Meat processing

1. Introduction

The first known methods of preserving meat were salting and drying, which in the Mediterranean region were used even before the Roman Empire. Since the Middle Ages, the manufacture of all sorts of sausages has been known to take place in many regions of the world. The methods of production and preservation were adjusted to the local environmental conditions. In southern Europe, the prevalent products salted/cured and dried, in the north - semi-dried, while in the countries of Central Europe - smoked and boiled sausages. Appert's invention in the late 19th century expanded opportunities for the production of meat products into the area of pasteurized and sterilized canned products. In later years the range of processed products widened, partly as a result of the development of transportation and migration of the population.

Initially, under the conditions of craftsmanship, the slaughter of animals and the production of meat preparations were carried out in the same workshop. The rise of municipal slaughterhouses resulted in a partial separation of these activities through the centralization of slaughtering and the establishment of a series of processing workshops. The transformation of butchers' workshops into industrial plants in the 20th century went different ways in Europe and in other regions of the world. In the relatively densely populated Europe, medium-sized industrial plants with full production profile (slaughtering, boning, processing) were being established. On the other hand, in the Americas, Australia or in South Africa, slaughterhouses were being built in the area of animal rearing, with the processing plants in more densely populated urban centers. In recent years, in Europe, slaughterhouses as well as processing plants are being located away from urban settlements.

The development of meat processing technologies assumes some basic goals:

• full utilization of all the products obtained in the slaughter of animals,
• the processing of raw materials into safe, nutritionally complete meat products providing the consumer with satisfactory sensory experiences,
• the most economical utilization of the relatively expensive raw material for the production of food.

Striving to implement these objectives, the meat industry was forced to make use of the latest scientific and technological solutions in the design, construction and operation of meat establishments. The current meat processing industry is highly mechanized and automated, in the phases of production, monitoring and quality control, packing, distribution systems and marketing.

Many types of processed meat products are made from ground meat, usually a mixture of several types of meat and non-meat raw materials. The contributions of individual components is specified in recipes. Assuming the applied technological processes to be the basis of categorization, meat products can be subdivided into two basic groups: cold cuts and canned goods. Among the cold cuts we can distinguish between ground meat products (raw, fermented and boiled sausages, offal cold cuts, luncheon products) and non-ground (whole muscle) (including smoked raw meats and smoked boiled meats, smoked fermented meats). In the group of canned products, we distinguish...
between pasteurized canned products (made from coarsely ground meat) and sterilized (with finely ground meat).

In industrial practice, in force are the European (EN), international (ISO) standards, as well as some national standards, particularly in regard to the naming of products. However, each food manufacturer must have their own plant norms (recipes), according to which they produce the processed foods and specifies them on the label, in accordance with the technological standard (along with all necessary additional information about manufacturer, raw materials used, etc.). The information provided on the label is a form of civil law agreement between the manufacturer and buyer.

In recent years, tremendous attention has been directed towards extending the shelf-life and safety of consumption of processed meats. Healthy life concerns have also gained in importance to meat industry. Efforts are being made to reduce the content of fat, salt and curing mixtures’ ingredients (nitrite) in the products, as well as to restrict the residue components of smoke (in case of smoked meats).

2. Raw materials for the production meat products

Meat products are made from raw meat and fat materials and numerous types of add-ons and casings. The raw materials come from carcasses of animals for slaughter which were approved by the veterinary services as fit for human consumption. For security reasons, and to ensure long life of meat products, these raw materials should have appropriate microbiological quality (Reg. UE (EC) no 1441/2007). The basic meat and fat raw materials are:

- **elements** – muscles or muscle groups trimmed out of anatomical parts after subprimal cuts of half-carcasses and/or quarters,
- **trimmings** - pieces the size from several to a dozen centimeters, obtained as a result of trimming and processing of elements, with varying participation of adjacent fat and connective tissue
- **mechanically separated meat (MSM)** - the product obtained by removing meat from the tissues adjacent to the bone after their separation from the carcass, or from poultry carcases, using mechanical means, resulting in the loss or modification of the muscle fiber structure (Reg. EU (EC) No 853/2004). Qualitative parameters of the MSM depend to a large extent on the applied boning method (high or low pressure). Due to the limited technological applicability resulting from a high degree of fragmentation, and from the inferior water-binding capacity and microbiological quality and the oxidative stability, as well as from lower nutritional value than that of meat trimmed manually, MSM has been excluded from the definition of meat for the purpose of marking, and the scope of its application has been more narrowly defined as applicable exclusively to products subjected to heat treatment,
- **fats** - adipose tissue of varying degree of grinding, produced during subprimal cuts of half-carcases and further supplementary cuts of elements. Fats from jowl and belly strip, cutting fat and back fat have the highest technological usability. In industrial practice, fats is divided into
hard and soft fats, different in melting temperatures, which depends on the mutual proportions of saturated and unsaturated fatty acids. The kind and quantity of the raw fat materials used in the recipe largely determines the (sensory) quality of the products, their nutritional value and the cost of production.

