The first creates a vacuum and then uses a high barrier packaging material to try to prevent the entrance of new oxygen and the second completely removes the oxygen and then employs modified atmosphere packaging (MAP), which also requires a high barrier material (Wen, P., Zhu, D. H., Wu, H., Zong, M. H., Jing, Y. R., & Han, S. Y., 2016). Combining either of these systems with an oxygen absorber or an active antioxidant material will extend the shelf life of the product (Lorenzo, J. M., Batlle, R., & Gómez, M., 2014). Active packaging is particularly important for these foods and is better accepted. Fresh meat is always the first target for active packaging, as its red colour disappears in a very short period of time (Vasile, C., Stoleru, E., Darie-Niţa, R. N., Dumitriu, R. P., Pamfil, D., & Tarţau, L., 2019). To maintain the fresh period of the meat and meat products, usually the addition of any kind of additive is not permitted. Therefore, active antioxidant packaging is the only solution and among the different approaches explained above, that of radical scavengers (e.g. essential oils or herb extracts) introduced into the packaging is the best one (Vasile, C., Stoleru, E., Darie-Niţa, R. N., Dumitriu, R. P., Pamfil, D., & Tarţau, L., 2019; Wrona, M., Nerín, C., Alfonso, M. J., & Caballero, M. Á., 2017).

EXPOSITION

Packaging of meat is one of the ways to protect meat from microbiological contamination (Pothakos, V., Devlieghere, F., Villani, F., Björkroth, J., & Ercolini, D., 2015). Based on the literature, the active packaging is presented as an innovative packaging system/technology that allows the product and its environment to interact which result with the food product shelf life extension and/or to optimise and increase its microbial safety, while maintaining the quality of the packed food (Fang, Z., Zhao, Y., Warner, R. D., & Johnson, S. K., 2017). Therefore, active packaging systems can be divided into antioxidant packaging including active scavenging systems (absorbers: oxygen scavengers, carbon dioxide absorbers, moisture absorbers, flavour absorbers), active-releasing systems (emitters: carbon dioxide emitters, ethanol emitters, ethanol emitters, flavour releasing) and antimicrobial-containing films (Marturano, V., Bizzarro, V., Ambrogi, V., Cutignano, A., Tommonaro, G., Abbamondi, R. G., Giamberini, M., Tylkowski, B., Carfagna, C., & Cerruti, P., 2019; Galić, K., Kurek, M., & Ščetar, M., 2019).

Antioxidant active packaging prevents oxidation by either absorbing components contributing to oxidation, such as oxygen or radicals, or by releasing antioxidants inside the packaging (Figure 1) (Horita, C. N., Baptista, R. C., Caturla, M. Y. R., Lorenzo, J. M., Barba, F. J., & Sant'Ana, A. S., 2018). Based on the literature, it is preferable to add antioxidants to the packaging material, rather than eliminate molecular oxygen from foods using barrier materials or oxygen scavengers (Domínguez, R., Barba, F. J., Gómez, B., Putnik, P., Bursać Kovačević, D., Pateiro, M., Lorenzo, J. M., 2018). The trend for using the natural antioxidants for meat and meat products packed in an active packaging has been increasing rapidly, reducing the problems related to the toxicological and carcinogenic influence of the synthetic antioxidants (Kumar, Y., Yadav, D. N., Ahmad, T., & Narsaiah, K., 2015). The first approach for producing the antioxidant active packaging, separated from the food, known as 'passive package' has been illustrated with the devices such as, sachets, pads and labels (Yildirim, S., Röcker, B., Pettersen, K. M., Nilsen-Nygaard, J., Ayhan, Z., Rutkaite, R., Radusin, T., Suminska, P., Marcos, B., & Coma, V., 2018).

Fang, Z., Zhao, Y., Warner, R. D., & Johnson, S.K., (2017) proved that the antioxidant, which was part of the packaging material, had more beneficial effect than direct application of the antioxidant to the food. For instance, in a study reported by Kumar, Y., Yadav, D. N., Ahmad, T., & Narsaiah, K., (2015) a concentration of 1% oregano extract in the packaging material significantly raised the shelf life of fresh beef, from 14 to 23 days. MAP and vacuum packaging cannot eliminate the presence of O_2 completely, therefore the usage of O_2 scavengers in form of labels, nanocomposites or integrated in the polymer material can absorb the surplus of O_2 within the package (Ahmed, I., Lin, H., Zou, L., Brody, A. L., Li, Z., Qazi, I. M., Pavase R. T., Lv, L., 2017). The use of oxygen scavengers mostly in the form of sachets inside the primary package is also an innovative method, which can exert some antibacterial effect against aerobic bacteria (Demirhan, B., & Candoğan, K., 2017).

