CASINGS

Casings are soft cylindrical containers used to contain sausage mixes (Fig. 314). Casings can be of **natural** origin or **artificial**. Natural casings are obtained from animal intestines derived from slaughtering. Manufactured artificial casings are made of cellulose, collagen or synthetic materials. Sausage fillings are mostly minced or comminuted meat mixes held together by the casings during further processing steps such as smoking, boiling, frying or roasting. In addition, casings also protect products during storage.

**Natural casings**

Natural casings are mainly derived from small and large intestines from **sheep**, **goats** and **pigs**, but also from **cattle** and **horses**. They

- are strong enough to **resist the pressure** produced by filling them with sausage mix
- are **permeable** to water vapour and gases, thus allowing fillings to dry\(^1\)
- **absorb smoke** for additional flavour and preservation
- **expand or shrink** firmly attached to the sausage mix and
- **can be closed** at the ends by tying or clipping.

Small intestines of sheep, goats and pigs are popular small calibre natural casings. They are processed in a way that makes them tender (**edible**) (see page 252) and are mostly eaten with the sausage (Fig. 323). Many other parts of the intestinal tract of slaughter animals can also be used for natural casings. Those casings are processed differently and have stronger and tougher casing walls. Due to their toughness they are generally **not considered “edible”** (although not unfit for human consumption) (Fig. 205, 320) and are usually peeled off before consuming the sausages.

\(^1\) Reduction in moisture content -“drying”- is only needed and desirable for raw-fermented sausages (see page 115).
In many parts of the world the **proper manufacture of sausage casings** from animal intestines is unknown. Intestines, if not used for human food, are often wasted. Many people in the livestock and meat sector are unaware that processing of intestines into natural casings for sausage production is relatively simple and can be a profitable business. If natural casings can be produced locally, this may help to reduce overall production costs. Even in remote or rural settings with no access to commercial casing suppliers, natural casings can easily be processed from intestines derived from local slaughter. The availability of locally produced natural casings will considerably facilitate rural meat processing but proper **advice** and **training** on casing preparation is essential (for technical instructions see page 253).

Anatomically the walls of the intestinal tract of slaughter animals consist of four layers of intestinal tissue. These layers from inside to outside are: Mucose membrane (I), submucose membrane (II), muscular layer (circular and longitudinal) (III) and serose membrane (IV). For natural casing manufacture, one or more of these layers are removed during casing processing depending on the type of casing (thin/thick, edible/non-edible) to be fabricated.

**Fig. 315: Animal small intestine, cross section**

From inside:

I   Mucose membrane with finger-like outgrowths for enlarged surface area ("slime")
II  Submucose membrane, firm-elastic layer mainly of connective tissue
III Muscular layer, the circular internal one, the outside one longitudinal
IV  Serose membrane (blue) thin coating covering the abdominal cavity from inside and surrounding all organs.

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1) Annual imports of natural casings into the EU are valued at US$0.5 billion.
Sheep and goat casings

From the gastro-intestinal tract of sheep and goats (Fig. 317) normally only the small intestines are processed to be used as casings for products such as fresh frying sausages, frankfurters, BBQ sausages, hot dogs and thin dried fermented sausages. These casings are processed in a way that they become tender enough to be easily chewed (see Fig. 316 and page 252). Usually they are not peeled off before consumption but eaten together with the sausage filling. Therefore

Fig. 316: Processing of casings from small intestines

Cross section through entire intestine

Casing (edible)
(casing not reversed; mucose membrane, muscular layer and serose membrane removed, remaining layer = submucose membrane)

Serose membrane
Muscular layer
Submucose membrane
Mucose membrane

Fig. 317: Gastro-intestinal tract of sheep

Natural casings from sheep:
Sheep casing (small intestines) (1)
Sheep fore-stomach and tripes (cleaned and scalded stomach) (2)
Sheep caps (3)
they are called “edible” in this context. All other natural casings are also edible in principle, but most of them are peeled off as they are too tough to be chewed.

**Processing of small intestines at medium- to the small-scale level**

The processing of natural casings must be started as soon as possible after slaughter, as bacterial spoilage of the intestines tissues sets in rapidly. For ease of processing it is recommended to start the operation while the intestines are still warm.