- **pork skins** are obtained after separation of fat adjacent to the hide. For the manufacture of cold cuts, they are usually utilized in the form a collagen emulsion, obtained by curing pre-ground skin with ice,

- **offal** (liver, heart, kidneys, lungs, tongue) and **blood for consumption** (fresh, stabilized, blood plasma) are used mainly in the production of offal cold cuts.

The raw materials mentioned are generally used in processing in the chilled form. In larger quantities, also the MSM is deep frozen. The quality of the processed meats is largely determined by the quality and **technological suitability of meat, since this is their fundamental component.** It is primarily dependent on the participation of the muscular, adipose and connective tissues. The most important technological property of meat is the **capacity to bind,** which refers to the ability to absorb and maintain meat's own water, and the water added in the course of technological process, as well as the ability to emulsify and bind fat, to create a compact product block product (jellification). These characteristics are primarily subject to the amount and state of protein of the muscle tissue: collagen and myofibrillar proteins. Thanks to the binding, emulsifying and jellifying properties of muscle proteins, it is possible to obtain proper texture, sensory characteristics (including consistency, firmness, juiciness) and efficacy of meat products. The technological properties of raw meat material can be modified in the course of the technological process by applying mechanical treatments (such as grinding, massaging), adding salt and functional additives (e.g. phosphates) to improve the functional properties of muscle proteins.

The technological usability of meat varies, since it is a result of many factors, the most important of which are: the degree of completion of post-slaughter changes, technological defects, chilling of meat and microbiological state of the raw materials. Post-slaughter changes in the muscle tissue (rigor mortis and maturation) play an important role in the shaping the capacity of the meat to bind and keep water. As a raw material for processing, meat retains its best properties in a short time after slaughter, i.e. before the onset of rigor mortis (the so-called "warm" meat). However, for reasons related to the organization of production, the technology of warm meat is limited in use in industrial practice in the world, and the most commonly used raw material is the chilled meat (after the process of maturation). Contemporary meat market conditions cause frozen meat to gain an increasing share in meat processing. It has inferior technological properties and a shorter life than chilled meat. In order to ensure as high quality of frozen meat as possible, attention should be paid both to the quality of the raw material, as well as to the process of freezing and thawing.

### 3. Functional additives used in meat processing

In addition to the meat and fat raw materials, meat processing utilizes functional additives, understood to be the allowed **additional substances** and **food additives.** The purpose of their use is to ensure the appropriate quality, shelf life and health safety, and also to obtain the sensory appeal
desired by the consumer, and the availability of meat products. Many of them allow to improve the efficiency of technological processes and to reduce production costs.

Additional substances are not customarily eaten separately as food, and do not constitute common food ingredients, although may have nutritional value. The use of additives (in terms of quantity and extent of use in food) is governed by the legal provisions (Reg. EU (EC) no 1333/2008, Reg. EU no 1129/2010) and is subject to strict control (in Europe this function is exercised by the EFSA). The use of additives should be technologically justified, because by serving specific functions in the shaping of the quality of the finished product, they become its ingredients. They must therefore be listed among the ingredients of a meat product, specifying the name of the substance or its E symbol and its technological function.