It is determined that most of the polymer materials are 3 – 5 times more permeable to carbon dioxide than to oxygen, thus CO_2 concentration has to be continually produced with CO_2 emitters to properly maintain its preferable high concentration in the package and decline the number of bacteria in fresh meat (Holck, A. L., Pettersen, M. K., Moen, M. H., & Sorheim, O., 2014). Moisture is one of the most detrimental factors that can influence the meat spoilage, where the moisture absorbers are presented as superabsorbent film located between two different types of films such as PP or PE. These absorbers have the ability to cease the moisture in the packaging from the environment (Table 1) (Galić, K., Kurek, M., & Ščetar, M., 2019).

In addition, another type of active packaging is well known as antimicrobial active packaging with the incorporation of natural antimicrobial particles into packaging materials that intend to minimize or eliminate the unpleasant changes in the meat quality (Takma, K. D., & Korel, F., 2019). The antimicrobial compounds used in the active packaging, such as essential oils, plant extracts, herbs are natural compounds that are presented as an alternative solution against chemical preservatives utilized for meat quality and hygiene (Bazargani-Gilani, B., Aliakbarlu, J., & Tajik, H., 2015).

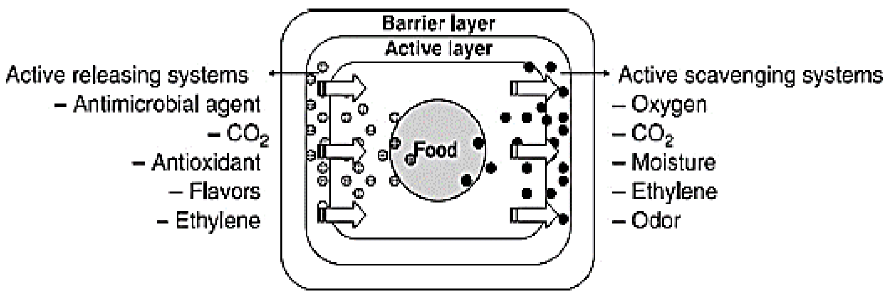

Fig. 1. Active packaging systems

It has been proven that the active packaging films can be enhanced with active compounds such as antioxidants or antimicrobials that may ensure the quality and safety of fresh meat in meat products (Noori, S., Zeynali, F., & Almasi, H., 2018). The proper selection of an effective delivery method of the antimicrobial substance in the packed meat with little or no impact on the sensory characteristics of the packed fresh meat or meat product are the most important key points for the application of the antimicrobial active packaging (Fang, Z., Zhao, Y., Warner, R. D., & Johnson, S. K., 2017). To give an example, one study conducted by Dawson, P., Cooksey, K., & Mangalassary, S., (2012) demonstrated that carrageenan added to bio-based coatings and films decreased the number of bacteria in poultry by almost 99%. The same study presented the results of adding organic acids and nisin to calcium alginate, which proved that adding those particles in during the film preparation, is more effective for reduction of the number of bacteria than direct addition of them on fresh beef tissue.

Table 1. Examples of commercially available products and manufacturer of the active packaging aimed for meat and meat products (Galić, K., Kurek, M., & Ščetar, M., 2019).

Activity	Name of the product	Active component	Type of the product
O_2 scavengers	Aegis HFX, USA		pads
	ATCO®, France		pads
	OxyGuard®, Switzerland		pads
CO_2 emitters	Superfresh, Norway	CO_2	box system with CO_2 emitter
	Verifraise, France	CO_2	pads
	Freshpax, USA	CO_2	sachets
Moisture absorbers	SORBED India™, India	PE-LLD	sachets
	MeatGuard, USA	PE-LLD	sachets
	MOISTCATCH™, Japan	PET/AL/film which absorbs moisture	film suitable for high temperature

