http://www.moderntechno.de/index.php/meit/article/view/meit23-01-025
DOI: 10.30890/2567-5273.2022-23-01-025

УДК: 636.54: 664.9.002.5

PACKAGING FRESH MEAT IN MODIFIED ATMOSPHERE

УПАКОВКА СВІЖОГО М'ЯСА У МОДИФІКУВАНІЙ АТМОСФЕРІ

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Abstract. *The article provides an overview of modern scientific data on the influence of a protective atmosphere (in most cases containing oxygen) on the properties and quality of fresh meat. However, recent scientific studies have shown that a high proportion of oxygen in the protective atmosphere, which ranges from 60 to 80%, is the cause of a number of negative concomitant phenomena, for example, accelerated autoxidation of fat, intensive formation of hazardous cholesterol oxidation products, an increase in meat stiffness due to protein oxidation, as well as the phenomenon of premature browning of meat. According to McMillin 2008, further research is needed in fresh meat packaging. First of all, this concerns packaging materials, the selection and processing of meat raw materials, the use of various packaging systems, taking into account the properties of meat, as well as logistics within the cold chain. For the industry, the solution of these issues is necessary to better understand the structure of production costs, inform consumers about packaging systems and replace national (international) packaging with regional meat packaging. In addition, successful customer-centric product management requires a focus on customer service, coupled with the effective application of information technology and appropriate logistics within the product's production and supply chain.*

Key words: *meat, packaging, fat, atmosphere, management, comfort, tenology.*

Most of the packaged fresh meat for self-service stores is sold in packaging with the so-called protective atmosphere (Modified Atmosphere Package - MAP). The purpose of such packaging is, first of all, to preserve the cherry-red color of the meat, as well as to increase its microbiological stability. However, recent scientific studies have shown that a high proportion of oxygen in the protective atmosphere, which ranges from 60 to 80%, is the cause of a number of negative concomitant phenomena, for example, accelerated autoxidation of fat, intensive formation of hazardous cholesterol oxidation products, an increase in meat stiffness due to protein oxidation, as well as the phenomenon of premature browning of meat.

Modified atmosphere packaging (MAP) concepts

The following concepts are known in the field of fresh meat packaging in a protective atmosphere, which is sold in self-service stores:

HiOx-MAP (Modified Atmosphere High Oxygen Packaging). The packaging is evacuated and filled with a gas mixture of 80% O2 and 20% CO2 before being hermetically sealed. As a result, the cherry-red color of the meat expected by the consumer is ensured. However, at the same time, the processes of fat and protein oxidation are accelerated and the color of the meat changes. The high CO2 content in the packaging inhibits the growth of microorganisms, but may cause undesirable changes in the color of the meat (Arvanitoyannis and Stratakos, 2012). Ground beef can have a shelf life of 10 to 14 days and whole muscle meat 12 to 16 days (Cornforth and Hunt, 2008; Belcher, 2006).

LowOx-MAP (packaged in a modified atmosphere with the absence of oxygen). This kind of protective atmosphere prevents the growth of microorganisms, but the color of the meat turns red-violet (Arvanitoyannis and Stratakos, 2012). A LowOx-MAP protective atmosphere of 70% N2 and 30% CO2 is used to increase the minimum shelf life of meat. A significant disadvantage of this packaging variant is the lack of oxygen, as a result of which it does not react with myoglobin and thus the desired cherry-red color of the meat is not formed. In this case, the color pigment deoxymyoglobin dominates. LowOx-MAP packaging of beef provides a minimum shelf life of 25 to 35 days (Delmore, 2009).

LowOx-MAP c CO. We are talking about modified atmosphere packaging, which, in addition to 69.6% N2 and 30% CO2, also contains 0.4% carbon monoxide CO. CO is added because myoglobin has a high degree of chemical affinity for CO, resulting in rich cherry red meat (Hunt et al., 2004).

This color complex is more stable than oxymyoglobin, which can easily be converted to metmyoglobin (brown) in the presence of free oxygen. The disadvantage is the negative image of CO (Cornforth and Hunt, 2008). As a result, its use in modified atmosphere packaging is permitted only in certain countries. When using LowOx-MAP plus CO modified atmosphere packaging, minced beef has a minimum shelf life of 28 days and whole muscle beef has a minimum shelf life of 35 days (Delmore, 2009).