The small intestines are detached from adhering mesenteric (connective and fatty) tissue (Fig. 318, step 1). The intestinal content is removed manually (Fig 318, step 2). The empty casings are flushed with water and subsequently de-slimed by using either manual or electrically operated casing-cleaning machines. For this purpose, the small intestines are passed through a set of rollers to loosen the tissue layers (Fig. 318, step 3) and to remove the “slime”. “**Slime**” is the internal layer of the intestine, basically the internal (“mucose”) membrane (Fig. 315, I and Fig. 316). In the slaughtered animal this membrane disintegrates rapidly and can easily be removed. Because of its structure it is commonly known as “slime”.

The removal of the “slime” can also be done manually by using a tablespoon or a specially shaped piece of wood. With the spoon firmly pressed onto the intestine, and pulling the intestine through in its full length between spoon and finger, the internal (“mucous”) membrane can be loosened and removed. The loosened tissues inside the casing are pressed out manually (see Fig. 318, step 5.) and the remainder rinsed off with water. Parts of the outside layers (“serous” membrane) are automatically removed when detaching the small intestine from the mesenteric tissue (Fig. 318, step 1 and step 4). The rest of the outside layer and the intermediate (“muscular”) layer will be removed during the casing de-sliming and cleaning operation.

The remaining strong-elastic tissue is a layer composed mainly of connective tissues (“submucous membrane”) (Fig. 315 II, Fig. 316, Fig. 318, step 6, b2). This connective tissue membrane forms the edible **sheep casing**. Sheep casings are not reversed (turned inside out) during their processing. For completion of the processing, the casings are inflated for grading, flushed with salted water, stripped for water removal, dry salted (Fig. 318, step 7) and stored in a cool place, preferably in the chiller. In this form they can be stored for three months, preferably under storage temperatures not exceeding $+15^\circ$C. By no means should natural casings be frozen, as they would lose their elasticity and firmness.
The average length of the small intestine from sheep is 17 to 24 meters depending on the size of the animal. Sheep and goat casings for the international casing trade are produced in largely mechanized operations, usually packed in hanks (91.4m or 100 yards) and graded according to their diameter and colour coded as follows:

- 28/ + mm   green/white
- 24/26 mm   red/white
- 20/22 mm   blue/white
- 16/18 mm   yellow/white
- 26/28 mm   green
- 22/24 mm   red
- 18/20 mm   blue
- 14/16 mm   yellow

Sheep casings, as well as other natural casings are soaked in water before filling the sausage mix. This treatment removes part of the salt and the casing walls become more elastic, as their collagen fibers absorb water. Addition of organic acids, in particular lactic acid (2% to the water), also assists in this process.

**Fig. 318: Processing steps for small intestines**

1. **Step 1: Separation of the small intestines from mesenteric tissue**
2. **Step 2: Stripping out intestinal content**
3. **Step 3: Loosening of tissue layers using a small-scale manual casing cleaning machine**
Fig. 318: Processing steps for small intestines (continued)

Step 4: Removal of remaining parts of the serose membrane

Step 5: Removal of “slime” by using spoon (white arrow)

Step 6: Flushing of clean casings
The photo shows the remaining submucous membrane b1/b2 (“edible” casing)

a = unprocessed casing
b1 = processed casing (slimed and cleaned)
b2 = processed casing (slimed and cleaned and being flushed with water)
c = “slime” removed from inside of casing
d = tissue layers removed from outside

Step 7: Salting of clean “edible” casings for storage
Pig casings

Several parts of pig intestines are processed to casings (Fig. 321). The most important are the small intestines. The processing technique used is similar to the procedure for sheep casings. Hence they are also considered “edible” (Fig. 322, 323).

Small pig intestines, also called rounds, with an average length of 15 to 20m, are mainly used as casings for fresh sausages (e.g. fried sausages, Fig. 322), raw/cooked sausages and dried fermented sausages (e.g. chorizos) (see also pages 103, 115, 127).

Pig rounds are packed in hanks of 100 yards (91.4 m), consisting of 15 to 20 single casing strings of 18 ft each (5.5m), sorted according to their diameter and colour coded as follows:
- /26 mm yellow
26/28 mm yellow/white
28/30 mm blue
30/32 mm blue/white
32/34 mm red
34/36 mm red/white
36/40 mm green
40/ + mm green/white

**Pig middles** (large intestines with an average length of 3 m) and the cap (Fig. 324) are used as casings for coarse liver sausage (see Fig. 320) and sometimes also for salamis. The bung (last part of the gastro-intestinal tract with an average length of 0.8 m) is due to its strength and shape used as casing for products such as cervelat (finely chopped dry fermented salami) and fine emulsified liver paste. Also the bladder can be used for products such as black pudding or gelatinous meat mixes (see page 164, 166).

