# RAW-FERMENTED SAUSAGES

## Definition

Raw-fermented sausages receive their characteristic properties (tangy flavour, in most cases chewy texture, intense red curing colour) through **fermentation processes**, which are generated through physical and chemical conditions created in raw meat mixes filled into casings. Typical raw-fermented sausages are **uncooked meat products** and consist of coarse **mixtures of lean meats and fatty tissues** combined with salts, nitrite (curing agent), sugars and spices as non-meat ingredients. In most products, uniform fat particles can clearly be distinguished as white spots embedded in dark-red lean meat, with particle sizes varying between 2-12mm depending on the product. In addition to fermentation, **ripening phases** combined with moisture reduction are necessary to build-up the typical flavour and texture of the final product. The need for moisture reduction requires the utilization of **water-vapour permeable casings** (see page 249, 261, 263). The products are not subjected to any heat treatment during processing and are in most cases distributed and consumed raw.

**Fig. 149: Raw fermented sausage products of different calibres and degrees of chopping**

## Biochemical processes in manufacture

Raw-fermented sausage products have been developed and produced for centuries in regions with moderate climates around the world. Traditionally, the fabrication took place during the cold season, as relatively low temperatures are required for fermentation, drying and ripening. At the end of the ripening phase, raw-fermented sausages, also known as "**dry sausages**", are considered **shelf-stable** even under higher temperatures. A sub-group of raw-fermented sausages are the semi-dry and/or spreadable products. Principles of manufacture of these semi-dry products are discussed at the end of the chapter.

In the past, when cooling facilities were not readily available, their shelf-stability made raw-fermented sausages very popular as an animal protein reserve for food security purposes. Nowadays, these products are fermented, dried and ripened in artificially climatized rooms or chambers and can therefore also be fabricated during warmer seasons and even in tropical climates.

In the specific case of raw-fermented sausages, **fermentation** refers to the breakdown of carbohydrates ("sugars") present in meat mixtures, mainly to lactic acid. Traditionally processors of raw-fermented sausages relied on the action of fermentation bacteria, naturally present in the meat contaminating flora. Relatively low temperatures (around 20°C) are instrumental in stimulating the growth of the desired **fermentation flora**, while the growth of the **spoilage bacteria** is suppressed. Conditions for spoilage bacteria become gradually more unfavourable, as the fermentation bacteria produce acids resulting in the decline of the pH-values in the product. The development of the desired fermentation flora also contributes to the **typical taste**, **appearance** and **texture** of raw-fermented sausages. An additional measure to control spoilage bacteria in the product is the controlled decrease of moisture (reduction of $a_w$) during fermentation and ripening. Spoilage bacteria need higher $a_w$ values than acid producing bacteria (see page 324).

These biological processes in raw-fermented sausages constitute a rare example where microbial activity can be useful. Another example is raw fermented ham. However, this biological process can get out of control, for example if temperatures in fermentation or ripening chambers are too high or if the contaminating flora is excessively numerous with an overwhelming share of spoilage bacteria. In such cases, fermentation bacteria will not sufficiently develop and the product spoils. This risk is minimized by the use of **fermentation and ripening chambers** with controlled air temperature and humidity favourable for fermentation and drying (Fig. 150, 151). The second measure is the use of **selected fermenting bacteria** (commercially produced microbial starter cultures), which are added to the sausage mix and develop the desired fermentation processes, until moisture contents reached are low enough to stop fermentation.

Raw-fermented sausages depend not only on fermentation to achieve the desired texture and flavour, but during their long ripening periods other biochemical and physical factors become increasingly important. Natural **fat alterations** (rancidity) take place and produce strong flavours. This process can be substantially slowed down by selecting suitable raw fat materials (preferably fresh pork back fat) and applying relatively low ripening and climatization parameters (e.g. 20°C and 75-80% rel. humidity). Prolonged ripening and drying also leads to **low moisture contents** with the consequence of more **concentrated flavour component** and **firmer sausage texture**. The water content of finished raw-fermented sausages is always below 35%, in many cases even less than 30%. This corresponds to an $a_w$ of 0.90 and below and makes the product shelf-stable. Under moderate climatic conditions and storage (e.g. 20°C and 70-75% relative humidity), the products have a prolonged shelf life of over one year.