Vacuum packaging.

With this method of packaging, first of all, a film with an extremely low water vapor and oxygen permeability is used. Film bags in which meat is placed, vacuumed and then thermally sealed. By exclusion of access oxygen, the growth of aerobic spoilage pathogens is almost completely suppressed, and the storage stability of meat increases. With this method of packaging, myoglobin retains its native state, and therefore the meat has a red-violet color, which does not meet the requirements of modern consumers. With appropriate low storage temperatures (1-20C) beef cuts can be stored up to more than 80 days (Delmore, 2009).

Vacuum tight packing (skin packing).

In this case, we are talking about a relatively new packaging technique that has advantages in terms of microbiological stability, juice-holding capacity of the meat inside the package and sensory properties. Scientific studies have shown that the loss of meat juice in a vacuum skin pack is lower and the meat has a higher density compared to a product in a traditional vacuum pack. In vacuum skin-packing, the growth of aerobic-mesophilic, aerobic and coliform bacteria at a temperature of 40C significantly slows down. Lagerstedt et al. (2011) found the lowest juice loss in vacuum skin-packed meat samples compared to MAP packaging (80% O2 and 20% CO2) and vacuum packaging.

Active packaging.

This type of packaging is a new variant in which components are integrated into the packaging that give their substances to the product or absorb them. For example, they can take in oxygen, regulate humidity, generate or absorb CO2 and/or reduce bacteria and thus protect the product from spoilage and extend its shelf life (Arvanitoyannis and Stratakos, 2012).

HiOx-MAP (packaging in a modified atmosphere with a high volume of acid) At the same time, the trend of centralized packaging of the communication is fading away due to the increased sales volumes and lowering the quality of the products. All these factors are a stimulus for zdijsnennya change in the field of meat packaging. In order to ensure successful distribution of packaged products at self-service stores, it is very important to waste on packaging materials, and there may be a trend towards a decrease in the number of practitioners employed in the meat trade (Eilgert, 2005). However, Carpenter and in. (2001) found that the installation of meat, packed in a modified atmosphere, that assessment of its quality by the singing world is super accurate. When buying meat, the comforts are most importantly taken into account by such aspects as the spiciness for health, as well as the sensory power of the meat, like the color, the anger, the tenderness, the juiciness, the smell and the taste (Krystallis and Arvanitoyannis, 2006; Destefanis et al., 2008) .

Zakrys et al. (2008) In their own opinion, they indicated that experts, when assessing the sensory power of meat, gave priority to products that were taken in an atmosphere with a mixture of sour below 50 and 80%, regardless those that were marked with a slight rancid taste of meat. Bulo zrobleno pripuschki, scho such an assessment is based on singing adaptation to oxidized fat or singing stars to such a relish. At that time, the color of the yalovichi steak or minced meat in the sequence of "chervony", "red-violet" and "brown" was the main factor in deciding how to buy the product, neither the color nor the method of packaging the meat (Carpenter and in., 2001). Even though it is easier to take advantage of the meat of a bright-red color in traditional packaging, the slower the color of the meat and the packaging does not add to the satisfaction that is taken in the form of meat (Carpenter et al., 2001).

Jeremian (1982) noted that consumers, when buying meat in a store, first of all pay attention to the color of the product, which is an indicator of freshness and good taste for them. Also interesting is the distribution of individual product properties in order of importance when grilling steaks. So 50% of consumers consider tenderness of meat the most important sensory property; followed by taste (38%) and juiciness (11%). Similar results were presented by Platter et al. (2003) and Huffman et al. (1996): tenderness - 51%, taste - 39% and juiciness -10%.

Today's consumers are increasingly demanding sustainable packaging and natural food. According to Cutter (2006), these requirements are driving the development of biodegradable and renewable materials. Films made from biopolymers are a potential replacement for synthetic films used in food packaging, but there are still limitations on the use of these materials, for example, regarding their hydrophilic properties (Han and Gennadios, 2005). Another source of bio-packaging is bacterial cellulose (Weber et al., 2002).

n recent years, there has been an increase in the trend towards the sale of fresh meat, as well as meat products and sausages in pre-packaged form. Most fresh meat and meat products are sold in protective atmosphere packaging, also known as MAP packaging (packaging in a modified gas atmosphere). According to the Central market research agencies, the share of fresh meat packaged in a protective atmosphere has increased from 32% in 2003 to 43% in 2005. This corresponds to an increase of more than 30% (Schulze and Spiller, 2007).