According to Blixt, Y., & Borch, E., (2002) the sustainability of meat has a major influence on the initial quality of the raw material, primarily the number of bacteria. The largest part in the initiation of the number of microorganisms in fresh pork has mesophilic and psychrotrophic bacteria (Motarjemi, Y., & Lelieveld, H., 2014). The total number of mesophilic bacteria is used as an indicator of product hygiene and indicator of contamination of fresh pork. Daniloski, D., Petkoska, A. T., Galić, K., Ščetar, M., Kurek, M., Vaskoska, R., & Nedelkoska, D. N., (2019) examined vacuum packed fresh pork meat in two different packaging materials, where the total aerobic mesophilic bacteria (AMB) counts in that study were 3.6 to 6.9 log CFU/g for BOPPcoex (biaxially oriented coextruded polypropylene) and 3.3 to 6.7 log CFU/g for meat packaged in BOPPAcPVDC (biaxially oriented polypropylene coated with acrylic/polyvinylidene chloride), for examined time period (initial day and day 21), respectively.

Furthermore, the results from the study of Jaberi, R., Kaban, G., & Kaya, M., (2019) represented that both packaging methods (vacuum and MAP), storage time and the interaction of packaging method had a very significant effect on total aerobic mesophilic bacteria (AMB) count of minced water buffalo meat stored over a period of 14 days (from 3.79 log CFU/g to 6.5 log CFU/ and from 3.79 log CFU/g to 7 log CFU/g, in MAP and vacuum, respectively). The research done by Ivanovic, J., Janjic, J., Dorddević, V., Dokmanović, M., Bošković, M., Marković, R., & Baltić, M., (2015) found a high initial value of AMB in packaged freshly ground pork (8.10 log CFU/g) over a period of 12 days. According to International Commission on Microbiological Specifications for Foods, (1986) the upper microbial limit of acceptability for meat is 7 log CFU/g. For these reasons, the first deterioration signs in chilled meat, mainly related to odour (Stahlke, E. von R., Rossa, L. S., Silva, G. M., Sotomaior, C. S., Pereira, A. J., Luciano, F. B., Macedo, R. E. F. de., 2019) usually start when the aerobic psychotropic bacteria (APB) count reaches 7 log CFU/g. Over 7 log CFU/g after 11 days of storage for chilled lamb meat packaged in atmosphere of 60% CO_2 + 40% N_2 and 16 days for lamb meat packaged in atmosphere of 80% CO_2 + 20% N_2 was reported by Karabagias, I., Badeka, A., & Kontominas, M. G., (2011). Djordjevic, J., Cobanovic, N., Boskovic, M., Dokmanovic, M., Ilic, N., Pecanac, B., & Baltic, M. Z., (2015) tested minced fresh pork packed in vacuum, stored for 12 days, at 3 ± 1 ^{0}C and found mesophiles at 7.00 - 9.05 log CFU/g.

The high oxygen content may have an influence on the growth of aerobic psychotropic bacteria Bórnez, R., Linares, M. B., & Vergara, H., (2009). Kennedy, C., Buckley, D. J., & Kerry, J. P., (2004) observed aerobic microbial count of 7 log CFU/g in chilled lamb loin stored under different MAP over a period of 12 days of storage. Lactic acid bacteria (LAB) had better conditions for growth in vacuum packaged lamb meat samples compared to MAP (80% O_2 + 20% CO_2) samples throughout the storage period (Berruga, M. I., Vergara, H., & Gallego, L., 2005).

LAB count in vacuum-packaged dry-aged beef has been doubled during the storage from 1.78 log CFU/g to 4 log CFU/g, at first and the seventh day of storage, respectively. However, the growth of LAB did not affect meat spoilage during storage in both vacuum and wrap-packaged beef (Lee, K. T., & Jang, M. J., 2013). Moreover, Jaberi, R., Kaban, G., & Kaya, M. (2019) proved the same, from 3.5 log CFU/g to 6.5 log CFU/g and from 3.3 log CFU/g to almost 7 log CFU/g, for High Oxygen (HiOx) – MAP and vacuum, respectively. On the other hand, Degirmencioglu, N., Esmer, O. K., Irkin, R., & Degirmencioglu, A., (2012) reported that there were no statistically significant differences between vacuum and HiOx - MAP applications in terms of Pseudomonas counts in minced meat samples stored at 4^{0}C for 7 days.