Raw-fermented sausages have **moderate acidity** with pH-values in the range of 5.0 to 5.5. Some manufacturers still rely on their typical meat plant flora to initiate the fermentation process. The use of **starter cultures** has the big advantage that the initial biological process can be controlled/directed and growth of spoilage bacteria is reduced. Raw-fermented sausages may be produced with or without **smoking**. Un-smoked products are called "**air-dried**". The **ripening** and **drying periods** are determined by the sausage formulation and casing diameter. Ripening periods can amount up to 90 days, but most raw-fermented sausages are finished within 3-4 weeks. Typical examples for dry sausages with more or less prolonged ripening periods are the various types of salamis (Hungarian, Italian, Central European, Spanish chorizo) (Fig. 152).

**Fig. 150: Recently filled raw-fermented sausage being transferred to ripening chamber**

**Fig. 151: Raw-fermented sausage after 10 days in ripening chamber**

## **Principles of manufacture** (recipes page 394 – 399)

The manufacture of raw-fermented sausages at the small to medium scale meat industry level is outlined hereunder. These sectors often lack a full range of comminuting equipment and in particular equipment for accurate climatization during fermentation and ripening and therefore face more **technological** challenges than larger, well equipped industries.

## *Raw materials*

The processing of raw-fermented sausages is dominated by biological and biochemical processes and raw meat materials of **excellent hygienic quality** are a precondition for the correct functioning of such processes. Lean meat from a variety of **animal sources** such as cattle, pigs, horses, donkeys, camels, sheep or goats can be used. The lean meat can be from older adult animals, as water content and water holding capacity of such meat is lower, which supports the necessary drying processes during fermentation and ripening. All meat used must be chilled for some time to reach its **lowest ph-values**. Beef meat should have pH-values at 5.4-5.5, pork meat 5.7-5.8. All lean meats for raw-fermented sausages need extra **careful trimming** of sinews and softer inter-muscular fatty tissue. Remaining sinews will remain tough and are not desired by consumers.

In most products fresh chilled **pork backfat** is used as it is firm and dry and remains stable without pronounced rancidity even after prolonged ripening periods. Softer inter-muscular fatty tissue should not be used as it cannot be chopped to clearly defined particles and would result in somewhat blurred unclear appearance of slices of the final products. Soft fat also increases the risk of early rancidity. If fats from other species of slaughter animals are used, only firm body fats should be considered (see page 10, 46).

## Importance of bacteria

Bacterial starter cultures have a variety of functions including:

- Boosting acidity (decreasing pH)
- Intensify the curing colour (acid environment catalyses curing reaction)
- Counteract rancidity of fats (due to enzymatic impacts)
- Development of flavour and taste
- Texture improvement of ripened products (by supporting formation of protein gel in sausage mixes).

Over the years, mainly bacteria belonging to the groups of *Lactobacillus, Pediococcus, Staphylococcus and Streptococcus* have been identified and cultivated for **commercial starter cultures**, as they proved to provide the best results in terms of producing lactic acid, developing ripening flavour, and are generally harmless in terms of product spoilage and impact on consumers' health. Depending on the desired taste, texture and appearance of the product, **specific cultures** are selected. The use of Lactobacillus results in fast acidification to lower pH-values, the use of Pediococcus leads to slower and milder acidification. Selected Staphylococcus strains cause a speedy reduction of nitrite, stable curing colour and reduced risk of fat rancidity, especially in products fabricated with Glucono-delta-Lacton (GdL, see page 120).

In most cases **mixtures** from different strains are used in order to achieve the best product specific results, for example in sausages with normal diameters (35-70 mm) an even mixture of Lactobacillus and Staphylococcus can be used to achieve the product-typical flavour, texture and taste. In sausages with of larger diameter (70-100 mm), the starter culture mixture normally contains a lower amount of Lactobacillus and a higher portion of Staphylococcus, as these products need more time to reach microbial growth inhibiting moisture contents. The strong potential of Staphylococcus to stabilize curing colour and fats is helpful in this context.