Among additives used in the processing of meat, a lot can serve several functions simultaneously. In respect of the most important functions of additives, they can be divided into the following categories:

- **extending the shelf life of products**: preservative additives, i.e. those preventing adverse microbiological changes (mainly nitrates and nitrites used as curing compound or brine in the process of meat curing), antioxidants, i.e. those inhibiting the fat and pigment oxidation processes (mainly the ascorbic and erythorbic acids and their salts) and acidity regulators (such as lactic acid, lactates and citrates),

- **texturing agents**: thickeners, stabilizers, which include polysaccharide hydrocolloids (including caragens, locust bean gum, xanthan), modified starches, emulsifiers (mono- and di-glycerides of fatty acids). A special place in this group of authorized substances is held by phosphates, which, thanks to their specific effect on muscle protein, increase their water absorptiveness and improve the binding and emulsifying properties. The effect of their activity is the improvement of texture of the product, stabilization of color and fat emulsion and the increase of production effectiveness,

- **sensory characteristics formation**: these highlight or enhance the natural or added through the technological process sensory characteristics of processed meat products. These agents include flavor enhancers, i.e. not having their own taste, but having the property of strengthening and extension of the gustatory sensations (including monosodium glutamate, nucleotides of guanosine and inosine acids) and color agents (including curcumin, cochineal extract, paprika extract, caramel), used in the processing of meat only in specific cases.

The ingredients added to food (also known as non-meat supplementary materials) are the substances other than food additives, the use of which is not a matter of health objections (do not require marking with the E symbol). Their use in the course of the technological process is carried out in accordance with good manufacturing practice in order to obtain certain qualitative and technological benefits.

The greatest practical significance in the group of such ingredients added to foods have the following:
• salt - used in the production of all processed meats. It performs three important functions: technological (dissolving the myofibrillar proteins and increases their hydration), preservative (inhibits the growth of micro-organisms) and sensory (influences palatability of meat and enables to obtain the desired texture),

• preparations of vegetable proteins (mainly soy proteins) and animal proteins (milk proteins, collagen proteins, gelatin, blood plasma proteins) - thanks to their functional properties (such as the capacity to bind water, emulsify, jellify, fat absorption) they enable to achieve a consistent, repetitive quality of processed meat products, increasing production yield, as well as to model the consumer appeal, and the composition and nutritional value of the products (e.g. lowering cholesterol levels)

• carbohydrate components. potato starch, used as a filling and structuring component, and sugars (sucrose, glucose), whose direct impact lies in the shaping of the deliciousness (mitigation of saltiness), in the production of fermented sausages are they the medium for the development of micro-organisms,

• the components shaping forming the tastiness - natural spices and ready-made spice compounds designed for specific selections of meats; flavors (natural and nature-identical), smoke flavorings,

• enhancing additives, such as probiotics, prebiotics and bio-active plant substances - they are used to improve the overall value of certain categories of meat preparations.

4. Methods of meat and meat products preservation

Preservation of meat and meat products is aimed at slowing down of the process commonly referred to as spoilage, resulting from adverse microbiological, biochemical and chemical changes. At the same time, it is very important to maintain the good processing potential of raw meat material and the sensory characteristics of the finished product.

Preservation methods can be divided into the physical ones (the use of both low and high temperatures as well as non-conventional methods), chemical (curing) and the physico-chemical (salting and smoking).

The most commonly used method of extending the freshness of meat is chilling and freezing. Chilling, that is, the use of cooling temperature (positive, close to 0 degrees C), is applicable to reduce the temperature of the carcasses of animals immediately after slaughter (from about 38°C to below 7°C). The chilling process and the related process of temperature lowering of the meat have the dominating influence on the rate of post-slaughter changes, and a co-dominating influence on its culinary and technological quality. Chilling is also the last stage of the production of most processed meat products.

In the refrigeration conditions, the activity of micro-organisms and tissue enzymes is not inhibited completely tissue but only restricted. Therefore, meat trimmed out of carcasses, if it is not additionally secured, can only be stored in the cold store, at the temperature of 0-4°C a few days.
Meat carcases and half-carcases of pork, veal and sheep can be stored longer, on average up to 2 weeks, beef up to 3 weeks.

Even longer storage of meat is allowed thanks to freezing, i.e. lowering its temperature below 0, most commonly to about -18°C. At the ambient temperature of -18 to -22 °C, it is possible to store pork carcases for 10 months, while beef quarters for 15 months.

The basic physical phenomenon occurring during freezing is a phase transition of water into ice. Most of the physico-chemical changes that cause adverse effects in frozen muscle tissue and its components occurs in the temperature range from -1 to -10°C, thus, passing this temperature range is a fundamental principle to ensure the retention of proper quality of raw material quality after thawing. Freezing water in the meat reduces water activity below the limit tolerated by the majority of microorganisms.