These parts of the pig intestines are stripped of their intestinal content and must be reversed (turned inside out), washed and slimed (removal of internal slimy cover, now situated outside due to reversing the intestine).
In contracts to the processing of “edible” sheep and pig casings from small intestines, only the mucose membrane is removed through “sliming” from the large intestines and most of the serosa will automatically be detached during separating from the mesenteric tissue. The casing wall is therefore composed of a submucose membrane and muscular layer. These casings are relatively strong and tough and are usually not eaten with the sausage (Fig. 320).

**Pig stomachs** can be processed in two ways. If the stomachs are to be incorporated into meat mixes for sausage, they are scalded before further processing. If they are used as casings, only a small opening is made, through which they are cleaned by flushing with plenty of clean water. Thereafter they are turned inside out and kept in salt. They are used as casing for precooked-cooked sausages such as gelatinous meat mixes (Fig. 205) and blood sausages such as black pudding (see page 164). Before being used they need to be soaked in warm water to regain elasticity and to wash out the adhering salt.

**Beef casings**

Several parts of the gastro-intestinal tract of cattle (Fig. 325) are used as casings in sausage production. Small intestines -“rounds”- have a typical circular shape and are used for stuffing sausages such as lyoner, liver and blood sausages and dried fermented beef products. Rounds are 40 m long and are normally readily available where cattle are slaughtered. They are used for all types of sausages in Muslim countries. The **middles** are around 7 m long and used for dried fermented and precooked-cooked sausages such as hunter’s sausage and coarse liver sausage. The **blind gut** is also used for precooked-cooked sausages and raw-cooked products such as large bologna etc. Their diameter varies from 76 to 102mm. **Beef bladders** are used for mortadellas and other specialities.

In preparation for processing, **beef rounds** are turned inside out and slimed. The mucose and serose membranes are removed from the intestines, leaving the submucose and muscular layer. The processing of beef small intestines does not remove the muscular layer (see Fig. 316) as it is the case when processing small sheep and pig intestines.

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1) If should be noted that from 2001 in the EU no beef casings can be processed but the cattle tract from duodenum to rectum must be condemned due to BSE concern. Certain non-EU countries are authorized to produce beef casings for the EU.
Although these natural casings are edible they are usually not eaten due to their tough casing walls. After submerging the casings in water and thorough washing, the beef rounds are calibrated, tied and salted. Salted rounds are marketed in sets of around 100 yards (91.4m), each set containing a maximum of five pieces.

The **beef middles** are separated from the mesenteric fat (ruffle), flushed out with water, trimmed free of fat, turned inside out, slimed and salted. Beef middles include the “straight” casing (long, not curved part) and are packed in sets each measuring about 17m after salting and composed of 5 pieces. Beef middles (narrow end, wide end and fat end) are used as containers for different salamis and other large-diameter sausage products.

**Beef bladders** are washed, turned inside out and either salted or inflated with air and dried, before they are used for different sausage specialties. Beef bladders are usually graded in large, medium and small sizes.

**Recommended treatment of natural casings**

Natural casings are usually available and best stored dry-salted. Prior to the filling of sausage mix into such kind of casings all the adhering salt must be washed off with cold water. Dry-salted casings need to be then soaked in water for several hours (3-5 hours in lukewarm water or over night in cold water). Soaking in water does not only remove remaining salt but also serves to make the connective tissue fibres of the casing wall more elastic in order to optimally enclose and hold the sausage mix to be filled. Addition of lactic acid (2%) to the water can support this process further.
An alternative way of storing natural casings is in saturated salt solutions. This is the ready-to-fill natural casing type, as it requires only brief soaking periods ranging from minutes to up to one hour, and proper rinsing. This type must always be stored chilled.

**Recommended periods for soaking in water**

*Dry salted natural casings:*

<table>
<thead>
<tr>
<th>Type</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>General</td>
<td>10-12 hours</td>
</tr>
<tr>
<td>For pig large intestines</td>
<td>up to 24 hours</td>
</tr>
<tr>
<td>For cattle intestines</td>
<td>5-10 hours</td>
</tr>
</tbody>
</table>

*Ready-to-fill natural casings (stored in saturated salt solution)*

<table>
<thead>
<tr>
<th>Type</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>General</td>
<td>maximum 10-60 min.</td>
</tr>
<tr>
<td>For large pig intestines</td>
<td>2-3 hours</td>
</tr>
</tbody>
</table>

**Transport and storage of natural casings**

The storage periods for natural casings depend on the storage temperature. Dry-salted casings in closed containers, which also protect them against light impact causing fat-rancidity, can be stored at 6-8°C from six months to 3 years. Storage periods are reduced with higher storage temperatures. Adhering fat reduces the shelf-life.