### *Importance of salt, curing agents and sugars*

One of the main targets during fermentation and ripening of raw-fermented sausages is the **reduction of their water content**. The moisture to be reduced is exclusively from the muscle meat which has a water content of around 80%. The addition of **salt** lowers the $a_w$ value of the mix by absorbing water, which presents an initial hurdle for unwanted bacteria. Furthermore, in the presence of salt, salt-soluble proteins are extracted from the small lean meat particles after grinding and chopping. These solubilized or gelatinous proteins act like an adhesive between the interfaces of lean meat and fat particles in the meat mix. The result is an **increasingly firm structure** with progressive ripening and drying of the products. The average quantity of salt added to raw-fermented sausages should be between 26-30 g/kg (2.6-3.0%) but not below 26 g/kg (2.6%). It should be noted that the salt content in percent in the final products will always be higher than in the initial mix, as these products lose a substantial amount of water. Salt contents in final products can be from 3 - 4.5% depending on the initial salting.

In raw-fermented sausages, salt is also used as a carrier for the curing agent, normally **sodium nitrite.** This curing agent is not only responsible for the development of a typical **red cured meat colour**, but also has **bacterial growth inhibiting properties**, especially on some pathogenic bacteria (see page 68). In raw-fermented sausages with a slow decrease of pH-values and prolonged ripening periods, **nitrate** can also be used as a curing substance. The use of both, nitrite and nitrate results in similar colour and taste. The main difference is that nitrate must first be reduced to nitrite by bacteria, which is a time-consuming process and hence only applicable to long-term ripened products. The slowly progressing acidity in such sausages allows the bacterial breakdown of nitrate to nitrite. The following reduction of nitrite to nitrogen oxide (NO), which is the substance effective in the curing reaction, is a relatively fast chemical process (principles of curing see page 34). The use of nitrate, mixed with nitrite is favoured by some processors as it is associated with better colour and flavour.

From the technical point of view, the purpose of adding **sugars** is to facilitate and strengthen the fermentation by bacteria. Provision of a sweet flavour to counteract acidity in the final product is normally not intended. The bacterial breakdown of sugars results in the accumulation of lactic acid and in a low pH-value (acidification) as well as the development of a typical flavour. In order to support this process, lactic acid producing bacteria (starter cultures such as lactobacillus or pediococcus, see page 118) can be added to the sausage mix. Simple sugars such as dextrose or fructose support an early drop in pH-values as they are easily broken down by bacterial action. The breakdown of lactose is slower and takes longer. Often a mixture of different sugars is used. Another sugar-based additive is **GdL** (Glucono-delta-Lactone), which accelerates and intensifies the acidification process by reacting to glucono-acid in the presence of water (muscle tissue water). It is preferably used in semi-dry and/or spreadable products, which are not for long-term ripening and storage, but for consumption within a short period after production.

## Production methods

As a rule of the thumb, raw-fermented sausages are fabricated with 20-35% fatty tissue and 65-80% lean meat, from one or more than one animal species, e.g. beef and pork or pork only or beef only. Other variations are also possible. If **fatty tissue** other than pork back fat is used the percentages for the fat are usually lower. The **techniques of comminuting** of meat and fat for raw-fermented sausages differ from other meat products. Raw-fermented sausages may be composed of coarse, medium or tiny meat and fat particles (Fig. 152). The **degree of chopping** can be visualized by the size of the fat particles in the final product. Some traditional Mediterranean (Italian, Spanish, French, etc.) salamis are chopped coarsely (6-12mm), but the majority of raw-fermented sausages are chopped moderately (2-5mm). Only a

**Fig. 152: Different degrees of chopping (different fat particle size)**

few semi-dry and/or spreadable products are finely chopped (see Fig. 158).

In small to medium-sized processing, there are two methods of manufacture of raw-fermented sausage mixes, which basically differ by the method of comminution of the raw materials. Applying a simple comminuting method, only **meat grinders** are used to prepare the sausage mixes. In more advanced techniques **meat grinders** and **bowl cutters** are used.

