CANNING / STERILIZATION OF MEAT PRODUCTS

Principles of food canning

Unlike pasteurized “cooked” meat products where the survival of heat resistant microorganisms is accepted\(^1\), the aim of sterilization of meat products is the destruction of all contaminating bacteria including their spores. Heat treatment of such products must be intensive enough to inactivate/kill the most heat resistant bacterial microorganisms, which are the spores of *Bacillus* and *Clostridium* (see page 95). In practice, the meat products filled in sealed containers are exposed to temperatures above 100°C in pressure cookers. Temperatures above 100°C, usually ranging from 110-121°C depending on the type of product, must be reached **inside the product**. Products are kept for a defined period of time at temperature levels required for the sterilization\(^2\) (see details on pages 293, 294), depending on type of product and size of container.

If spores are not completely inactivated\(^3\) in canned goods, vegetative microorganisms will grow from the spores as soon as conditions are favourable again. In the case of heat treated processed meat, favourable conditions will exist when the heat treatment is completed and the products are stored under ambient temperatures. The surviving microorganisms can either spoil preserved meat products (see page 354) or produce toxins which cause food poisoning of consumers, (see page 357).

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\(^1\) The acceptance of surviving microorganisms implies that strict cooling conditions for the storage of such products have to be observed. As heat resistant microorganisms are mesophilic or thermophilic, i.e. their growth is only possible in the temperature range of approximately 20-37°C, an uninterrupted cold chain in the range of \(0°-7°C\) will suppress their growth.

\(^2\) In this chapter only **fully sterilized meat products**, which can be stored under ambient temperatures, are discussed. So called semi- or three-quarter sterilized products, which require lower than ambient storage temperatures, are not considered as they are not particularly well suited for developing countries.

\(^3\) Heat treatment, which due to erroneous sterilization parameters used, did not inactivate all spores in the meat product is called “**under-sterilization**”. Another reason for the presence of viable microorganisms in canned food may be **recontamination** due to faulty sealing or faults of the containers. In these cases microorganisms penetrate into the cans after sterilization during the cooling phase in cold water or during handling and distribution of the cans.
Amongst the two groups of spore producing microorganisms (see page 277), Clostridium is more heat resistant than Bacillus. Temperatures of 110°C will kill most Bacillus spores\(^1\) within a short time. In the case of Clostridium temperatures of up to 121°C are needed to kill the spores within a relatively short time.

The above sterilization temperatures are needed for short-term inactivation (within a few seconds) of spores of Bacillus or Clostridium. These spores can also be killed at slightly lower temperatures, but longer heat treatment periods must be applied in such cases to arrive at the same summary effect of heat treatment.

From the microbial point of view, it would be ideal to employ very intensive heat treatment which would eliminate the risk of any surviving microorganisms. However, most canned meat products cannot be submitted to such intensive heat stress without suffering

- degradation of their sensory quality such as very soft texture, jelly and fat separation, discolouration, undesirable heat treatment taste and
- loss of nutritional value (destruction of vitamins and protein components).

In order to comply with above aspects, a compromise has to be reached in order to keep the heat sterilization intensive enough for the microbiological safety of the products and as moderate as possible for product quality reasons.

A method was developed for such a balance between food safety and food quality requirements by measuring and quantifying the summary amount of heat treatment to which a canned product is exposed during the entire sterilization process.

**Fig. 359: Cold point in cans with solid (a) and liquid (b) content**

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1) The exception are the group of thermophilic bacillus strains, in particular Bac. stearothermophilus, which are extremely heat resistant but need high storage temperature (>35°C) for growth. Even in case of survival of such strains they pose only a risk (spoilage of cans) if the storage temperatures are extremely high (35°C and above), which, however, may occur in tropical regions.
The amount of heat treatment applied to a meat product can be measured using the **F-value-concept** (see page 289). This concept is practiced in canning plants, in particular as part of the HACCP-system (see page 344). Small producers, who are not equipped to employ the F-value concept, are not excluded from producing properly sterilized canned goods. In these cases **established technical reference parameters** of sterilization temperatures and times to the type of product and to the size of the cans can be employed. The size and format of cans is of utmost importance for the speed of heat penetration. Temperatures to be achieved at the “cold point” (Fig. 359) of the can where the heat arrives last, are reached faster in small cans due to the shorter distance to the heat source than in large cans.

When comparing cans with the same bottom area (99 mm) but different height (36, 63 and 113 mm) (Fig. 360), heat penetration to the cold point of the high can (Fig. 360, c₁) takes twice the time as needed for the lowest can (a₁). These are approximate values, which can differ slightly depending on the materials filled into the cans. When comparing cans of same volume but different format (see Fig. 361), heat penetrates faster to the cold point of flat cans (a₂, b₂) than to compact square cans (c₂), although the content (volume) of all these cans is the same.

**Processes and equipment**
Process

The sterilization process in the canned product can be subdivided into three phases (see Fig. 385). By means of a heating medium (water or steam) the product temperature is increased from ambient to the required sterilization temperature (phase 1 = heating phase). This temperature is maintained for a defined time (phase 2 = holding phasing). In (phase 3 = cooling phase) the temperature in the can is decreased by introduction of cold water into the autoclave.

Autoclaves or retorts

In order to reach temperatures above 100°C (“sterilization”), the thermal treatment has to be performed under pressure in pressure cookers, also called autoclaves or retorts.