In industrial practice, the following methods are used for freezing:

- ambiance - in the air stream (freezing tunnels), most often applied to carcasses, half-carcases and quarters, non-boned elements from primal cut and large size culinary elements,
- contact - through direct contact with cooled plates of the appliance; most commonly used for boned culinary elements,
- cryogenic - using liquefied gases (typically nitrogen); for freezing a large variety of meat and products of small dimensions, for example, hamburgers,
- immersion - through immersion in liquids with very low boiling point; used mostly in poultry industry.

If carried out incorrectly, the process of freezing exerts a negative impact on the quality of meat. Too slow freezing causes the formation of large ice crystals, increasing the amount of leakage after thawing the meat. An important factor limiting the storage life of frozen meat are the oxidative changes in fats, since - unlike other enzymes of the muscle tissue - negative temperature only slightly inhibits the activity of lipases.

The processing of frozen meat requires its thawing, which should be carried out in the conditions allowing to the largest possible extent for the recreation of the original characteristics of the raw material. An indicator of adverse qualitative changes during thawing is the size of the weight loss (under optimal conditions reaching 5%). Modern methods of thawing start to utilize the microwave thawing technique, whose main advantage is shortening the duration of the process.

Another method of preservation of meat is curing. The term "curing" denotes subjecting the meat to a (nitrate or nitrite) curing mixture and/or brine. Nitrite curing mixture (called curing salt) is a mixture of sodium chloride with sodium nitrite (usually in the proportions: 99.4% NaCl and 0.4% of nitrite).

The activity of nitrates and nitrites in the curing process, as very reactive chemical compounds is versatile, allowing to achieve the following objectives:

- create and fixate the reddish-pink color of cured meat,
- inhibit the development of certain micro-organisms,
• create flavor characteristic of cured meat,
• impede oxidation processes.

This is a very complex process, whose effect depends on many factors, such as the type of raw meat material and the content of heme pigments, functional uses of additives supplementing the process of curing and the curing method itself. The main purpose of meat curing is creating the reddish-pink color, stable even after heat treatment. From the chemical viewpoint, the color change is a result of the formation of derivatives of pigments: myoglobin (muscular pigment) and hemoglobin. In simple terms, it can be assumed that the intensely red color to the meat is a consequence of mainly the complex of nitric oxide complex, which forms from the nitrite reduction, with myoglobin; the complex being called nitrosyl myoglobin. When heated, nitrosyl myoglobin is denatured and becomes a pink pigment, nitrosyl myochromogen. In order to achieve the stability of the color of the cured meat, the extent of reaction of heme pigments to nitosyl pigments should be at least 50%.

Another desirable effect of meat curing is giving the meat and its products the so-called "curing aroma", i.e. a specific, desired by consumers, flavor quality.

The preserving action of nitrite consists in preventing the growth of many species of pathogenic bacteria, e.g. of the Salmonella family. The most important is the inhibition of growth of Clostridium botulinum and of the formation of botulinum toxin.

The extension of life of the cured meat products is also a result of the antioxidant properties of nitrite, a consequence of its oxidation reaction (consuming oxygen), the capacity to compound iron ions and form compounds of antioxidant capacity (e.g. S-nitrosocysteine).

In industrial practice, the following methods are used for curing:
• dry method - it consists in mixing the meat with a nitrite curing mixture, it is used to cure fine meat (intended for the production of sausages and other processed products); addition of curing salt is most commonly 2%, at the curing room temperature of 4-6°C, time 1-2 days,
• wet method - nitrite curing mixture and supplementary substances are added to the meat in the form of an aqueous solution (brine); immersion of meat in brine is now rarely used (mainly in the manufacture of products according to the traditional technology); curing large pieces of meat (e.g. for the boiled cold cuts) is performed with the injection method, in which brine is injected into the meat with a multiple injection needles, the injected meat material is usually subjected to massaging, in order to improve the efficiency of the process.
• combined method - first the meat is rubbed with curing salt, then immersed in brine.

The use of functional additives improves the efficiency of meat curing. The most commonly used for this purpose are the reducing substances: ascorbic and isoascorbic acids and their sodium salts, citric acid, GDL and sugars.

For security reasons, the size of the nitrite and nitrate addition to meat is restricted. A potentially adverse effect of the application of the process of curing of meat, affecting selected groups of processed meats, is the formation of N-nitrosamines.
It should not be forgotten that also salt has significant impact on the shelf life of processed meats, a substance which is quantitatively a dominant component of the curing mixture.