Method 1: In small-scale operations with only **meat grinding equipment** available, production is restricted to ground sausage mixes. The lean meat needs to be thoroughly chilled (+1°C) or even slightly frozen. The fat portion should be cut into small and uniform dices (10-20 mm, domino chip size) and frozen (-12°C) in order to obtain clearly and evenly cut particles in the initial chopping of the sausage mix. Clearly cut particles of firm solid fat also avoid greasing of the casing from inside, which would make drying more difficult. Firstly, part of the lean meat is minced 3-5mm (approx. 30%) and the remaining lean meat is cut into small pieces (20-50 mm). The chilled meat pieces and frozen fat dices are thoroughly mixed with all additives (curing salt, sugars, starter cultures, spices, etc), before the minced meat portion is added and incorporated in the mixture. The entire mixture is now passed through the meat grinder (disc size 3-6 mm), packed into the sausage stuffer and stuffed into casings. Delays leading to warming up of the mixture need to be avoided as this would result in greasing during the stuffing.

For the stuffing, natural or artificial casings can be used. Typical natural casings, depending on the desired sausage diameter, are those derived from the small intestines of pigs, sheep, cattle or horses. Artificial casings used are fibrous or collagen casings. One important requirement for casings used for raw-fermented sausages is to closely adhere to the sausage mix not only after filling but also during the drying period when sausages shrink. The casings used must be water vapour permeable, otherwise no drying during fermentation and ripening can take place and the products would spoil. The required conditions are met by natural casings, and fibrous and collagen casings (see page 249).

Method 2: With a **bowl cutter** available, a different technology can be applied. With this method 50% of the lean meat material is minced (3 mm) and kept at 1°C. The remaining 50% of the lean meat is cut into pieces of 30-50 mm diameter and slightly frozen (-10°C). As per method 1, the fat is cut into small dices (preferably 10-20 mm, domino chip size) and also frozen (-12°C). Firstly, the large pieces of frozen lean meat are chopped. If starter cultures are used, they must be added at this stage. After several rounds of the frozen lean meat in the bowl cutter, the frozen fat is added together with the spices and sugars and chopping is continued at a medium speed until the fat has reached the desired particle size. Then the minced chilled meat is added under low chopper speed until an even distribution is achieved. In the next step, the nitrite curing salt is added and mixed at low speed for at least 6-8 rounds until a final temperature of around -5°C is reached. This mix temperature should not be exceeded in order to avoid the greasing of the interior of the filling funnel and casings.

When lean beef and pork is used for the above raw-fermented sausage fabrication, the beef should be chosen for the 50% lean meat portion to be minced, while the pork portion is preferably used frozen.

The sausage mix is packed into the sausage stuffer and stuffed into the casings as firmly as possible to avoid air pockets. Excessive air inside the casing will discolour the meat and reduce the shelf life of the sausage (Fig. 153). Selected natural or artificial casings can be used as above.

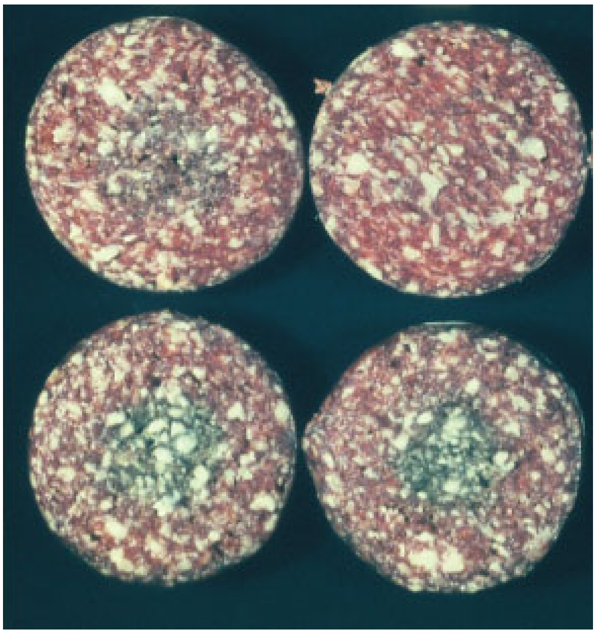

**Fig. 153: Air pockets caused by loose stuffing. Discoloration caused by enclosed air. Above right tightly stuffed, no discoloration**

## Drying / ripening

The freshly filled sausages are subjected to the crucial part of their manufacturing process, namely **fermentation**, **drying** and **ripening**. To this purpose they are transferred to either a climatized room or a modern combined smoking/drying chamber. Directly after stuffing, the sausage mix is still in the temperature range below zero (below freezing point). It is therefore advisable to include a **tempering period** of three hours at moderate room temperature before the sausages are transferred to the drying/ripening chamber (Fig. 150).

