MEAT PROCESSING HYGIENE

Principles of meat processing hygiene and regulatory practices (incl. GHP and HACCP)

Meat processing hygiene is part of Quality Management (QM) of meat plants and refers to the hygienic measures to be taken during the various processing steps in the manufacture of meat products. Regulatory authorities usually provide the compulsory national framework for food/meat hygiene programmes through laws and regulations and monitor the implementation of such laws. At the meat industry level, it is the primary responsibility of individual enterprises to develop and apply efficient meat hygiene programmes specifically adapted to their relevant range of production.

Operations in **meat processing plants** comprise the **manufacture of value-added meat products** from primary products of meat origin and non-meat origin. There are three principles of meat hygiene, which are crucial for meat processing operations.

- **Prevent microbial contamination** of *raw materials*, intermediate (*semi-manufactured*) *goods* and *final products* during meat product manufacture through absolute cleanliness of tools, working tables, machines as well as hands and outfits of personnel.
- **Minimize microbial growth** in *raw materials*, *semi-manufactured*[1] *goods* and *final products*[2] by storing them at a low temperature.
- **Reduce** or **eliminate**[3] **microbial contamination** by applying heat treatment at the final processing stage for extension of shelf life of *products* (except dried and fermented final products, which are shelf-stable through low a_w and pH)[4]

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1) Semi-manufactured goods must be stored **refrigerated** during production breaks and resting periods. Processing steps, such as cutting, grinding, comminuting, mixing, filling, smoking and cooking take place under **climatized conditions** or **ambient temperatures**. Ambient temperatures are hygienically acceptable as long as these processing phases are of short duration or when product temperatures are rising as a result of the processing.

2) In some final products **low pH** or **low a_w** also serve to contain microbial growth in combination with or in replacement of refrigeration.

3) Elimination of contamination only in fully sterilized (canned) products.

4) For some food products useful, but in the meat industry not commonly used, are other methods for food preservation, such as **irradiation** and **high hydrostatic pressure treatment**.

Fig. 452: Microbiological contamination in the meat processing chain

Carcass contamination during slaughtering (red dots) Unavoidable – keep as low as possible.

Meat cutting No reduction of contamination possible, but further contamination should be prevented.

Further processing No reduction of contamination possible, but prevent further contamination and create challenges / hurdles for microbial growth and survival (a_w, preservatives).

Heat treatment of final product Pasteurization (approx. 80°C): Substantial reduction of contamination, but products need refrigeration. Sterilization (above 100°C): Total elimination of contamination, products can be stored without refrigeration (in sealed food containers).

The above three principles guide meat hygiene programmes in the further processing of meat (see also Fig. 452). However, meat processing hygiene is more complex. In particular, the hygienic treatment of meat before reaching the processing stage is of utmost importance for the processing quality of the meat. Failures in **slaughter hygiene**, **meat cutting** and **meat handling/transportation** and in the **hygiene of by-products** and **additives** will all contribute to quality losses and deterioration of the final processed meat products.

Highly contaminated raw meat is **unsuitable** for further processing. Final products made from hygienically deficient raw meat materials are **unattractive in colour**, **tasteless** or **untypical in taste** with **reduced shelf life** due to heavy microbial loads (see page 353, 356). Moreover, there is also the risk of presence of **food poisoning** microorganisms, which can pose a considerable public health hazard (see page 357).

In the light of growing consumer consciousness as well as regionalization and globalization in trade, quality conscious meat plants need *internal quality control/quality management schemes* not only for the **final**

products but also for the **raw materials** and the **various processing steps**.

Such **Quality Management** Schemes **(QM)** have technical and hygienic components. *Technical* aspects encompass *product composition*, *processing technologies, packaging, storage* and *distribution*. Details on the manufacturing practice for each individual group of meat products are included in the chapters on processing technology (see page 103 - 212). For the *sanitary quality and safety* related to meat processing, two useful schemes[1] can be applied known as

- **Good Hygienic Practices (GHP)** and
- **Hazard Analysis and Critical Control Point (HACCP) Scheme**.

Both schemes are not verbally laid down in codes ready to be used for the various purposes in the meat sector although some generic examples can be accessed in handbooks or via internet. Factory and production specific versions need to be established and compiled by taking into account official laws and regulations as well as recommended codes of practice.

Good Hygienic Practices (GHP)

Good Hygienic Practices/GHP follows general hygienic rules and applies recognized hygienic principles[2] as well as laws and regulations issued by the competent authorities, referring to *meat and meat products*, *equipment*, *premises* and *personnel*. GHP schemes are ***not factory specific***, they apply to all types of meat plants. They are intended to establish and maintain acceptable hygienic standards in relevant meat operations. There is more emphasis on slaughter hygiene in GHP schemes for slaughterhouses and more emphasis on meat processing hygiene in GHP schemes for meat products manufacturing enterprises. However in principle, GHP schemes remain interchangeable for similar types of meat plants.