Smoking of meat and meat products involves saturating them with wood smoke constituents - obtained as a result of incomplete combustion of wood of deciduous trees in controlled conditions, and subsequent partial dehydration. Today smoking is aimed, above all, to form the color and flavor of the meat product in a way to satisfy the customer, and its role as a preservation process is diminishing in its original significance.

During the smoking process, simultaneous operation of heat and chemical compounds contained in cigarette smoke occurs. The effect of smoking depends on the temperature (smoking can be cold, warm and hot), the composition of smoke and the duration of the process (may last from several minutes to several days).

The preservative action of smoking is a result of the drying of the surface of the meat/product, and applying there smoke condensate containing numerous chemical compounds with acting bacteriostatically, bactericidally (formaldehyde, phenolic compounds, organic acids) and preventing oxidation (especially phenolics).

The provisions of food law specify the maximum content of benzo(a)pyrene as a tracer substance in smoked meat preparations (5 µg/kg of the product, as of 1.09.2014. -2.0 µg/kg). Currently, traditional smoking is being increasingly replaced by the use of smoke flavorings.

Heat treatment at high temperature is used for preservation and/or achieving suitability for human consumption of raw materials and semi-finished products. Meat technology utilizes various methods of heat treatment: cooking, steaming, roasting, frying, braising, canning. The selection criterion for a given method depends on the intended, specific product flavor and/or its stability.

The preservation of meat products benefits most from the appertization process, i.e. the process of heating meat products in air-tight packaging, used in the manufacture of canned food. Appert's canning method is related to the following methods: pasteurization, in which the products are heated to about 72-100°C, tyndalization, that is, 2-3 -fold pasteurization at 24 hour intervals, and sterilization, which involves heating canned meat products to over 100°C (most often 110-121°C). Sterilization is used in the production of most ranges of canned ground meat products, and pasteurization only for canning raw material with a lesser extent fragmentation (pasteurized hams). Application of the temperature above 100°C and an appropriately long time of heating allows to obtain a sufficiently large dose of heat, resulting not only in the de-activation of meat's own enzymes, but, above all, in the destruction of all vegetative forms of bacteria and, unlike pasteurization, also the survival structures.

In addition to the desired changes of sensory character, and the increased digestibility of meat and meat products, heating processes give rise to negative chemical and biological changes, such as the loss of vitamins and water-soluble proteins, denaturation of proteins, and oxidation of fat. The extent of changes depends on the chemical composition of the meat product, the method of heating and heat treatment parameters as well as on the absorbed heat dose.
Drying is a method of preservation applied only to the traditional products (e.g. jerky). However, industrial practice extensively uses semi-drying of sausages intended for long-term storage.

The traditional (conventional) methods of curing meat and meat products listed above are subject to continuous improvement, aimed both at intensification of the processes, and addressing the necessity to meet ever more stringent safety requirements. Among the many non-conventional methods of food preservation, the world’s meat processing industry already use on an industrial scale: high hydrostatic pressure and ionizing radiation methods. Despite the fact that they belong to non-thermal preservation methods, they allow for an effective destruction of pathogenic microflora.

In modern meat processing technology, the preservation of products using just one method is virtually not practiced. However, it has become common to use the so-called associated preservation methods, arising from the combination of various methods of preservation (both the established ones and the more modern) (the so-called "hurdles", that is, barriers for the development of microorganisms). Thanks to this, it is possible to use their synergistic interaction to obtain the desired effect of microbial stability at a much lower levels of hurdles' activity than with each of them used separately. Barriers to the development of micro-organisms are constituted by the "hurdles": physical (e.g., low and high temperature, modified atmosphere), physico-chemical (e.g. water activity, pH, nitrite, salt) and microbiological (e.g. starter cultures). In addition to the effect of microbiological stabilization of the product, all the "hurdles" are of paramount importance in shaping the generally understood quality of the finished product, including the nutritional and sensory value.

An examples illustrating the preservative result of the application of the concept of hurdles is the process of production of salami type sausage, in which, in the proper order and with varying degrees of intensity the following preservative actions are utilized, curing mixture, changes in the oxido-reducing potential, starter cultures, reduced pH and dehydration.