The immediate goal is to allow **moisture** release from the sausages and to initiate the fermentation processes, e.g. to provide proper growth conditions for the fermentation bacteria. A high relative humidity at the outset of the drying operation, which keeps sausage casings wet and soft, and the gradual lowering of the air humidity in the advanced stages of the process are the key factors to enable the moisture to migrate from the interior of the sausage to the outer layer.

**Temperatures** and **air humidity** inside the drying/ripening chambers need to be adjusted carefully to support the ripening/drying process. The temperatures in the ripening chamber are initially kept at +22°C and are slowly reduced to +19°C. The relative humidity decreases gradually from typical values of 92-94% on the first day to 82-84% before the sausages are transferred to the ripening/storage room. During ripening the temperature is maintained at <16°C at a relative humidity of 75-78%. These physical parameters are applied to ensure controlled bacterial fermentation resulting in lowering of pH to 4.9 – 5.4 and controlled gradual dehydration resulting in remaining moisture content in finished raw-fermented sausages as low as 30%. The duration of the drying/ripening process mainly depends on the diameter of sausages and type of sugars and starter cultures used (Table 6, see also page 320, 322).

If the humidity is kept **too high**, excessive surface moisture is retained usually resulting in increased bacterial growth on the surface, thus forming a slimy layer. If humidity is **reduced too fast** especially in the early stages of the process, a hard and dry crust is formed at the outer layer of the sausage. This crust is unable to adjust to the reducing diameter caused by continuous loss of moisture and as a result cracks will appear in the centre of the product (Fig. 154).

**Fig. 154: Raw-fermented sausage. Crack in centre as a consequence of excessively fast drying**

In the first phase of drying, the **red cured meat colour** is built up in the previously grey sausage mix. The curing colour progresses from the centre of sausage to the outer region. Fermentation processes start practically from the point of transfer of the sausages into the drying/ripening chamber. The **duration of the fermentation** varies depending on the calibre of the sausages, particle size of the mix, temperature and ingredients. In a typical raw-fermented sausage (particle size 3 mm, stuffed in casing of calibre 65, where a sugar mix and starter culture mix is used), the lowest pH-values should normally be reached within 5-6 days. The typical flavour and texture of the products are developed after completing fermentation and ripening (Fig. 157).

One problem during the ripening period can be **mould and yeast growth** on the sausage casings, even under substantially decreased

**Fig. 155: Undesirable mould growth**

**Fig. 156: Desirable mould growth. Casing surface inoculated with mould starter culture (below), without mould growth (above)**

humidity. If these occur they can be brushed off and reoccurrence or further growth can be stopped by exposure of the sausages to smoke. Early (day 3-5) application of **cold smoke** at temperatures below +22°C as an additional preservation measure is highly recommended. Of course, smoking is also intended to contribute to flavour and taste. Sausages are smoked from several hours to several days or even weeks according to their diameter and type of product.

One specific group of raw-fermented sausages are the "**air-dried**" type, as they do not undergo smoking. The air-drying combined with prolonged ripening periods produces a typical yeasty-cheesy flavour, which is often intensified by intended mould-growth on the casing surfaces. Not all moulds are suitable. Some species are even capable of producing poisonous substances, which may penetrate into the sausages (see page 359). There are several **cultures of selected moulds** (e.g. Penicillium) available, which serve as starter cultures for desirable mould growth. A watery suspension of such moulds can be applied onto the surface of the sausages. This suspension of moulds will adhere to the casing surface and grow over the course of the ripening period to a thin white-coloured mould overlay. These microorganisms are harmless from the health point of view but provide typical appearance and flavour to the sausages (Fig. 156).