In autoclaves (retorts) (Fig. 362) high temperatures are generated either by direct steam injection, by heating water up to temperatures over 100°C or by combined steam and water heating. The autoclave must be fitted with a thermometer, pressure gauge, pressure relief valve, vent to manually release pressure, safety relief valve where steam is released when reaching a certain pressure (e.g. 2.5 bar), water supply valve and a steam supply valve. The steam supply valve is applicable when the autoclave is run with steam as the sterilization medium or when steam is used for heating up the sterilization medium water.

1) See table 16 showing the autoclave temperature and associated pressure (page 296).
Simple small autoclaves are usually vertical autoclaves (Fig. 362, 364) with the lid on top. Through the opened lid the goods to be sterilized are loaded into the autoclave. The cans are normally placed in metal baskets. The baskets are placed in the autoclave, either singly or several stapled on top of each other. Before starting the sterilization, the lid must be firmly locked onto the body of the autoclave. The autoclave and lid are designed to withstand pressures up to 5.0 bar (pressure/temperature relation see table 16). These types of autoclaves are best suited for smaller operations as they do not require complicated supply lines and should be available at affordable prices.

Larger autoclaves are usually horizontal and loaded through a front lid (Fig. 365). Horizontal autoclaves can be built as single or double vessel system. The double vessel systems (Fig. 363) have the advantage that the water is heated up in the upper vessel to the sterilization temperature and released into the lower (processing) vessel, when it is loaded and hermetically closed. Using the two–vessel system, the heat treatment can begin immediately without lengthy heating up of the processing vessel and the hot water can be recycled afterwards for immediate use in the following sterilization cycle.

If steam is used instead of water as the sterilization medium, the injection of steam into a single vessel autoclave will instantly build up the autoclave temperature desired for the process.

Another technology employed is rotary autoclaves in which the basket containing the cans rotates during sterilization. This technique is useful for cans with liquid or semi-liquid content as it achieves a mixing effect of the liquid/semi-liquid goods resulting in accelerated heat penetration. The sterilization process can be kept shorter and better sensory quality of the goods is ensured (Fig. 363, No. 2).
At the final stage of the sterilization process the products must be **cooled down** as quickly as possible. This operation is done in the autoclave by introducing cold water. The contact of cold water with steam causes the latter to condense with a rapid pressure drop in the retort. However, the overpressure built up during thermal treatment within the cans, jars or pouches remains for a certain period (Fig. 366). During this phase, when the outside pressure is low but the pressure inside the containers is still high due to high temperatures there, the pressure difference may induce permanent deformation of the containers.
Therefore, **high pressure difference** between the autoclave and the thermal pressure in the containers must be avoided. This is generally achieved by a **blast of compressed air** into the autoclave at the initial phase of the cooling (Fig. 367). **Sufficient hydrostatic pressure** of the introduced cooling water can also build up counter pressure so that in specific cases, in particular where strong resistant metallic cans are used, the water pressure can be sufficient and compressed air may not be needed. For the stabilization of metallic cans, stabilization rims (Fig. 368) can be moulded in lids, bottom and bodies.

**Types of containers for thermally treated preserves**

Containers for heat-preserved food must be hermetically sealed and airtight to **avoid recontamination** from environmental microflora. Most of the thermally preserved products are in metal containers (**cans**). Others are packed in **glass jars** or plastic or aluminum/plastic **laminated pouches**.

Most metal containers are **cans** or “tins” produced from **tinplate**. They are usually cylindrical (Fig. 369, 370). However, other shapes such as rectangular or pear-shaped cans also exist (Fig. 368, 380, 382). Tinplate consists of steel plate which is **electrolytically coated** with tin on both sides. The steel body is usually 0.22 to 0.28mm in thickness. The tin layer is very thin (from 0.38 to 3.08 µm). In addition, the interior of the cans is lined with a **synthetic compound** to prevent any chemical reaction of the tinplate with the enclosed food.

Tin cans consist of two or three elements. In the case of **three-piece steel cans**, they are composed of the **body** and **two ends** (bottom and lid) (Fig. 370). The body is made of a thin steel strip, the smaller ends of which are soldered together to a cylindrical shape. Modern cans are **induction-soldered** (Fig. 370) and the soldering area is covered inside with a **side-strip coating** for protection and coverage of the seam. The use of lead soldered food cans was stopped decades ago. Hence the risk of poisonous lead entering canned food no longer exists.
Two-piece steel cans have a lid similar to the three-piece cans but the bottom and body consist of one piece, which is moulded from a circular flat piece of metal into a cup. These cup-shaped parts may be shallow-drawn (with short side wall) or deep-drawn (with longer side walls) (Fig. 369, 371). However, the length of the side walls is limited through the low moulding ability of steel (example: tuna tins 42/85mm, i.e. side wall: diameter = 1:2)

Aluminium is frequently used for smaller and easy-to-open cans. Aluminium cans are usually deep-drawn two-piece cans, i.e. the body and the bottom end are formed out of one piece and only the top end is seamed on after the filling operation. The advantages of aluminium cans compared to tin cans are their better deep-drawing capability, low weight, resistance to corrosion, good thermal conductivity and easy recyclability. They are less rigid but more expensive than steel plate cans.
Glass jars are sometimes used for meat products but are not common due to their fragility. They consist of a glass body and a metal lid (Fig. 372). The seaming panel of the metal lid has a lining of synthetic material. Glass lids on jars are fitted by means of a rubber ring.