In contrast to vacuum packaging, when packaging in a protective atmosphere, a gaseous environment is created around the product, which differs from the composition of the air atmosphere (about 78% nitrogen, 21% oxygen and 0.03% carbon dioxide). Air, respectively oxygen, is removed from the packaging and in most cases replaced by a mixture of carbon dioxide (CO2) and nitrogen (N2). In this case, carbon dioxide is used because of its bacteriostatic effect, which was already noted in 1877 by the scientists Pasteur and Joubert during the inactivation of Bacillus anthracis. Molin (1983) found that the use of 100% CO2 compared with 5% CO2 increased the effect of suppressing the growth of E. coli by 40% and by 47% of Staphyloccocus aureus. The growth of Bacillus cereus can be reduced even by 67%. The minimum concentration of CO2 to ensure bacteriostatic and fungistatic action at low temperatures should be 20%. This is done in order to preserve the quality of food products and improve their shelf life by limiting chemical, microbiological and enzymatic processes that cause food spoilage. The protective atmosphere in most cases consists of a mixture of gases: oxygen, carbon dioxide and nitrogen, the proportion of which in the mixture may vary depending on the product. As practice has shown, if a high level of hygiene is observed during the processes of production, cutting and packaging of fresh meat, its shelf life in MAP packaging at 70C can reach 7 to 9 days. In packaging with fresh meat, nitrogen at a maximum of 10% serves as a so-called protective gas to prevent the formation of a pseudo-vacuum effect. Nitrogen is an inert gas that is neutral in taste and smell and does not dissolve in fat and water, and thus does not adversely affect the quality of the product.

The packaging of fresh meat in a protective atmosphere, compared to the packaging of meat products using a mixture of gases, has one peculiarity: the modified atmosphere consists of 60-80% oxygen (O2) and 20-40% carbon dioxide (CO2). Oxygen, 21% of which is in the air, is used in higher concentrations in such packaging in order to obtain a light red color of fresh meat and keep it for a long time. This color is obtained by oxidizing the red meat pigment myoglobin to oxymyoglobin.

In addition to quality, a decisive success factor in the chilled food segment is the consistent and reliable maintenance of the continuity of the cooling chain and the quality of the packaging. Packaging serves more than just conveying information about a product; it should also be easy to use, have an attractive design for consumers, provide reliable protection of the product and, if possible, its long shelf life. A properly selected mixture of gases for the packaging process and compliance with the appropriate proportions of gases in the packaging of the food product until it reaches the consumer is a necessary condition for maintaining the quality of the product, its attractive appearance and shelf life. Conducting an analysis of the quality of the protective gas allows you to identify errors in the technology of sealing the package, as well as the shortcomings of the packaging material used. In packages that do not have sufficient sealing, during storage, increased gas exchange may occur as a result of diffusion through microcracks in the welds or in the packaging material. Based on the lower gas pressure of ambient air, which typically has an oxygen content of 21% and carbon dioxide of exactly 0.03%, the gases inside the package tend to diffuse outwards. The situation is different with nitrogen. The content of nitrogen in the air is 78%, therefore, as a result of strong diffusion pressure, it tries to penetrate into the inside of the package. Thus, intense gas exchange is preprogrammed if the package is not properly sealed (Lautenschläger and Müller, 2006). The use of high quality packaging material also helps to improve the gas tightness of the packaging, since, depending on the structure of the polymers of the used artificial materials and films, as well as on the ambient temperature, the diffusion of gases occurs with a greater or lesser degree of intensity. As a rule, trays made of polypropylene (PP), as well as expanded polystyrene and polyethylene terephthalate (PET) are used for packaging fresh meat. As a film material, polyethylene of various degrees of density, polypropylene (PP), polystyrene (PS), polycarbonate (PC) or olivinyl chloride (PVC) is used. Higher efficiency and stability in terms of resistance to increased gas and moisture exchange, as well as to mechanical stress during transportation, have multilayer films that are part of the combined polymer packaging as an additional protective layer. In this case, several layers of film are very often superimposed on each other, and ethylene-vinyl alcohol copolymers (EVON) and polyvinylidene chloride (PVDC) are used as a barrier that prevents the penetration of oxygen. However, these packaging materials are much more expensive than plain film without a protective layer (Lautenschläger and Müller, 2006).