**Table 6: Raw-fermented sausages of different calibres**
**Normal fermentation process assisted by starter cultures**

| Sausages 75 mm diameter | | | | | | Sausage 40 mm diameter | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Day | Rel. humidity in % | Temp °C | $a_w$ | pH | | Day | Rel. humidity in % | Temp °C | $a_w$ | pH |
| 01 | 92 | 23 | 0.95 | 5.80 | | 01 | 92 | 22 | 0.95 | 5.80 |
| 02 | 92 | 23 | 0.95 | 5.70 | | 02 | 91 | 22 | 0.94 | 5.70 |
| 03 | 91 | 22 | 0.94 | 5.40 | | 03 | 90 | 22 | 0.93 | 5.40 |
| 04 | 90 | 21 | 0.93 | 5.20 | | 04 | 88 | 20 | 0.91 | 5.10 |
| 05 | 89 | 21 | 0.92 | 5.00 | | 05 | 87 | 20 | 0.90 | 5.00 |
| 06 | 88 | 20 | 0.91 | 4.90 | | 06 | 86 | 20 | 0.89 | 4.90 |
| 07 | 87 | 20 | 0.90 | 4.80 | | 07 | 85 | 20 | 0.88 | 4.80 |
| 08 | 86 | 20 | 0.89 | 4.80 | | 08 | 84 | 19 | 0.87 | 4.85 |
| 09 | 85 | 19 | 0.88 | 4.85 | | 09 | 83 | 19 | 0.86 | 4.85 |
| 10 | 84 | 19 | 0.87 | 4.90 | | 10 | 82 | 18 | 0.85 | 4.90 |
| 11 | 83 | 19 | 0.86 | 4.90 | | 11 | 80 | 18 | 0.83 | 4.90 |
| 12 | 82 | 18 | 0.85 | 4.95 | | 12 | 78 | 18 | 0.81 | 4.95 |
| 13 | 81 | 18 | 0.84 | 4.95 | | 13 | 76 | 17 | 0.80 | 5.00 |
| 14 | 80 | 18 | 0.83 | 5.00 | | 14 | 76 | 17 | 0.79 | 5.00 |
| 15 | 80 | 17 | 0.82 | 5.00 | | 15 | 76 | 17 | 0.79 | 5.05 |
| 16 | 78 | 17 | 0.81 | 5.05 | | 16 | 76 | 17 | 0.78 | 5.05 |

Rel. humidity, Temperature } in ripening chamber

$a_w$, pH } in products

## Semi-dry sausages

These products (Fig. 158) are produced by **forced rapid fermentation**. Certain starter cultures (Staphylococcus for speedy reduction of nitrite, stable colour) are used in combination with GdL (Glucono-delta-Lacton). This boosts the growth of the desired bacterial flora (lactic acid bacteria) and drops the pH-value fast, resulting in the rapid formation of a protein gel and firm structure of the sausage, which allows slicing and cutting at an early stage. The initial fermentation and ripening period takes place at slightly higher temperatures (+24-26°C) than used for long-time ripened sausages and rarely exceeds 4-7 days. The low pH of 4.8 to 5.4 also supports the fast release of meat tissue water from the sausage, but because of the short production period, the final moisture content will not go below **40%**. The shelf life of such sausages is surprisingly long, up to one month, due to the accumulation of acids and smoke compounds. These products rarely spoil even in ambient temperatures but they may develop excessive acidity, hence **climatized** (<+18°C) or **refrigerated storage** is recommended, in particular in subtropical and tropical countries. Acidity in semi-dry raw-fermented sausages is relatively pronounced, which makes such products less attractive to consumer groups not familiar with acid foods. But they are popular in Europe ("Cervelats", "Mettwurst") or in North America ("Summer sausage”). The product name “summer sausage” was coined due to the fact that this product’s fabrication was possible by forced fermentation during the warm season and not only in winter.

A special type in the group of semi-dry sausages are the **spreadable raw-fermented sausages**. As the name implies, these products are designed to remain soft so that they can be used as a sandwich spread. For their production the same combination of starter cultures and GdL is used, but for a different reason. The formation of protein gel must be achieved rapidly before the final mechanical chopping step. The onset of gel formation must already develop in the semi-processed sausage mix and is destroyed again by additional chopping in order to retain a soft and creamy texture in the final product. For these products, softer fatty tissues can be used as they will further facilitate the spreadable texture.

**Fig. 157: Raw-fermented sausages. Long ripening period (50 days)**

**Fig. 158: Semi-dry fermented sausages. Short ripening period (10 days)**