Retortable pouches, which are containers made either of laminates of synthetic materials only or laminates of aluminium foil with synthetic materials, are of growing importance in thermal food preservation. Thermo-stabilized laminated food pouches, have a seal layer which is usually PP (polypropylene) or PP-PE (polyethylene) polymer, and the outside layers are usually made of polyester (PETP) or nylon. They can be used for frankfurters in brine, ready-to-eat meat dishes etc. From certain laminated films, for instance, polyester / polyethylene (PETP/PE) or polyamide/polyethylene (PA/PE), relatively rigid containers (Fig. 374) can be made, usually by deep drawing. They are used for pieces of cured ham or other kinds of processed meat. Small can-shaped round containers are made from aluminium foil and polyethylene (PE) or polypropylene (PP) laminate (Fig. 373) and are widely used for small portions, particularly of sausage mix. PE or PP permits the heat-sealing of the lid made of the same laminate onto these containers, which can then be subjected to intensive heat treatment of 125°C or above. One advantage of the retortable pouches/laminated containers is their good thermal conductivity which can considerably reduce the required heat treatment time and hence is beneficial for the sensory product quality.
Cleaning of containers prior to filling

Rigid containers (cans, glass jars) are delivered open to meat processing plants, i.e. with the lids separate. During transport and storage, dust can settle inside the cans, which must be removed prior to filling the cans. This can be done at the small-scale level by manually washing the cans with hot water. Industrial production canning lines are equipped with steam cleaning facilities, where steam is blown into the cans prior to filling (Fig. 375).

Seaming of cans

After the can is filled with the product mix the can is sealed with a tight mechanical structure - the so-called **double seam** (Fig 376). The double seam, in its final form and shape, consists of three layers of lid (D, black colour) and two layers of body material (D, striated). The layers must overlap significantly and all curves must be of rounded shape to avoid small cracks. Each double seam is achieved in two unit operations referred to as “first operation” (A, B) and “second operation” (C, D).

**Fig. 376: Can seaming operation (schematic)**

**Fig. 375: Empty cans being cleaned by steam injection**
The can covered with the lid is placed on the base plate of the can seaming machine. The can is moved upwards while the seaming chuck (Fig. 376, 1) keeps the lid fixed in position. The pressure applied to the can from the base plate can be regulated and must be strong enough to ensure simultaneous movement of the lid and the can to avoid scratching-off of the sealing compound.

In the first operation the lid hook and body hook are interlocked by rolling the two into each other using the seaming roll with the deep and narrow groove (Fig. 376, A/B). The body hook is now almost parallel to the lid hook and the curl of the lid adjacent to or touching the body wall of the can. In the second operation, the interlocked hooks are pressed together by a seaming roll with a flat and wide groove (Fig. 376, C/D). Wrinkles are ironed out and the rubber-based material is equally distributed in the seam, filling all existing gaps thus resulting in a hermetically sealed container.

Design of seaming rolls

The seaming rolls for the first and second operations are designed differently in order to facilitate the respective operations. The seaming roll for the first operation has a deep but narrow groove to interlock body and lid hook (rolling the hooks into each other) (Fig. 376, A/B). The seaming roll for the second operation has a flat but wide groove to press the interlocked hooks together (sealing the seam) (Fig. 376 C/D). The different grooves of the first and the second seaming roll are shown in the pictures below. The first action (first roll) is rolling (interlocking) the hooks, the second action (second roll) is compressing (sealing) the seam (Fig. 378).
Meat products suitable for canning

Practically all processed meat products which require heat treatment during preparation for consumption are suitable for heat preservation. Meat products which do not receive any form of heat treatment before being consumed, such as dried meat, raw hams or dry sausages, are naturally not suitable for canning as they are preserved by low pH and/or low water activity.

The following groups of meat products are frequently manufactured as canned products:

- cooked hams or pork shoulders (Fig. 380)
- sausages with brine of the frankfurter type (Fig. 238, 372)
- sausage mix of the bologna or liver sausage type (Fig. 374, 381)
- meat preparations such as corned beef, chopped pork (Fig. 382, 383)
- ready-to-eat dishes with meat ingredients such as beef in gravy, chicken with rice (Fig. 239, 379, 384)
- soups with meat ingredients such as chicken soup, oxtail soup
Definition of F-value and practical applications

The need for safe but not excessive heat sterilization requires practical methods for the exact measurement of the amount of heat treatment received by a product. For the development of such a method the following physical facts have to be considered:

a) The amount of heat treatment applied to a product is the combination of two components:
   - heat treatment temperature
   - heat treatment time.

b) Heat sterilization at a lower temperature, e.g. 110°C over the period of 20 minutes results in a lower summary amount of heat treatment than at a higher temperature, e.g. 117°C over the same period of 20 minutes. Similarly, when using the same temperature, e.g. 117°C but different sterilization periods (e.g. 20 and 30 minutes respectively), the longer sterilization period (30 minutes) accounts for the higher summary amount of heat treatment.

c) The same amount of heat treatment can be achieved when using either lower temperature/longer heat treatment time or higher temperature/shorter heat treatment time (different time-temperature regimes resulting in same heat impact).

As measurement for the amount of heat treatment imposed on a product, the term F-value\(^1\) has been created, which represents the combination of heat treatment time and heat treatment temperature.