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1) There are a number of additional specialized norms and standards for auditing purposes in meat/food industries in use, some of them with regional scope and mostly with links to GHP and HACCP.

2) The FAO/WHO Codex Alimentarius Commission has issued a new CODE OF HYGIENIC PRACTICE FOR MEAT in 2005 (CAC/RCP 58-2005). In addition to relevant laws and regulations by the competent authorities, this recommended international Code of Practice provides a suitable platform for the development of official or individual meat hygiene programmes.

GHP for **meat processing plants** refers principally to:

- Appropriate functional plant layout and sanitary design of equipment
- Raw materials that meet hygiene quality standards
- Processing methods that allow safe handling of food
- Appropriate waste and pest control measures
- Appropriate sanitation procedures (cleaning and disinfection)
- Compliance with potable water criteria
- Functional cold chain
- Regular examination of health and personal hygiene of staff
- Regular training of staff on hygiene requirements

Hazard Analysis and Critical Control Point Scheme (HACCP)

HACCP are ***factory*** and ***product specific*** strictly sanitary control schemes that shall prevent, detect, control and/or reduce to save levels ***accidentally occurring hazards*** to consumers' health. Despite GHP in place, accidental hazards cannot be ruled out and may occur at any processing step of the individual meat product. Specifically for ***meat processing plants***, such hazards may be provoked by failures such as:

- batches of incoming raw meat materials with abnormal tissues or heavy contamination,
- breakdowns in refrigeration,
- failure in cooking/sterilization operations,
- abnormal pH or a_w in raw or finished products,
- errors in levels of application of curing salts and other additives,
- technical problems in sealing of vacuum packages or cans with the risk of recontamination.

HACCP schemes serve as additional **alarm systems** in the interest of consumer protection to prevent such problems occuring.

The revolutionary idea of HACCP is to implement control measures that focus on prevention rather than relying on end-product-testing. All relevant possible hazards in the entire production chain, from primary production to consumption of each individual product, must be identified and measures taken for their prevention. In case potential hazards should occur, they can be **detected, contained or eliminated at any stage**.

Plant personnel have a key role to play and must be trained in hazard detection and elimination. For practical purposes, those possible hazards may be listed on **specific templates** for confirmation of presence or absence during routine controls. **Specific control mechanisms**, in the

first place of *physical, chemical and visual nature* (temperature, pH, visual check etc.), are installed at selected control points to detect such potential hazards. These control mechanisms are designed to deliver most results almost instantly and allow **immediate intervention** during the processing phase of food/meat products.

The need for immediate action within HACCP systems **excludes** *microbiological control* (of raw materials, semi-fabricated products, tools, equipment, and premises) as a directly applicable control measure. Microbiological control takes hours or days to obtain the results, which does not allow corrective interventions during the usually short manufacturing period. However, this does not mean that microbiological control is worthless for HACCP. Routine microbiological control carried out within the **framework of GHP** is an extreme helpful tool also for HACCP as its results will demonstrate the efficiency of the HACCP-system. Hygienically acceptable microbiological test results are an indicator of the proper functioning of the meat plant's HACCP scheme.

HACCP[1] is *not* a scheme for the assessment and improvement of the general hygienic status of a meat plant. HACCP is not designed to further raise hygienic standards. Excellent conditions as applicable for GHP-conform plants must already be in place. GHP is a prerequisite requirement for the introduction of HACCP.

The misconception still exists that HACCP is intended to raise levels of general hygiene in meat plants **with low hygienic standard.** HACCP is not workable where plant layout/structure, equipment and/or processing methods **do not comply** with good hygienic standards.

One important point to distinguish HACCP from GHP is that **GHP** describes *process requirements and practices* incl. personal hygiene of staff to ensure safety of food. The individual product is not specifically targeted. Unlike GHP, **HACCP** always focuses *on the individual product*. As technologies vary from product to product, it is obvious that **separate** HACCP approaches are required for each category of products.

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[1)] More detailed information on HACCP see boxes on pages 344-348.

HAZARD ANALYSIS CRITICAL CONTROL POINT (HACCP)

What is HACCP?