The casing industry has established the following minimum requirements regarding storage and transport:

<table>
<thead>
<tr>
<th>Type</th>
<th>Temperature</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry-salted</td>
<td>maximum +15°C</td>
<td>at least 3 months</td>
</tr>
<tr>
<td>Ready-to fill</td>
<td>maximum +10°C</td>
<td>at least 4 weeks</td>
</tr>
</tbody>
</table>

(saturated salt solution)

**Sensory and hygienic quality**

The principle for optimal natural casing production is to start processing the casing as soon as possible after slaughter. Intestines should ideally be processed when still warm as they are easier to manipulate (cleaning, sliming, washing) and bacterial growth can still be contained. The subsequent salt treatment, usually dry salting, will create high salt concentrations in the casing tissue, which easily reach the concentration of 15%, at which bacterial growth is halted (see page 33).

Some countries have established requirements for imported natural casings most of which derive from developing countries. A summary of such requirements is given hereunder:
Sensory quality:

Odour: Free of signs of putrefaction
       No rancidity
       No sour (acidic) smell

Appearance: Colour may vary from white to pink to grey

Microbiological norms (per gram)

<table>
<thead>
<tr>
<th></th>
<th>Fully acceptable</th>
<th>Critical numbers (not to exceed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total aerobic colony count</td>
<td>&lt;10^5</td>
<td>5 x 10^6</td>
</tr>
<tr>
<td>Enterobacteriaceae</td>
<td>&lt;10^2</td>
<td>1 x 10^4</td>
</tr>
<tr>
<td>Staphylococcus aureus</td>
<td>&lt;10^2</td>
<td>1 x 10^3</td>
</tr>
<tr>
<td>Clostridium (sulphite reducing)</td>
<td>&lt;10^2</td>
<td>1 x 10^3</td>
</tr>
</tbody>
</table>

Artificial (manufactured) casings

Artificial casings were developed at the beginning of the 20th century when, in some countries, the supply of natural casings could no longer cope with the demand for such natural casings from the growing meat industries. Following the development of highly automated sausage filling equipment, artificial casings proved to be better suited to those systems, mainly due to their uniformity.

Also from the hygienic point of view, there were certain advantages to artificial casings as the microbial contamination is negligible, refrigeration is not needed and there are no spoilage problems during transport and storage. Nowadays, for wide sausage calibres, artificial casings are the material of choice, while for smaller calibre products, artificial and natural casings remain equally important.

According to their structure and composition of material, artificial casings can be subdivided into

1) casings made of natural materials, with two groups:
   a) casings made of organic plant material, namely cellulose
   b) casings made of animal by-products, namely collagen

2) casings made of synthetic substances deriving from thermoplastic materials (“synthetic casings” which can be subdivided in “polymer casings” and “plastic casings”).

1) There are also casings made from textiles or co-extruded coatings based on alginate used for special products. They are not discussed here.
Cellulose casings

Cellulose as a natural material derived from wood or cotton has proven to be suitable for sausage casings as it is:

- mechanically resistant
- widens when soaked in water and shrinks when dried (which exactly meets the requirements for a tight and smooth casing without formation of wrinkles on the sausage surface)
- permeable for gases, smoke and water vapour

Simple thin cellulose casings are used as so called peeling casings for frankfurter type sausages. The batter is filled into such casings (calibre range 12-42 mm) and portioned. Thereafter the products undergo smoking and cooking (at 74°C), which causes the build-up of a firm layer of coagulated protein under the casing. After this heat treatment, the cellulose casings are removed and the sausages maintain their shape due to the firm external layer of coagulated protein. As ready-to-eat sausages do not have a casing, they are also known as “skinless sausages” (Fig. 326, 327, 328).

Cellulose casings are not suitable for larger sausage calibres as frequent breakages may occur due to rupture of the cellulose wall. In order to solve this problem, fibrous casings were developed. Fibrous casings are cellulose casings reinforced with strong cellulose fibres. These fibrous casings are resistant enough for large sausage calibres and still suitable for smoking (Fig. 329).