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\(^1\) The denomination "F-value" is derived from "Fahrenheit" (Fahrenheit temperature scale used in the USA). For practical reasons a simplified approach has been taken in this context. The F-values mentioned always refer to the amount of heat treatment received in the critical thermal point, the cold point, where heating is slowest. For solid canned goods it is the centre of the can. In liquid or semi-liquid goods it is one third of the height from the can bottom (see Fig. 359).
For practical applications the reference temperature of 121°C and reference time of one minute is the basis of the F-value unit. The amount of heat treatment delivered at 121°C during one minute is F-value 1.

**Definition:**

- F-value 1 = amount of heat treatment at 121°C over 1 min and similarly:
- F-value 2 = 121°C over 2 min
- F-value 3 = 121°C over 3 min, etc.

The reference temperature of 121°C does **not** mean that this is the recommended or optimal sterilization temperature. For any other relevant temperature, the amount of heat treatment per minute (expressed in F-value) can also be determined. Temperatures lower than 121°C will result in partial F-values per minute of less than 1 and temperatures of higher than 121°C will result in partial F-values per minute of higher than 1. For easy reference the F-values associated with temperatures starting from 100°C and referring to one minute heat impact time are summarized in table 1.¹

**Table 14: F-values (per minute) for the temperature range of 100°C to 135°C**

<table>
<thead>
<tr>
<th>°C</th>
<th>F – value</th>
<th>°C</th>
<th>F – value</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>0.0077</td>
<td>118</td>
<td>0.4885</td>
</tr>
<tr>
<td>101</td>
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<tr>
<td>104</td>
<td>0.0194</td>
<td>122</td>
<td>1.2270</td>
</tr>
<tr>
<td>105</td>
<td>0.0245</td>
<td>123</td>
<td>1.5446</td>
</tr>
<tr>
<td>106</td>
<td>0.0308</td>
<td>124</td>
<td>1.9444</td>
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<td>0.0388</td>
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<td>110</td>
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<td>117</td>
<td>0.3880</td>
<td>135</td>
<td>24.5098</td>
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</table>

¹ The partial F-values indicated in table 1 have been established experimentally and mathematically.
The overall amount of heat treatment (= summary F-value) for a fully sterilized product can be calculated by adding up/summarizing partial F-values achieved during sterilization. For this purpose the temperatures achieved in a product during sterilization must be registered every minute. The individual temperature measurements (readings per minute) at the cold point (Fig. 359) of the can, result in a temperature curve for the entire sterilization process composed of heating, holding and cooling phase (Fig. 385).

The temperature inside the containers during heat treatment must be measured at the “coldest” or critical thermal point of the product, which is the point where the heat transferred arrives last. This is usually the centre of the container (can), except in case of liquid fillings (see Fig. 359). This situation also implies that the outer parts of the canned product always receive higher amounts of heat treatment than the centre. But for product safety reasons the summary F-value required for a product must be reached and measured at the critical thermal point (cold point). The outer parts of the product will always receive higher F-values, which means that these areas will be more intensively heat treated than the central parts (see Fig. 361). This fact plays a role in the sensory quality of the product. The sterilization process must therefore be carried out in a way that also the outer product portions are not deteriorated by excessive heat treatment and are acceptable to consumers both in texture and taste.

The reference temperature for the F-value definition is 121°C. In commercial meat canning, for quality reasons, temperatures lower than 121°C are applied for most meat products due to their heat sensitivity. Theoretically temperatures above 100°C can be used for meat product sterilization. However, temperatures close to 100°C are associated with very low F-values (see table 14), which would require a long period of heat treatment in order to reach summary F-values considered sufficient for full sterilization. On the other hand, F-values associated with temperatures higher than 121°C would assure a short-term sterilization process. But these high temperatures have to be applied with caution, as they may have a negative impact on the product quality.

There are a number of meat products, e.g. Cooked ham, Luncheon meat or Liver pate, which would suffer quality losses if heated up to internal temperatures of around 121°C. These products are usually sterilized at temperatures between 112 and 115°C. Other meat products such as Corned beef or meat pieces in gravy are less heat sensitive and can be sterilized at higher temperatures, e.g. 118-121°C. The temperatures to be used also depend on the size of the cans. Solid products in large-size cans may have to be sterilized by using lower autoclave temperatures to prevent the outer parts to be exposed to high temperatures for too long a time (Fig. 360).

The proper application of the F-value approach in heat sterilization is an important part of product quality. It allows for all container sizes and types of products to determine the optimal sterilization pattern and to find the balance between food safety and food quality requirements.
Calculation of summary F-value achieved in a product

By measuring the product temperature during thermal treatment through inserting a thermocouple into the critical thermal point (cold point) of the container (can), the summary F-value achieved can be determined. The temperature taken in the critical thermal point of the can/container each minute during sterilization corresponds to a partial F-value (see table 14). All partial F-values obtained starting from the internal temperature of 100°C until the sterilization is ended and including the cooling phase until the product temperature falls below 100°C are added up. The sum of all partial F-values is the summary F-value achieved in the product.

Please note: It is important that the F-value calculation is continued during the cooling phase (until the product temperature falls to 100°C), as the F-values achieved during the initial phase of cooling contribute considerably to the overall F-value (Fig. 385). Omitting this would result in over-sterilizing of the product possibly resulting in quality losses.