Internal sanitary related control and monitoring system in food plants with the aim of preventing/minimizing or eliminating **health hazards** to consumers. HACCP identifies, evaluates and controls hazards, which are significant for food safety. The characteristics of HACCP are:

- Potential for immediate **prevention measures** before or during production to counteract suspected or emerging health risks
- Exclusively **aimed at health risks** to consumers

Food plant internal control procedures based on HACCP principles have become an obligation worldwide in many countries with advanced food industries. HACCP procedures are imposed on relevant food plants by the competent authorities, whose task is to assess and evaluate the correct application and conduct of HACCP. The food plants themselves are responsible for the proper implementation of HACCP, such as monitoring of sensory, physical and chemical parameters during production and immediate intervention in case of emerging health risks and recording of results.

Requirements for introduction of HACCP schemes are yet different from region to region. In a number of countries (e.g. EU, US) meat plants in general have to comply with HACCP, whereby for smaller plants or such specializing in limited activities or products, simplifications or exceptions exist. In some other parts of the world, HACCP schemes are not yet commonly introduced. However, it can be anticipated that such plants involved in regional or global distribution of food will also be obliged to comply with HACCP principles.

Basic elements of HACCP in meat processing plants

- Every single meat product with product specific technology requires a specifically designed **individual** HACCP scheme.
- As a precondition for implementing HACCP concepts, **hazard analysis** and **risk assessment** referring to meat plant specific processing methods or products, have to be carried out.
- **Critical control points** (**CCPs**) have to be identified, critical limits be established and **monitoring systems** properly implemented.

The HACCP scheme is subdivided into seven consecutive steps (“principles”). Through these seven HACCP principles a practical approach is provided to identify potential significant hazards to consumers’ health and to take relevant corrective actions:

1. Hazard analysis and risk assessment

The first principles requires initially the **exact description** of the products to be fabricated, including product composition, texture/structure, processing details (such as degree of comminuting, additives, filling, heat treatments), packaging and if applicable chemical and microbiological criteria.

Once the characteristics of each product are detailed, potential hazards to consumers' health during processing are identified. Hereunder, a summary listings of hazards are given, from where those hazards likely to be associated with the fabrication of a specific meat product can be identified.

Examples for hazards in meat processing

Biological hazards: Parasites (causing zoonotic diseases), bacteria (causing food poisoning/food borne infections and intoxications), moulds (mycotoxins causing food borne intoxications), viruses (causing food borne infections) (see page 357)

Physical hazards: Rests of unwanted materials (glass, bone fragments, animal teeth/in case of processing head meat, metal fragments such as sausage clips, broken knife blades, needles, plastics, stones)

Chemical hazards: Contaminants (heavy metals, PCB's, chemical solvents, cleaning and disinfection compounds)
Residues (veterinary drugs, feed additives, pesticides)
Food additives with risk of overdoses (nitrate/nitrite, chemical preservatives)

2. Identification of Critical Control Points (CCP)

A CCP is defined as any point or procedure in a specific food system, where loss of control may result in an unacceptable health risk. CCPs can be located at any point along the production line of a specific meat product, where biological, physical and chemical hazards may occur and where such risks can be controlled and/or eliminated. CCPs should only be established, where firm methods for control and monitoring can be applied.

CCPs must be used only for purposes of product safety. They should not be confused with control points that do **not** control safety and where loss of control does **not** lead to unacceptable health risks, e.g. reduced or strong water binding capacity of meat, knives of grinders or choppers with reduced cutting capability, mechanical problems in portioning sausages or can fillings etc. Moreover, issues of meat plant hygiene routinely covered by GHP and which are not product specific, are normally **not** CCPs. Such examples are:

Potable water outlets,
Hot water container for tool disinfection ("sanitizers"),
Cleaning and **disinfection** equipment, chemicals and methods.
Sanitation measures (e.g. periodic cleaning and disinfection of meat cutting boards)
Personal hygiene

Specific preventive measures to avoid cross contamination (e.g. plant internal transports of raw materials and finished products must not cross each other)
Specific food handling procedures (e.g. meat containers must not directly be placed on the floor, but on stands, pallets etc.)

Suggested control points directly related to meat processing and therefore suited for the establishment of **CCPs** are:

- unloading bay for **raw materials** (meat and non-meat ingredients),
- **cold storage rooms**,
- meat **cutting** and **preparation facilities**,
- facility for **handling non-meat additives**,
- meat **comminuting** units (grinders, bowl choppers etc.),
- **filling equipment** and **casings**,
- **heat treatment facilities** (smokehouses, cooking vats, autoclaves),
- **packaging equipment** and **materials** (including canning),
- **cold store** for final products,

It is up to the individual meat processing plant to decide, at which points in the processing line **CCPs** should be established. This will vary from meat plant to meat plant, depending on plant lay-out equipment, type of products and also on previously experienced accidentally occurred shortcomings.