Since part of the carbon dioxide dissolves in water, and this gas penetrates through the packaging in a higher (three or five times) volume per unit time compared to oxygen, then when using conventional packaging, by the end of the storage period, there is a danger of the so-called "pseudo-vacuum packaging." In this case, the top cover film shrinks, which leads to deformation of the package. To prevent this defect, packaging manufacturers have developed a gas mixture specifically for fresh meat that contains nitrogen as a reference gas. Such a mixture may, for example, contain 70% oxygen, 20% carbon dioxide and 10% nitrogen. The gas mixture of packaging with fresh meat at the end of the shelf life must contain at least 15% carbon dioxide (from 20% CO_2 5% dissolves to form carbon dioxide) and 60% oxygen (the lowest limit of the usual gas mixture). The content of the nitrogen reference gas must not exceed 10% (Lautenschläger and Müller, 2006). When oxygen is used to pack fresh meat, in addition to the benefits of developing and stabilizing the color of fresh meat, there are a number of evidence-based factors that have a negative impact on meat quality and may harm the health and safety of consumers.

The best known is the fact that oxygen contributes significantly to the autoxidation of fat and thus the formation of rancidity (O'Grady et al., 1998). This fact was established by analysis of the reactive substances of thiobarbituric acid (TBARS value). Oxygen increases the TBARS value (Zakrys et al., 2007), the sensory limit of which is acceptable according to Campo et al. (2006) should be less than 2 mg of malondialdehyde (MDA) per 1 kg of sample.

A concern in terms of consumer health hazards is the formation of cholesterol oxidation products (COPs). Cayuela et al. (2004) found that the content of cholesterol oxidation products at an oxygen concentration of 70% increased by 86.4%. Münch (2011) found that at an oxygen concentration of 80%, when packing bovine longissimus dorsi muscle after butchering, both in fresh and chilled form, compared with very low air oxygen, after 14 days of storage, there is a significant increase in the content of cholesterol oxidation products. . Depending on the individual chemical compounds that are formed during the oxidation of cholesterol, the COP content when packaged in a modified atmosphere with a high oxygen content can be 8 to 20 times higher. Oxygen also leads to the oxidation of proteins, which, in the first place, reduces the tenderness of the meat.The formation of cross-linked myosin heavy chains as a result of protein oxidation has been repeatedly observed in fresh meat stored in a modified high oxygen atmosphere (HiOx-MAP) (Zakrys-Waliwander et al., 2012). The authors found that in beef steaks during storage in HiOx-MAP, due to a decrease in the number of free thiol groups, as well as an increase in the content of carbonyls, protein oxidation occurred, followed by the formation of cross-linked myosin heavy chains (molecular weight 500 kDa). This phenomenon had a negative effect on the tenderness of the meat and the loss of juice. In this regard, Kim et al. (2012) attributed their observed increase in shear force of sheep muscle longissimus lumborum in HiOx-MAP packaging to the formation of cross-linked myosin heavy chains. In addition, the phenomenon of premature browning of muscle tissue plays an important role in terms of consumer protection (Suman et al., 2010).

The effect of various MAP systems on premature browning of meat was investigated in beef muscle longissimus lumborum (LL). Vacuum packaging (VP) was used as a control, and HiOx-MAP (80% O2 + 20% CO2) and MAP with carbon monoxide (CO) - 0.4% CO + 19.6% CO2 were used as modified atmosphere packaging. + 80% N2. The samples were stored in a dark place for 5 days at 40C. At the end of storage, the minced steaks were heated to a temperature in the center of the product of 660C or 710C, and then the color inside the product was analyzed. HiOx-packed steaks showed less red color (a* value) than vacuum-packed (VP) and modified-atmosphere carbon monoxide (CO MAP) steaks. Muscle longissimus lumborum (LL) steaks stored in high oxygen modified atmosphere packaging (HiOx-MAP) were more susceptible to premature browning when heated to 66°C than steaks in vacuum and CO MAP packaging.