**Fig. 385: F-value calculations during heating, holding and cooling phase**

Starting from +100°C during the heating phase (a) – measured in the critical thermal point of the product – the F-values (per minute) are added up until a temperature below +100°C is reached during the cooling phase (b).

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1) The partial F-values associated with temperatures below 100°C are very small and hence do not contribute significantly to the overall amount of heat treatment or summary F-value of the product. Partial F-values below 100°C can therefore be neglected in the summary F-value calculation for meat product sterilization.
Production of fully sterilized canned products

Canned meat products must be microbiologically safe, which means pathogen free and non-spoiling. This implies that apart from all vegetative microorganisms, the spores must also be inactivated. Thermal processing uses the most heat resistant known organisms that could cause spoilage or disease/food poisoning as reference organisms for a safe and stable product. In the food industry the most heat resistant pathogens are Clostridium botulinum spores (see also page 358) for which a minimum F-value of 2.52 needed. The most heat resistant spores for spoilage are the Clostridium sporogenes spores which require minimum F-values of 2.58.

Based on these microbiological considerations and including a sufficient safety margin, sterilized canned products should be produced with F-values of 4.0-5.5. The retort temperatures to be used may vary between 117 and 130°C (depending on the heat sensitivity of the individual products). A shelf life of up to four years at storage temperatures of 25°C or below can be achieved.

In tropical countries, where the storage temperatures may exceed 25°C, specific canned products for tropical conditions are manufactured. In these cases the summary F-values have to be increased to F-value 12-15\(^1\), which permits safe storage of the finished products under storage temperatures up to 40°C.

Information about the exact summary F-value of a product is of great importance to food processors because

- it ensures the appropriate thermal treatment of the product, thus avoiding over- or undercooking.
- it enables the determination of the product storage conditions.

In practice it is not necessary to calculate the F-value repeatedly for the same type of products processed in the cannery. The F-value can be determined once for each batch taking into account the size of the containers and intensity and duration of thermal treatment. If these parameters remain unchanged, the F-value will be constant during subsequent production.

\(^1\) The sterilization technologies used are generally based on the elimination of mesophilic bacteria. Certain thermophilic organisms such as Bac. stearothermophilus are extremely heat resistant and may survive F-values of 4-5.5. In case of survival they will not grow under normal storage conditions of up to 25°C and do not pose a risk in countries with moderate temperatures. However, they may grow under tropical conditions in particular with storage temperatures of 25°C and above. Hence, F-values of 12-15 have to be employed in such cases to contain this risk (see also page 278).
Commercial sterility

F-values of 4 and above as required for fully sterilized canned products are often detrimental for the quality of certain canned goods. Thus technologies have been developed, which use a sterilization pattern of slightly less than F-value 4, which means that under certain circumstances some spores may survive. In order to tackle this risk, other “hurdles” can be employed to curb microbiological growth. In the first place, the curing substance nitrite, which is added to many canned meat products, as an additional safety measure or “hurdle”. Nitrite inhibits the growth of spores. Lowered water activity \((a_w)\) due to reduced water content or \(a_w\)-reducing ingredients (fat, non-meat proteins, salts) can also be useful.

Product acidity (low pH) such as in many canned vegetable or fruit products, is effective to allow the “softening” of the sterilization pattern, as Clostridium species do not grow below pH 4.5. However it is not applicable for canned meat products, which practically all fall in the category of low-acid products (pH higher than 5.5).

The definition for commercially sterile products according to Codex Alimentarius\(^1\) is:

“Commercial sterility of food means the conditions achieved by application of heat which renders such food free from microorganisms capable of growing in the food at temperatures at which the food is likely to be held during distribution and storage.” The criterion is ability to grow not presence or absence.

Commercially sterile goods are canned products sterilized under not too intensive heat treatment in order to maintain good sensory product quality. It is accepted that non-pathogenic microorganisms may not have been completely inactivated, but it must be ensured that their growth is practically not feasible as one or more of the above “hurdles” are present in the product (see also page 92).

The characteristic of commercially sterile products is that they have been heat treated to eliminate all pathogenic organisms and to reduce spoilage organisms to a level where they will not produce a health hazard or reduce the quality and acceptability of a product.

\(^1\) Joint FAO/WHO Food Standards Programme CODEX ALIMENTARIUS COMMISSION Recommended International Code of Hygienic Practice for Low Acid Canned Foods, 1993
Experimental and mathematical determination of F-values

F-values (per minute), at and above the reference temperature of 121°C as indicated in table 14, are based on the heat tolerance / heat resistance of microorganisms relevant in food/meat canning. In order to facilitate the approach, one single microbial species was selected, Clostridium botulinum, which is the most heat resistant pathogenic microorganism (see also page 357). Canned food, where Cl. botulinum is inactivated, is hygienically safe, as it can be assumed that also all other food poisoning and food intoxicating microorganisms are eliminated. By adding a defined safety margin to the heat treatment, it can further be assumed that any surviving food spoilage bacteria will also be inactivated.

For the calculation of the Cl. botulinum–based partial F-values (F-value per minutes) the following additional parameters apply (which are based on experimental results):

**D-value** = decimal reduction time of Cl. botulinum, which is the time at a given temperature needed to reduce the microbial population to 10%, of its original numbers (e.g. at 121°C approximately 12 seconds)

**z-value** indicates the necessary increase in temperature (°C), which is needed to decrease the decimal reduction time (in the above example 12 seconds) to 10% (=1,2 seconds in the example). For Cl. botulinum this z-value is 10°C (is different for all other microorganisms).