As a further step in the development of strong fibrous casings for large calibres, a layer of synthetic material, (e.g. PVDC) was added to the inside or outside of the casings (coated fibrous casings). The coating made the casing mechanically very resistant and created a complete barrier for gases, i.e. no evaporation losses can occur (Fig. 330).

However, fibrous casings with an inside or outside synthetic coating cannot be used for products to be smoked, as no smoke penetration is possible, and for products to be dried and fermented, as no water vapour evaporation is possible. They are mainly used for cooked sausages of the raw-cooked and the precooked-cooked type. The main advantage of coated fibrous casings for cooked sausages is the casing wall tightly enclosing the sausage mix and the easy peeling. As smoke does not penetrate through coated fibrous casings, smoke flavour can be added during manufacture of the sausage mix if desired.
Fig. 326: Products in transparent cellulose casings (cal. 22) (after filling and before smoking/cooking)

Fig. 327: Product in red coloured cellulose casings (cal. 22) used to transfer colour to sausage surface

Fig. 328: Sausage after removal of peeling casing (middle); removed casing (left); peeling casing still on (right)

Fig. 329: Fibrous casings (medium calibres)

Fig. 330: Coated fibrous casings
Collagen casings

This type of casings is fabricated from collagen, which is obtained from the corium layer of selected split cattle hides. The collagen-rich tissue is homogenized under high pressure, ring-extruded (hose-shaped) and hardened and results in a mechanically strong casing. Collagen casings are permeable for smoke and water vapour. While wide calibres must have a relatively thick casing wall as increased stability is required, small calibres can be made with relatively thin casing walls. As collagen is an animal tissue fit for human consumption, the thin collagen casings are easy to chew and “edible”. They are an alternative to replace natural sheep, goat or thin pig casings (page 251, 255). The advantages of collagen casings are their standard diameter and strength and that they can be “shirred” i.e. folded together, in long lengths and used for manual or automatic filling stations without pre-soaking in water (Fig. 331).

Traditionally many consumers still prefer frankfurter type sausages in the natural casing, although with recent advances in edible collagen casings there is not much difference between both types terms of in tenderness and mouth-feel.

The edible collagen casings are also used for fried sausages (including the typical breakfast sausages) and small calibre dry sausages such as beef sticks, etc. Collagen casings of 32 mm and above are not intended to be eaten as part of the sausage, they have to be peeled off. They can be used for most fresh sausages, raw-cooked and smoked sausages or raw-fermented sausages (Fig. 332).

1) For leather fabrication the middle portion of the cattle hide, also called corium, is used. The corium can be separated by using splitting machines in up to three layers for leather fabrication. Tissues from the corium middle layer are used for production of collagen casings.
Synthetic casings

These casings are made of synthetic thermoplastic materials (Fig. 203, 333, 334). Suitable materials are Polyamide (PA), Polyethylene (PE), Polypropylene (PP), Polyvinylidenchloride (PVDC) and Polyester (PET).

While previously only synthetic casings from individual synthetic substances (mono-materials) could be fabricated, recently developed co-extrusion\(^1\) techniques can be used to produce casings composed of combinations of several synthetic materials. Synthetic casings can therefore be manufactured with tailor-made properties.

The resulting casings are **mechanically strong**, relatively **heat resistant**, **impermeable** for smoke, gases and water vapour. Synthetic casings are particularly well suited for:

- Sausages with larger calibre
- Sausages where water vapour losses are not wanted
- Sausages to be cooked at relatively high temperatures
- Sausage ends to be clipped
- Sausages with long shelf life and good preservation of taste and flavour (prevention of rancidity, discoloration, flavour losses)

The latest development in synthetic casings are casing walls consisting of two to five layers of synthetic material with extreme barrier properties for gases and temperature resistance from -18° to 105/121°C. They are suitable for production of sausages with long shelf life as they can be mildly sterilized and stored frozen if necessary.

Synthetic casings cannot be used for products which have to undergo drying, ripening and fermentation, such as dry sausages, as the casings are impermeable for gases and water vapour.

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1) Co-extrusion is the combination of thin layers of different synthetic materials, which are fused during the extrusion process.
PACKAGING OF FRESH AND PROCESSED MEAT

The function of packaging is to surround or wrap meat products with suitable protective material (Fig. 335). Packaging materials were in the old days simple natural materials, e.g. leaves, but nowadays exclusively manufactured materials such as paper or synthetic films.