In one study the active antimicrobial packaging (polyethylene, chitosan and zataria multiflora essential oil) showed tremendous capabilities of extension the shelf life of poultry meat kept at 4^{0}C, over a period of 16 days, whereas the number of total visible counts was in range from 4.04 - 4.86 log CFU/g (Mehdizadeh, T., & Langroodi, M. A., 2019). Moreover, one CH edible coating with 1% propolis extract decreased the number of AMB and the last day counted only 7 log CFU/g, which is in the accepted limit of AMB in fresh meat and meat products (Jafari, J. N., Kargozari, M., Ranjbar, R., Rostami, H., & Hamedi, H., 2018). Duman, M., & Özpolat E., (2015) conducted their results which showed that psychotropic bacteria number in polutry packed in PE was just over 6 log CFU/g on the 18 day of examination.

The most important microflora of chicken meat refrigerated at 4^{0}C responsible for fresh meat spoilage is Pseudomonas spp. when their number is approximately 8 log CFU/g (Raeisi, M., Tabaraei, A., & Behnampour, N., 2016). The effects of active packaging on total aerobic mesophilic counts and psychrotrophic counts of refrigerated chicken breast meat stored at 4°C for 5 days were examined in the study conducted by Takma K. D., & Korel, F., (2019). Their results showed that the number of bacteria in both control and active packaging slightly increase from 4.53 log CFU/g to 7 log CFU/g, however, the active packaging had only slight influence for suppressing the growth of both types of bacteria. Another study by Yang, W., Xie, Y., Jin, J., & Zhang, H., (2019) presented that the viable counts of Listeria monocytogenes in pork packed in polyethylene terephthalate/polyvinylidene chloride/retort casting polypropylene coated with plantaricin and chitosan were decreased tremendously by 3.6 log CFU/g in liquid medium and approximately 1.4 log CFU/g in meat stored at 4^{0}C for 8 days compared with the control. Moreover, linear low-density polyethylene film coated with an enterocin decreased the number of L. monocytogenes in frankfurter samples in the first day of packaging, keeping the same decreasing effect over a period of 7 days (Yang, W., Xie, Y., Jin, J., Liu, H., & Zhang, H., 2019). Additionally, Jin, T., Liu, L., Zhang, H., & Hicks, K., (2010) established that pectin and nisin incorporated in a PLA film notably declined the number of L. monocytogenes counts.

The evaluation of total visible counts in cooked ham packed in three different packs, including control (CON), active packaging with 1 % green tea extract (ATGT) and active packaging with 1 % of a mixture of green tea and oregano essential oils (ATRX) over a period of 3 weeks and kept at 4^{0}C, had been examined in the study by Pateiro, M., Domínguez, R., Bermúdez, R., Munekata, E.S. P., Zhang, W., Gagaoua, M., Lorenzo, J. M., (2019). The final number of bacteria was between 3.95 log CFU/g and 5.49 log CFU/g in ATGT and CON, respectively, presenting that the lowest value of TVC was found in samples packed in ATGT films. In addition, minced chicken meat packed in polyvinyl alcohol enriched with citric acid and aloe vera proved that the TVC of samples stored in active films increased very slowly and only after 13 days of storage it reached a count of 6.15 log CFU/g. Shahrezaee, M., Soleimanian-Zada, S., Soltanizadeh, N., & Akbari-Alavijeh, S., (2018) observed that an addition of 3.5% AV to chicken nugget decreased microbial count during storage at 4^0C.

CONCLUSION

The intention of this review of trends in meat packaging was to check the possibility of some meat packaging systems and prolonged meat storage. They showed good potential in replacement of existing polymeric films, currently used for meat packaging. Vacuum and MAP showed similar effects on most of the meat quality parameters, however, vacuum might be better suited for fresh meat storage since it maintains the red colour, which is associated to meat freshness.

In case of the author's study, it has been shown that BOPP – based packaging foils extended the shelf life of fresh pork meat for 7 – 14 days in comparison with the traditional packaging foils used for fresh meat packaging and currently available on the market. Namely, the pork quality and safety (packed in above-mentioned foils) in terms of microbiological attributes showed that examined BOPPAcPVDC foil performed better storage of the fresh pork than the BOPPcoex foil. Authors reckon that the future trends of meat packaging should be combination of AP with antioxidant, antimicrobial and/or nutritive components (e.g. chia, oregano, rosemary, thyme, citrus, green tea extracts, oils etc…) that will extend the shelf life of the meat and will completely eradicate the possibility of microbial growth in fresh meat or meat products. At the same time, the meat safety and quality could be monitored in a smart way by usage of suitable sensors or indicators. The trend of biodegradable or edible materials from renewable sources for food packaging is not excluded for meat products as well.

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