This fact of the z-value being 10 for the reference microorganism Cl. botulinum facilitates F-value calculations. The rule is that temperature increases/decreases by 10°C will change partial F-values by the factor 10 (decimal increase/decrease) (see table 15)

<table>
<thead>
<tr>
<th>Temp.</th>
<th>F-value (minutes)</th>
<th>Temp.</th>
<th>Minutes at 121°C to achieve F-value 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>101°C</td>
<td>0,01</td>
<td>101°C</td>
<td>100</td>
</tr>
<tr>
<td>111°C</td>
<td>0,1</td>
<td>111°C</td>
<td>10</td>
</tr>
<tr>
<td>121°C</td>
<td>1</td>
<td>121°C</td>
<td>1</td>
</tr>
<tr>
<td>131°C</td>
<td>10</td>
<td>131°C</td>
<td>0.1</td>
</tr>
</tbody>
</table>
12 - D - concept

Knowledge of the decimal reduction rate of Cl. botulinum enables the calculation of the safe elimination of this microorganism. It is assumed that a batch of cans is contaminated with one spore of Cl. botulinum per can (which is extremely unlikely). It is required that the sterilization be such that there is a likelihood of only one spore surviving in a trillion \((10^{12})\) cans, or in other words a 12-fold decimal reduction (down to \(10^{-12}\)). Mathematically the complete elimination to zero microorganisms cannot be established.

The decimal reduction time of Cl. botulinum at 121°C is 0.21 min., and for the 12-fold effect the result is 12x0.21 min. = 2.5 min. The period of 2.5 min. at 121°C is equivalent with F-value 2.5. This F-value of 2.5 is also called “botulinum cook” or “12-D-concept” and signifies the elimination of Cl. botulinum under practical conditions.

When applying the above decimal increase/decrease rule at 111°C (10°C lower than 121°C), the “botulinum cook” would be achieved only after the ten-fold time = 25 min. instead of 2.5 min. at 121°C (see also box on page 295).

Table 16: Steam temperature and associated pressure\(^1\)

<table>
<thead>
<tr>
<th>°C</th>
<th>Bar</th>
<th>°C</th>
<th>Bar</th>
<th>°C</th>
<th>Bar</th>
<th>°C</th>
<th>Bar</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>1</td>
<td>164</td>
<td>7</td>
<td>234</td>
<td>30</td>
<td>322</td>
<td>120</td>
</tr>
<tr>
<td>111</td>
<td>1.5</td>
<td>170</td>
<td>8</td>
<td>248</td>
<td>40</td>
<td>328</td>
<td>130</td>
</tr>
<tr>
<td>120</td>
<td>2</td>
<td>174</td>
<td>9</td>
<td>260</td>
<td>50</td>
<td>334</td>
<td>140</td>
</tr>
<tr>
<td>128</td>
<td>2.5</td>
<td>179</td>
<td>10</td>
<td>271</td>
<td>60</td>
<td>340</td>
<td>150</td>
</tr>
<tr>
<td>134</td>
<td>3</td>
<td>185</td>
<td>11</td>
<td>281</td>
<td>70</td>
<td>345</td>
<td>160</td>
</tr>
<tr>
<td>139</td>
<td>3.5</td>
<td>187</td>
<td>12</td>
<td>290</td>
<td>80</td>
<td>354</td>
<td>180</td>
</tr>
<tr>
<td>144</td>
<td>4</td>
<td>191</td>
<td>13</td>
<td>300</td>
<td>90</td>
<td>363</td>
<td>200</td>
</tr>
<tr>
<td>148</td>
<td>4.5</td>
<td>198</td>
<td>15</td>
<td>304</td>
<td>95</td>
<td>372</td>
<td>225</td>
</tr>
<tr>
<td>152</td>
<td>5</td>
<td>213</td>
<td>20</td>
<td>308</td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>158</td>
<td>6</td>
<td>225</td>
<td>25</td>
<td>315</td>
<td>110</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^1\) Autoclaves are usually designed to withstand 6 bar. In practice autoclave temperatures remain below or do not exceed 128°C (=2.5 bar).
HANDLING AND MAINTENANCE OF TOOLS AND CORE EQUIPMENT

Meat processing plants should supply personnel with the correct types of hand tools and basic equipment. Such tools and equipment must be subject to simple routine servicing and maintenance to be carried out by the personnel on a regular basis. This does not include the servicing of more sophisticated equipment which has to be undertaken by specialized technicians usually sourced through the equipment supplier.

Knives

Due to the multiple operations in the meat sector different types of knives are used for different purposes. There are knives for bleeding, flaying and evisceration of animals as well as for deboning of carcasses, cutting of meat and slicing of choice cuts and processed products. All these knives have very specific design features to support the operations they are made for (Fig. 387). Knives are also used for cutting of other raw materials and casings.

Knives used in meat operations should have basic safety features. The handle should be made of plastic material with non-slip surface and designed to allow a firm and safe grip. Plastic handles are also a hygienic requirement. The end of the handle is often slightly enlarged (handle knob) to prevent the knife from slipping out of the hand and the portion close to the blade should have a similar enlarged design to avoid the hand from slipping over onto the blade (see Fig. 386, 387).