3. Establishment of Critical Limits for each CCP

Critical limits correspond to the **extreme** (highest and lowest) **values acceptable** from the point of view of product safety. This does not always imply that a numerical value has to be fixed. Monitoring may also be based on **visual observation**, e.g. dirt/faecal contamination of meat, changes to untypical colour, changes in product structure or texture. Besides such sensory parameters, numerical critical limits must be specified for each **objective control measure** at each CCP. Criteria often used include temperature, time, moisture level, pH, and water activity.

Examples
Visual check of damage to packaged incoming raw materials (rejection in case of severely damaged packages of meat materials or additives)
Visual check of contamination of raw materials (meat, fat). Discolouration (rejection of meat or fat in severe cases), meat potentially contaminated with food poisoning agents (e.g. minimal dirt contamination to be trimmed off, critical dirt or fecal contamination leads to rejection of the meat)
Temperature control of meat derived from slaughterhouses/cutting plants (e.g. $\leq$ +4°C)
pH of incoming meat (e.g. < 6.0 for pork, < 5.7 for beef)
Visual check during meat cutting and grading (e.g. to separate and discard unsuitable meat tissues such as those containing parasites, abscesses, etc.)

Moisture content expressed as a_w (refers mainly to dry fermented products which should not be packaged or marketed if moisture content keeps above a certain level)
Additives (some products require a certain salt level for better stability in hot environments; nitrite levels should be high enough to inhibit bacterial growth but below toxic levels; the same applies to chemical preservatives)
Control of pasteurization parameters (ensure sufficient cooking, measured as core temperatures in products, e.g. 74°C)
Control of sterilization temperature and time for canned products (e.g. ensure that desired F-values are reached, e.g. F value 4 in fully sterilized canned products)
Visual appearance and texture of final products (greenish discolouration and slimy surfaces as signs of microbial growth, mould growth on surfaces of dried sausages)

4. Establishment of a monitoring system for each CCP

Monitoring is the **regular/periodic** measurement or observation at a CCP to determine whether a critical limit or target level has been met. The monitoring procedure must be able to detect loss of control at the CCP. Monitoring at CCPs should deliver results **rapidly** in order to enable corrective action during processing. Lengthy analytical testing is not practicable in the context. Hence most of the testing for critical limits listed in (3) is visual, physical and to some extent chemical. The slower microbiological testing (see also page 331) does not allow immediate corrective action.

Physical and chemical pattern to be instantly measured or monitored in meat processing lines include:
Temperature
Time limits see No. 3
pH
Moisture

5. Establishment of corrective actions

Corrective actions are those actions to be taken either when monitoring results show that

- a CCP has deviated from its specified critical limit or target level or
- when monitoring results indicate a trend towards loss of control

Action taken must reduce to safe level or eliminate the actual or potential hazard identified.

Corrective actions are for example

- **Reject** incoming meat with too high internal temperatures
- **Adjust** temperature for refrigerated storage and transport of meat
- **Remove** with clean knives minimal visual contamination of meat surface, **reject** heavily contaminated meat
- **Adjust** cooking and sterilization parameters (temperature/time)

- **Reject** meat with too high pH
- **Adjust** quantity of curing substances (level of nitrite, nitrite curing salt should contain 99,5% common salt and 0,5% nitrite)
- In case of dry fermented products: If a_w of processed products is too high, **stop** packaging in water vapour impermeable packages

Products with suspected hygienic deficiencies have to be separated from other products. Additional treatments may have to be applied, e.g. additional heat treatment in case of undercooking. Final judgement (if fit or unfit for consumption) has to be made by responsible, competent persons. Interventions at CCPs are carried out based on instant observation of hygienic failures/shortcomings. Corrective actions should be documented in the HACCP written records.

6. Establishment of verification procedures

Procedures are needed to ensure that the HACCP system is working correctly. Particular attention must be given to the **monitoring frequency,** which may be daily or several times a day or more frequently. **Checks on the persons** doing the monitoring should be done regularly as well as **calibration of instruments** used.

Established critical limits can be **revalidated** (changed) in the light of new developments. The system as a whole for individual products has to be reviewed in case of introducing **changes in the processing technology** such as changes in raw materials, product composition, processing equipment or packaging systems.

Test results derived from GHP **routine quality control**, in particular microbiological analysis, are valuable supplementary information within the HACCP system, support the verification process and prove the practicability of HACCP.

7. Establishment of documents and records

Documents and records must be produced commensurate with the nature and size of the food business to demonstrate the application of principles 1-6. These documents serve for the competent authorities to evaluate the efficacy of the HACCP procedure carried out at the plant. Records also help to trace causes of problems that were encountered during past production.