Purpose of packaging

The basic purpose of packaging is to protect meat and meat products from undesirable impacts on quality including microbiological and physio-chemical alterations. Packaging protects foodstuffs during processing, storage and distribution from:

- contamination by dirt (by contact with surfaces and hands)
- contamination by micro-organisms (bacteria, moulds, yeasts)
- contamination by parasites (mainly insects)
- contamination by toxic substances (chemicals)
- influences affecting colour, smell and taste (off-odour, light, oxygen)
- loss or uptake of moisture (evaporation or water absorption)

Adequate packaging can prevent the above listed secondary contamination of meat and meat products. But the further growth of microorganisms, which are already present in meat and meat products, cannot be interrupted through packaging only. To halt or reduce microbial growth, packaging has to be combined with other treatments, such as refrigeration, which will slow down or stop the further growth of microorganisms, or with heating/sterilization, which will reduce or completely eliminate contaminating microorganisms.
The packaging procedure results in an inner package, where the packaging material is in direct contact with the product. In some cases it is combined with an outer package often a cardboard box, or other materials.

There are various synthetic packaging films available for the inner packaging, e.g. transparent or opaque, flexible or semi-rigid, gas proof or permeable to certain gases. These materials are selected to serve specific purposes, such as protection from unwanted impacts or attractive presentation.

**Requirements for packaging materials**

A range of synthetic materials suitable for meat packaging are available mainly in the form of plastic films\(^1\) or foils.

Packaging films must be/have:

- flexible
- mechanical strength
- light weight
- odourless
- hygienic (clean and toxicologically harmless)
- easy recycling
- resistance to hot and cold temperatures
- resistance to oil and fats
- good barrier properties against gases
- sealing capability
- low-cost

**Barrier against gases**

Good barrier properties against oxygen and evaporation are the most important features in order to ensure:

a) Exclusion of oxygen

Air contains about 20 percent oxygen. Oxygen negatively affects unpackaged meat and meat products during prolonged storage periods. It changes the red meat colour to grey or green and causes oxidation and rancidity of fats resulting in an undesirable off-flavour.

\(^1\) Oil is the raw material for plastics, 4% of the annual production of crude oil is used for making plastics.
The oxygen permeability of films used for the packaging of meat products varies. The lower the oxygen permeability the more efficient the protection of product quality. The best protection will be achieved using **oxygen-proof** packaging films together with vacuum packaging of the product (see page 271). This ensures that practically no oxygen remains in the package and no oxygen will penetrate from the air into the packaged product.

While oxygen is generally undesirable in packages of meat and meat products, there is one exception where **oxygen-permeable** foils are desirable, namely for fresh ready-to-sell meat portions in self-service outlets. In this specific case the utilization of oxygen-permeable foils produces a desirable bright red meat colour (see page 269 “Fresh Meat Packaging” and page 276 “Modified Atmosphere Packaging”)

b) Prevention of evaporation of product moisture

Fresh meat or fresh sausages, cooked ham, etc. have a relatively high moisture content and will suffer considerable weight and quality losses by evaporation and drying during storage if such products remain unpacked. The packaging material must therefore be sufficiently **water-vapour-proof**.

**Barrier against light**

The prolonged exposure of meat and meat products to daylight or artificial light accelerates unattractive **colour changes**, **oxidation** and **rancidity** because light provides the energy for these processes. Transparent packaging films normally used for meat products allow attractive product presentation as the packaged product is visible. However, such films provide no protection against light impact. Normally products in transparent packaging films are sufficiently protected when stored in the dark or moderate light conditions. For light sensitive products or products exposed to strong light, coloured or opaque films (Fig. 336) should be used. Films laminated with aluminium foil (Fig 337) are very effective.
Sealing capability

Some packaging materials are required to have good thermoplastic properties. They are heat sealable, which means that two of these films, put closely in contact to each other under slight pressure and with simultaneous high temperature application, will melt or seal together along the heated area, resulting in hermetically closed plastic pouches or bags.

Types of packaging films

Practically all films used for meat packaging derive from synthetic “plastic” materials.

Cellulose, which is not a synthetic but a natural material derived from wood, was formerly widely used in the form of transparent films. It is now no longer of great importance in meat packaging although still used for some specific purposes. However, cellulose is still important for the manufacture of certain kinds of artificial sausage casings (see page 261).