Typically, steaks that remained red in the center after cooking were considered underdone. However, if, already at a relatively low temperature, a complete formation of a brown color (brownishing) was observed in the center of the product, this may mean that pathogenic bacteria are not completely inactivated, and this is dangerous for the health of consumers. For this reason, in order to ensure the microbiological safety of beef steaks that have undergone thermal processing, vacuum packaging is the most suitable (Suman et al., 2010) .Lagerstedt et al. (2007) investigated the effects of HiOx-MAP on sensoryindicators of the quality of minced beef, as well as the formation of productsoxidation. They found a significant effect of high oxygen concentration on the sensory properties of the product, as well as on the degree of formation of oxidation products - both lipid and protein oxidation. The value of BARS as an indicator of fat oxidation doubled after 8 days of storage, while the content of vitamin E decreased. The disadvantage in terms of sensory quality of the products was the taste of the old product, which was established in samples stored in packaging with 80% oxygen concentration at 40C. In addition, an increase in losses during the heat treatment of meat was noted.

Upcoming tasks.

The sale of fresh meat in Modified Atmosphere Packages has been practiced since 1960. The aim of these studies was to improve the ease of use of packaging, improve retail marketing, reduce weight and energy costs, ensure safety and protection against adulteration, and take into account environmental aspects. The key to creating successful packaging concepts is the right choice and design of packaging, as well as ensuring the necessary balance between the various requirements that relate to product quality, costs, marketing, customer needs, and environmental aspects, including the problem of waste disposal. This also includes the problem of traceability of products, the detection of falsification and the provision of convenience in consumption. As far as the fresh meat marketing system is concerned, an irreversible process of centralization must take place (McMillin, 2008). In the future, both active and "intelligent" packaging and sustainable packaging made from renewable raw materials should have a high potential. In the first case, radio frequency identification technology (RFID), temperature and time indicators (TTI), as well as freshness and crack indicators in the package should be used. In the second case, we are talking mainly about biodegradable and renewable raw materials for the manufacture of packaging.

The need for research. According to McMillin 2008, further research is needed in fresh meat packaging. First of all, this concerns packaging materials, the selection and processing of meat raw materials, the use of various packaging systems, taking into account the properties of meat, as well as logistics within the cold chain. For the industry, the solution of these issues is necessary to better understand the structure of production costs, inform consumers about packaging systems and replace national (international) packaging with regional meat packaging. In addition, successful customer-centric product management requires a focus on customer service, coupled with the effective application of information technology and appropriate logistics within the product's production and supply chain.

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Анотація. *У статті наведено огляд сучасних наукових даних щодо впливу захисної атмосфери (у більшості випадків містить кисень) на властивості та якість свіжого м'яса. Однак останні наукові дослідження показали, що висока частка кисню в захисній* *атмосфері, яка становить від 60 до 80%, є причиною цілого ряду негативних супутніх явищ, наприклад, прискорене самоокислення жиру, інтенсивне утворення небезпечних для здоров'я продуктів окислення холестерину, збільшення жорсткості м'яса за рахунок окиснення білків, а також феномен передчасного побуріння м'яса. Згідно з даними McMillin, 2008 необхідне проведення подальших досліджень у галузі пакування свіжого м'яса. Насамперед, це стосується пакувальних матеріалів, вибір та обробка м'ясної сировини, застосування різних пакувальних систем з урахуванням властивостей м'яса, а також логістики всередині холодильного ланцюжка. Для промисловості вирішення цих питань необхідне кращого розуміння структури виробничих витрат, інформування споживачів про системи упаковки та заміни національної (міжнародної) упаковки на регіональну упаковку м'яса. Крім того, для успішного менеджменту продукту з урахуванням інтересів споживачів необхідно головну увагу приділяти обслуговуванню покупців у поєднанні з ефективним застосуванням інформаційних технологій та відповідної логістики всередині ланцюжка виробництва та постачання продукції.*

***Key words**: м'ясо, упаковка, жир, атмосфера, менеджмент, споживачі, тенологія.*