5. Technological production of meat products production

Blanched sausages and luncheon products

The process of the production of blanched (pre-cooked, boiled) sausages and luncheon products includes the following stages:

- assessment of the quality of the raw material, including the examination of veterinary documentation and hygienic condition,
- "dry" or "wet" curing,
- selection of material input - combination of the necessary primary and complementary raw materials in accordance with the recipe for the product,
- grinding (in the meat grinder) of meat and fat raw materials into particles of the required size. Most commonly between 5 and 20 mm, depending on the product,
- mincing, during which processes such as grinding, solving and extraction of myofibrillar proteins, emulsification of fat and mixing of ingredients occur. In the course of the mincing, the so-called sausage pseudo-emulsion is formed, which is a characteristic compound of protein and fatty components and water along with the organic and inorganic substances solved in it.
• mixing for even distribution of the individual components in the mass of the stuffing, used in the manufacture of sausages and luncheons of medium and coarse grind.
• stuffing the casings, or (natural or artificial) or filling molds with stuffing,
• embedding, whose purpose is to gravitationally position the stuffing in the casing, to complete the curing process and to dry the surface of the sausage bar.
• smoking - giving the products characteristic taste and smell qualities, as well as the brownish red or golden color so characteristic for the smoked products. Luncheon products are not smoked.
• Boiling (blanching, pre-cooking) or roasting, the geometric center of the sausage bar/luncheon blocks must reach the temperature of 70-72 °C,
• cooling - initially under the shower of cold water, down to the temperature of about 30 °C, and then, in air stream, down to about 4 °C.

**Raw maturing sausages**
The technological process of the production of raw maturing sausages (fresh) involves the following steps:
• The assessment of the raw material quality, particularly in terms of the presence of meat quality defects (PSE and DFD),
• grinding frozen or very chilled fat and meat and raw material. This enables to achieve the right texture of the ground pieces of meat and fat, and thus the characteristic appearance of the finished product in the cross section,
• curing, carried out in the course of mixing or mincing the stuffing,
• stuffing the casings (natural or artificial, varying caliber), permeable to water vapor and gases.
• Production and post-production maturation which takes place in air-conditioned rooms with controlled temperature, relative humidity and air circulation speed. During the maturation, beneficial changes in the quality of meat and meat products are taking place; the changes are consequences of the biochemical and physical transformations during which is the final quality of the product is established. During maturation, many processes take place, such as water evaporation, curing, microflora exchange, carbohydrates fermentation, and changes in the rheological properties of the stuffing. The effect of production and post-production maturation is the achieving of specific, characteristic and desired taste and smell values of raw maturing sausages.

**Cooked smoked meats**
The technological process of the production of cooked smoked meats includes the following stages:
• the assessment of the quality of the raw material in terms of color, texture, pH (no PSE/DFD defects) and hygienic condition,
• "wet" curing, with the immersive or injection method (depending on the quality of the meat, the composition of the brine and the expected yield of the finished product),
• massaging in order to enhance the texture of the meat and to extract some myofibrillar proteins (which constitute a "binder" which, during the heat treatment, holds and binds together meat pieces),
• shaping and lacing to give meat the proper shape, typical for a given range of smoked meats,
• smoking with smoke at the temperature of about 40-60 ºC. Smoking time is adjusted, taking into account: the required degree of smoking, smoke density, temperature of smoking treatment, the weights and dimensions of bars.
• cooking or roasting to produce the temperature no less than 68 º C (mostly 70-75 º C) in the geometric center of the piece.
• cooling - initially under the shower of cold water, down to the temperature of about 30 º C, and then, in air stream, down to about 4 º C.

Maturing raw smoked meats
The technological process of the production of maturing raw smoked meats involves the following steps:
• The assessment of the raw material quality, particularly in terms of the microbiological quality and the presence of meat quality defects (especially DFD),
• trimming and forming meat pieces,
• salting or curing with the "dry", "wet" and "combined" method. During the curing process (which can last between a few days and a few weeks) physical, chemical and biochemical changes occur which favorably affect the indicators of the quality of the product.
• maturation is carried out in air conditioned rooms, with control over the parameters such as temperature, relative humidity and air movement. This is the longest stage production, reaching as much as a few months. The biochemical changes of meat occurring during the maturation, especially affecting proteins and fats, lead to the production of products that shape the taste and smell profile, characteristic of this range of meat products. Smoking treatment gives the maturing raw smoked meats the distinct gustatory and aromatic qualities and extends the shelf life of the product.

6. Packaging, customizing, labeling and distribution of meat and meat products

The role of packaging of meat and meat products is the protection of the product from external factors, extension of shelf-life, adaptation of the portion sizes to the expectations of the customer, the best possible presentation of the product, facilitation of logistics activities (transport, storage and display) as well as promotion, information and advertising.