The most common synthetic materials used for meat packaging are:

- Polyethylene (PE) (oxygen +, water vapour -)
- Polypropylene (PP) (oxygen +, water vapour -)
- Polyvinylchloride (PVC) (soft) (oxygen +, water vapour -)
- Polyester (PET) (oxygen ±, water vapour -)
- Polyamide (PA) (oxygen -, water vapour +)

+ = relatively permeable
- = relatively impermeable

Polyvinylidenchloride (PVDC) used as barrier plastics
Ethylenvinyl alcohol (EVOH) (see Fig. 342B)

Foils made from the above synthetic materials are selected based on their different properties related to oxygen and water vapour.

For the various purposes in the meat industry packaging films can be divided into

- Single-layer films
- Multi-layer films
Single-layer films

One common use of single-layer films (Fig. 338, 339) is the wrapping of meat pieces, processed meat products, bone-in or boneless meat cuts or even entire carcasses. These films are usually self-adhesive, i.e. they cling together -"cling film"- in the overlapping areas. Hence they provide good protection from external contamination and to some extend from evaporation, but no protection from oxygen, as they are not hermetically closed or sealed packages. Foils with good self-adhesive properties are PE, PA, PVC and PP.

Another important utilization for single-layer films is in freezer storage. For meat blocks, meat cuts or smaller portions of meat or meat products, single-layer films are stretched tightly around the meat surface before freezing. The tight film prevents evaporation losses, which occur during freezer storage of unpacked products. The film is in tight contact with the products surface, in order to avoid evaporation, ice formation and freezer burn at non contact spots (Fig. 340). Suitable cold resistant films for freezer storage are PA or PE.

One specific utilization for single-layer films is the wrapping of chilled meat portions for self-service outlets (supermarkets, etc.) (Fig. 341). Those meat pieces (beef, pork or chicken) are placed in a hygienic cellulose or plastic tray and tightly wrapped with single-layer plastic film. The ends of the foil are overlapped at the bottom side of the tray, where they firmly cling together. Films to be used should have low water vapour permeability to avoid the drying out of the meat during storage. But for making...
Packaging of fresh and processed meat

attractive to customers, such meat needs to retain an attractive bright red meat surface colour (oximyoglobin) (see page 7) especially in the case of fresh portioned beef. For this reason the plastic foils to be used shall have a high oxygen permeability so that the oxygen of the air can react with the myoglobin of the meat and form the bright red oximyoglobin. Oximyoglobin is not a chemical compound but a loose aggregation of oxygen to the red meat pigment myoglobin, which keeps meat bright red for a number of hours. Suitable single-layer films for fresh meat packaging are PE or soft PVC. Formerly cellulose films were also used, which have the same permeability pattern but are less self-adhesive and the overlapping ends do not cling together very well.

Multi-layer films

Practically all the other films used for meat packaging are designed as strong oxygen and water-vapour barriers. In order to fully achieve these requirements, films with good barrier properties for oxygen and water vapour respectively are combined.

**Fig. 342: Typical multi-layer films (a = two layers, b = three layers)**

- **Layer A:** Outside layer (mechanically strong, gas barrier to oxygen)
- **Layer B:** Middle layer (barrier to oxygen)
- **Layer C:** Inside layer = sealant layer (capable of being melted and welded under pressure to the sealant layer of the opposite sheet of the bag/pouch, serves also as barrier to water vapour)

A very efficient combination is **PA/PE**. **PA** is used as the outside layer for example for films for vacuum bags. **PA** is relatively oxygen proof but permeable to some extend to water vapour. **PE** has the opposite properties, it is water vapour proof but permeable to oxygen. The combination of both renders such a multi-layer film very tight against oxygen and water vapour evaporation. Moreover, the PE used as the inside layer has good thermoplastic properties and is therefore well suited for heat sealing. The **PA/PE** combination is the most simple
structure for a multi-layer film (Fig. 342a). The packaging industry has refined the systems by introducing additional layers which serve as strong oxygen barriers (Fig. 342b).

Sealant layers consist mostly of Polyethylene (PE) or Ionomer (I) (Fig. 345, 346, 347). Outside layers may be Polyamide (PA), Polyester (PET) or Polypropylene (PP). Barrier layers for oxygen are made of Polyvinylidenechloride (PVDC) or materials with similar properties (see page 268).