Fig. 386: The recommended knife design to facilitate safe handling and avoid injuries
It is of utmost importance that knives are handled with care to avoid injuries to workers and damages to the knife itself. When working with meat, knives must be cleaned frequently to eliminate the risk of cross-contamination. Knives must also be sharpened in a proper way to avoid unnecessary wear and kept sharp to reduce the potential for injuries. Working with a blunt knife requires more force and results in a higher risk of slipping off the meat or bone. It also leads to early fatigue and slower work speed.

The correct shape of the blade at the cutting edge is very important to facilitate a long-lasting sharpness and allow for easy whetting during operations. The recommended shape is a slightly convex cutting edge area as this ensures a firm structure and facilitates smooth cutting through meat and sausages (Fig. 388). Cutting edges showing straight or even concave shapes result in very thin blade edges with an increased risk of small cracks and also require more handling force by workers.

Knife sharpening is a delicate process and requires a special device (Fig. 389). The knife sharpening machines (sand-paper abrasive belts, sand-paper flap-wheels, rotating stones) should be air-ventilated or water-cooled and rotate at a moderate speed. Air ventilated sharpening often causes overheating of the blades, which increases the risk of cutting edge breakage. During work operations, all knives should be whetted regularly using special steels. These steels are often called sharpening steel, but are in fact only for whetting (polishing of the knife edge). Care must be taken that only steels with safety handles (knob-type handle front for finger protection) are used.
During knife whetting (Fig. 390), the steel is firmly gripped with one hand and the other hand holds the knife. The hand with the steel remains static. Starting from close to the grip of the knife (1), the blade is moved down along the steel from the steel’s tip towards the handle. During this movement the edge slides in its full length over the steel. This move is performed several times on both sides of the steel (2), thus polishing both sides of the edge of the knife (3).

Knives must be kept clean and dry and should also be stored safely and visible to avoid accidental injuries to workers (Fig. 391).
Hooks used in the meat sector

In general, two types of hooks are essential for smooth operations in the meat sector. Slaughterhouse or **carcass hooks** are used for moving and hanging of carcasses. Their design depends on the type of rails (tubular, flat bar) installed. These heavy duty hooks are for sliding or moving on rollers along the rails and have a rotating lower hook part.

**Slaughterhouse hooks**

![Slaughterhouse hooks](image)

- for tubular rail, sliding
- for tubular rail, rolling
- for flat rail, rolling

**Meat shop hooks**

![Meat shop hooks](image)

- two flat ends
  - used for hanging of sausages
- one sharp end, one flat end
  - used for hanging fresh meat
  - regular bend
  - 90 degrees bend

**Fig. 392: Various hook designs used in slaughterhouses and meat shops**

The **meat shop hooks** are used for hanging meat pieces or sausages. To avoid injuries during handling, the upper end of those hooks is always kept flat. A flat lower end is also used for sausage hooks, while meat hooks display a sharp tip which facilitates the penetration into the meat piece to be suspended.
Grinders and grinder plates and knives

Meat grinders are indispensable equipment in the meat processing industry and are part of practically every meat processing line. Meat processors must be familiar with this type of equipment (see page 18).

Installation:

Care must be taken that grinders are positioned properly. Most grinders have adjustable rubber feet. This allows the horizontal levelling and avoids transfer of vibration from the machine to the table (small models) and floor (industrial grinders). The initial electrical connection to the power supply line should be done with an empty housing (auger / feeding worm and cutting set removed) for safety reasons. Industrial size meat grinders are usually driven by three-phase motors and the direction of rotation must be checked. When viewed from the front, the feeding worm must rotate counter-clockwise. The cutting set is attached to the feeding worm with the cutting edges of the star knives facing counter-clockwise. Before starting the machine for the first time, all parts must be thoroughly cleaned and dried. A useful option often used by meat processors, is to run some clean fat through the system to make sure that remains of grease are removed from the housing and the cutting set.

Operations:

Apart from the need for frequent cleaning (see page 379), the cutting system of grinders has to be assembled and dismantled at various times per shift or day to be adjusted to the desired particle size. Care must be taken of the following:

- The grinder plates must be frequently checked for any damage to the surface, as a clear cut is only possible when the grinder plates are kept smooth. If damage such as grooves or scratches appear, the grinder plates must be planed (reground) immediately.

Fig. 393: Cutting sets in meat grinders, assembled on feeding worm (auger)
Left: UNGER five-piece cutting set          Right: ENTERPRISE two-piece cutting set
Handling and maintenance of tools and core equipment

- The star-knives (cutters) must also be kept sharp. Cutters are usually sharpened at the cutting edges. In systems with replaceable blades these blades are not sharpened but replaced regularly.
- Grooved grinder plates and blunt star-knives result in poor cutting (mashed ground meats).
- Parts from different cutting sets must not be mounted together, as they might be made of materials of different hardness. This can result in grooved grinder plates or damaged star-knives.
- The cutting assembly must never be over-tightened to avoid excessive friction heat and undesirable heat transfer to the meat.
- A grinder should never run empty as this will damage the knives and blades.

In industrial-size grinders, the electrical motor and driveshaft are connected via V-shaped belts. These belts usually require little servicing. Care must only be taken that the belts are kept at the correct tension. If the belts are not sufficiently tightened they show increased wear, excessively tightened belts lead to increased power consumption and could cause damage to the motor or driveshaft.