Recently, consumers have become increasingly interested in products which can be used as, or to prepare a single meal. This puts demands on the meat industry to prepare sufficiently small servings (slices, cuts) of meat and meat products and to package them in a way enabling them to be marketed in retail stores.
Of all industrially available packaging methods, meat industry mostly utilizes vacuum and modified atmosphere packaging (MAP).

In the vacuum packaging technology the packaging material closely clings to the surface of meat or meat product, and the air is removed almost completely. Lack of oxygen restricts the development of aerobic microflora and slows down the process of oxidation (rancidation) of fat, extending the shelf life of the product packaged in this way.

During the vacuum packaging, meat pigment, myoglobin (Mb) remains in the reduced form and the meat is characterized by dark red color. This is a correct and desirable color for the culinary meat packed by this method. After opening and removal of the packaging, the surface of the meat is reached by a large amount of oxygen, and after a few minutes the myoglobin is oxidated to oxymyoglobin (OMb), light red in color, appreciated by consumers.

MAP technology packaging involves the change in the composition of the atmosphere (or replacing the vacuum) around the meat or meat product with a properly crafted mixture of gases: carbon dioxide (CO$_2$), nitrogen (N$_2$) and oxygen (O$_2$). Carbon dioxide restricts the development of microflora, especially gram-negative rot bacteria, as well as yeast and mold. The inhibiting effect is achieved at the concentration of CO$_2$ in MAP packaging at the minimum level of 20%. This effect increases as the temperature of storage decreases. Nitrogen is an inert gas, which is used as a filler to 100% of the volume of packaging (it prevents the packaging from collapsing). Depending on the concentration of oxygen in the package, high- and low-oxygen MAP packaging are distinguished (high-oxygen, ultra-low oxygen MAP).

Meat establishments use the high-oxygen MAP (60-80% O$_2$ and 20-40% CO$_2$) technology for packaging of meat in the form of culinary single portion pieces (intended for retail sale), mainly due to the maintenance of the light red color of the meat, so attractive to the consumer (the pigment is in the form of muscular oxymyoglobin - OMb). In some countries (USA, Norway) a mixture of gases is also used which contains carbon monoxide (CO), a gas strongly inhibiting the development of microflora and having a favorable effect on the color of the meat (used in concentrations of 0.4% it causes the formation of long-lasting, light red carboxymyoglobin). Due to its toxicity and the possibility of masking the spoilage of the product (the color in this case is not an indicator of quality and freshness of the meat), it is not approved for use in the EU.

Ultra-low oxygen MAPS packing technology (preferably with 0% O$_2$, 20-30% CO$_2$ and 70-80% of N$_2$) is mainly used for packaging of meat products, including sliced ones, because it protects them from adverse changes in the quality and extends their shelf life (inhibits the development of microorganisms, mostly aerobic ones), and also provides a more attractive display to the product. When the culinary meat is packed using the ultra-low oxygen MAP technology, myoglobin (Mb) is in the reduced state and the meat is characterized by dark red color. Similarly, as in the case of vacuum-packing, after opening, the reduced myoglobin (Mb) transforms into the form of oxymyoglobin (OMb)-light red.

The basic principle of the storage of meat and meat products is the FIFO (first in, first out) principle: the products of a given group entering the store as the first, should also leave the store as the first.
At the stage of production, storage and distribution of meat and meat products, their quality and suitability for human consumption are conditioned by the continuity of the cold chain. Most meat products (culinary meat, meat products, excluding smoked meats and semi-dry sausages) require storage, transport and display under refrigeration at the temperature as close as possible to 0 ° C and not more than 7 ° C. The semi-dry products require storage, transport and exposure at slightly higher temperatures (12-18 ° C).

Single packaging products, collective packaging intended directly for the consumer, must be labeled. In addition to basic information about the product (name, net weight, best before date and the identification of the production batch), and the data allowing for the identification of the manufacturer, the label is an important means of communication of commercial information to the customer, about the commercial name of the product, the ingredients of the product (taking into account the quantitative content of the meat), storage requirements, as well as the technological function of the food additives. It is also a form of civil law agreement between the consumer and producer. The information on the packaging should therefore be provided legibly, not inconveniencing the consumer in understanding it. It should also ensure the proper use and handling of the product after its purchase, at the same time allowing to compare different products in the same product group (choice based on quality and price).