Vacuum bags, used for vacuum packaging machines (Fig. 343, 344, 350) are composed of two or more sheets of multi-layer films. By drawing the vacuum and sealing of such bags, the air is excluded from the package and the damaging effects of oxygen such as rancidity or discoloration of the packed products will be significantly slowed down or not develop at all. However, exposure to strong light may cause discoloration even under vacuum.
Processed meat products in slices or as entire pieces are packed in small to medium-size vacuum bags. For larger sized products, bags made of shrinkable films can be used where, after vacuum-packaging, the product in its package of synthetic film is sprayed with or dipped into hot water (80°C). The contact with the hot water causes the shrinkage of the thermoplastic film and results in tight impermeable wrapping of the goods. Shrink films may for example be composed as follows: PET/PA/EVOH/PO

Vacuum packaging for fresh chilled boneless beef cuts is mainly done to promote meat ripening. The beef meat cuts can remain for a number of weeks (maximum 3 months) in the vacuum bag, provided oxygen remains excluded and the storage temperature is kept at -1°C (which is just above the freezing point of meat). During these storage conditions lactic acid bacteria (which do not cause spoilage!) will inhibit the growth of most other bacteria, which results in the prolonged microbial stability. Beef becomes very tender during such extended ripening periods without losing much of its typical flavour (Fig. 349).
Fig. 350: Manual vacuum packaging machine – Phases of operation
Heat treatment or cooking for some meat products can be carried out in the package after vacuum-packing. Temperatures of 60°-80°C or even higher up to sterilization temperatures (above +100°C) can be employed for hams, sausages, etc. In these cases a pasteurization or sterilization effect of the uncooked packaged products is achieved and re-contamination avoided as long as the package is not opened.

For specific products such as entire sausages, semi-automatic vacuum-packaging can be employed. A bottom film is moulded according to the shape of the sausages by using heat and force (by compressed air or mechanical) (Fig. 351). These machines are called thermo-formers. The sausages are loaded (Fig. 351) and a rigid top film is sealed on after evacuating the moulded spaces. Individual product portions are cut apart along their sealing layers (Fig. 352).

A packaging method commonly used in larger meat industries is skin packaging. For this method the products are placed in the packaging machine, usually on a rigid film, which serves as the bottom layer of the final package. Another flexible film (top layer, which is heated for increased flexibility) drapes itself from above around the product, resembling a tight “skin” on the product surface avoiding wrinkles and purges. The skin-like coverage of the product takes place in a sealing station in the packaging machine, where the top and bottom film are sealed around the edges. Individual
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Packages are separated by cutting around the bottom seal perimeter (Fig. 353, 354).

The latest development in this sector is the “form-shrink” packaging technology. Products e.g. meat cuts, chicken carcasses, entire sausages, smaller portions of meat products, are placed between two shrinkable films, which are moulded without wrinkles around the goods. Sealing seams can be kept extremely small. This technology is very cost-effective in terms of usage of packaging films but requires high-tech equipment and is only of relevance for large-scale industries.

A useful technology is Modified Atmosphere Packaging (MAP) of meat and meat products. The packaging materials used are gas-proof multi-layer films composed for example of PE, PA and barrier layers. Rigid films may be used to mould cup or box shaped containers which are filled. A flexible lid foil is then sealed on (Fig. 355). MAP packaging can also be done for ordinary plastic bags/pouches. MAP packages are firstly subjected to a vacuum. A mixtures of gases is the introduced into the air-free space before sealing. The gas mixture usually contains nitrogen (N₂) and carbon dioxide (CO₂). N₂, which is also the major constituent of atmospheric air, is inert, i.e. it does not react with meat product components such as fat or myoglobin. Its function is to replace the atmospheric oxygen (O₂) and thus prevents O₂ induced negative impacts (see page 266). The other component of the gas mix, CO₂, has a protective function, as it inhibits to some extend the growth of bacteria and moulds.

The gas mixture commonly used is 20%-30% CO₂ and 70%-80% N₂. This is applicable for all processed meat products. If fresh meat pieces are to be packed in gas-proof packages instead of wrapping them with oxygen-permeable foil (see Fig. 341), the bright-red fresh meat colour can be achieved by adding oxygen to the gas mix to be injected.
into the package and replacing the N₂ content accordingly. As sufficient oxygen is needed to maintain the bright-red colour, gas mixes for fresh meat are usually composed of 70%-80% O₂ and 20%-30% CO₂.

**Skin- and MAP-packaging** are often too sophisticated for the small producers, but may be of increasing interest to medium-size meat plants. There are now small manual and semi-automatic packaging machines available (Fig. 356, 357, 358), which are designed for smaller throughputs. However, the utilization of those machines implies that the necessary types of synthetic films, and in the case of MAP-packaging, also the relevant gases, are available.