**Fig. 394: Feeding auger housing:**
Critical areas for cleaning are the threat (a) in the housing and the connection point of feeding worm and drive shaft (b)

Cleaning:

Ginders are normally used for mincing raw fresh meat and other animal tissue. Meat grinders and their cutting parts must therefore be **cleaned and disinfected frequently** - during or at the end of each production cycle in order to maintain a good hygienic status. The most critical spots for cleaning are inside the barrel (feed auger housing). Any meat materials or fats left in the grooves of the thread must be removed by
Handling and maintenance of tools and core equipment

hand, followed by thorough flushing and brushing until all residues are washed out.

The driveshaft pin, where the feeding auger is interlocked, must also be brushed and flushed with plenty of water. The use of a high-pressure water cleaner is discouraged here, as this could damage the rubber seal in which the driveshaft pin rotates. After cleaning, the barrel should be dried properly, also to avoid metal corrosion.

Cleaning of grinder plates provides a special challenge for responsible staff as care must be taken that the many holes are totally free of impurities. This is very difficult in discs with tiny holes for smaller particle sizes. If a high-pressure water cleaner is available, it should be used.

Bowl cutter

Most meat processing lines include a bowl cutter as these machines allow improved processing ("comminuting") and production of a greater variety of products. Bowl cutters are available in different sizes from single-phase table models for small-scale butcheries and restaurants to bigger three-phase models for medium to larger industries (see page 20). The basic maintenance requirements are the same for all models.

Installation:

Small table models operate on single-phase electrical power. The equipment is usually positioned on a suitable working table. The operator has to make sure that the knives are installed in the right position and securely tightened (see page 21). Upon connection to the power supply, the bowl cutter is operational. Other details are similar to bigger models and are explained in the following paragraphs.

Fig. 395: Standard design bowl cutter:

- a = bowl
- b = knife head
- c = knife
- d = knife shaft
- e = clearance between knife from bowl
Bigger bowl cutters (floor models) need to be positioned with the rim of the bowl levelled horizontally, using the adjustable rubber-feet. The rubber feet should not be replaced by metal bolts, as they facilitate the smooth running of the bowl cutter.

The knives (blades) (Fig. 395c) are inserted following the recommended scheme (Fig. 396) and must be tightened firmly. Care must be taken that the knife head (Fig. 395d) rotates freely in the bowl and cover (always rotate one initial round by hand) and all knives have a sufficient but not too wide clearance (1-2 mm) from the bowl (Fig. 27, 395e). After a few rounds at slow speed, the knives must be tightened again firmly. To avoid unnecessary vibrations from the knife head, bowl cutter knives should be balanced (equilibrated). In bigger bowl cutters with large knives, special balancing sets are used.

The following knife assemblies are common:

- **Bowl cutters up to 100 litres**
  - 3 knives – coarse products, partly frozen materials
  - 4 knives – coarse products, fresh soft materials
  - 6 knives – finely chopped products, pre-ground meats

- **Bowl cutters above 100 litres**
  - 4 knives – all coarse products
  - 8 knives – all finely chopped products

The tension of the drive belt should also be checked. A correct tension
is achieved when the belt can be manually pressed down between its two fixations only as far as the thickness of the belt itself. A weak tension of the belt will cause premature wear and insufficient drive force. If the belt tension is too strong, it can cause damage to shaft and bearings. The maintenance manual by the equipment manufacturer should always be checked for details.

Operation:

Care must be taken that no metal or other hard materials accidentally find their way into the bowl cutter. It is advisable to frequently check all bolts, nuts and screws, especially around the cover. The cut-out safety switch must be checked regularly to ensure that the knife shaft brake stops the machine immediately if the cover is erroneously opened during operations. The built-in thermometer should also be frequently checked as it could get damaged by vibrations.

All lubrication points (grease nipples) (Fig. 397) have to be greased following the instructions given by the equipment manufacturer and oil changing intervals must be observed. As a rule of the thumb, the knife shaft (Fig. 395d) is usually greased monthly and the motor shaft six-monthly. The oil in the gear assembly (gear box) should be changed yearly.

Cleaning:

Special care must be taken during cleaning. The spaces between the knives (Fig. 398) must be properly cleaned to remove all residues of batter mixes. A brush with long handle should be used to avoid injuries. A critical spot for cleaning is the narrow gap between the rotating bowl and the housing of the knife shaft (Fig. 399) as well as the paddle on the bowl cover (Fig. 400). The knife head should be dismantled regularly for proper cleaning (once a week) and reassembled following the instructions given before.

Moisture and defective seals in switches have a significant negative effect on the functioning of a bowl cutter. When high pressure cleaners are used, direct contact of the water jet with the switches must be avoided. The noise protection lids and front parts of vacuum covers are often
made of transparent plastic and must be cleaned with mild cleaning agents to maintain their see-through appearance.

**Sausage stuffer**

A sausage stuffer is one of the core pieces of machinery for every meat processor. The different designs and sizes are described on page 22. In this context, the focus is on the **hydraulic piston stuffer** as this model is commonly used in small and medium enterprises. This type consists of a steel frame mounted stainless steel cylinder with a stainless steel piston. The piston is attached to a solid shaft, which is moved up and down inside the cylinder by hydraulic force. The top of the cylinder is covered by a horizontally sliding lid, which can be hermetically closed. Some models have the outlet opening for the stuffing funnels integrated in the upper edge of the cylinder, others attached to the lid (Fig. 401).