This documentation includes amongst others

- Certification on receipt of raw meat materials and non-meat ingredients documenting supplier compliance with processor's specifications
- CCP determinations (for each product)
- Critical limits set and results achieved for each CCP (including possible deviations from critical limits and corrective actions)
- Modifications introduced to the system in the light of changes of technology or other developments

HACCP in small meat processing plants

The rather complex HACCP approach including identification of critical control points and measurement and interpretation of test results, demonstrates the **difficulties in introducing HACCP schemes in small food or meat processing enterprises**. Comprehensive test systems would require a multidisciplinary approach, as well as knowledge of microbiological, chemical and physical hazards, technical processes and operation of equipment. This is available in large industries but generally not in small- to medium-scale enterprises. Flexibility should be given in these situations for **simplified approaches**, if HACCP schemes are to be introduced in small food businesses. Competent authorities tend to accept these views. In plants dealing with limited numbers of products or technologies, these simplified approaches can even go so far as to use GHP schemes instead of HACCP. It is obvious that in such cases GHP approaches may be more practical and less cost-intensive than HACCP.

Two examples for preparation of HACCP plans (see page 350, 351)

These are summary plans, which need to be expanded in more detail if adapted for relevant meat plants, depending on the plant layout, equipment and processing technology. Potential hazards, which are indicated as physical, chemical and biological, would have to be specified in detail according to the listings given on page 344. The majority of the potential hazards are “biological”, which mostly refer to microbiological risks. This corresponds with the aim of HACCP, which is prevention of health hazards to consumers. Health hazards through food are mostly caused by microbiological activity, which can be prevented if properly controlled.

The first example (**cured cooked ham**) is a product which is heat treated during manufacture and hence was stabilized microbiologically to a certain extent, but requires refrigerated storage. The second example refers to a meat product, which does not undergo heat treatment during processing (**fresh frozen beef burger**) and therefore remains particularly sensitive from the hygienic point of view.

Due to the nature of the two products, periodic microbiological tests are recommended in the framework of GHP. Periodic microbiological testing is particularly important for the product “Fresh Frozen Beef Burgers” to be marketed raw. Microbiological test results can be incorporated in HACCP. They are **not** a means for immediate intervention in ongoing productions (microbiological tests take too long to use their results for immediate action), but rather in the verification procedure, which serves to prove whether the HACCP system is working. Microbiological results

are a means to confirm the efficiency of the meat plant internal HACCP system, when it can be proved that the established limits were not exceeded.

The Critical Control Points (CCPs) indicated are examples for the establishment of CCPs. It is up to the processing plant to increase or decrease their number according to the plant specific risk assessment.

Table 17: HACCP plan for Cured Cooked Ham

HACCP PLAN

Product: **Cured Cooked Ham (cooked in vacuum bag and cooking mould)**

Process steps	Hazard	Target level/ Critical limit	Monitoring Procedure	Corrective action if standards are not met	Records
Reception of raw meat materials (pork hind legs without feet) **CCP**	Physical, chemical, biological	Red meat color, pH[1] not above 6.2 (DFD!), no visual defects of meat/fat/skin surfaces, core temperature ≤4°C	Check purchase specification. Inspection by random sampling of appearance, odour, temperature and pH[1]	Trim surface if only few minor visible contaminations or remaining hairs. Reject delivery, if other target levels not met	Physical characteristics of meat received, certificate of sanitary status and origin of meat. Meat temperature recordings.
Storage in reception chiller	Biological	Chiller temperature ≤4°C	Periodic temperature control	Minor temp. deviation: Adjust temperature Major temperature deviation: Reject meat[2]	Temperature/ time recordings
Cutting, deboning, trimming **CCP**	Biological	Room temperature +10°C, meat temperature ≤+7°C. Absence of alterations in meat such as abscesses, purulent or blood infiltrations	Meat temperature control. Check for meat alterations and abnormal tissues	Further cooling if meat temperature too high. Reject / discard entire meat parts with alterations such as abscesses, purulent/blood infiltrations	Record meat temperature. Record accidential findings
Evaluation and weighing of non-meat ingredients	Chemical	Nitrite content in curing salt ≤0.6% (if curing salt mix done by operator). Curing salt free of impurities. No impurities in other non-meat ingredients	Check storage conditions of nitrite salt, exact weighing of nitrite portion (if mix done by operator), Curing salt quality check. Check other non-meat ingredients for impurities	Adjust weight of nitrite portion correctly or use freshly mixed curing salt. Replace other non-meat ingredients	Records of status and expiration dates of non-meat ingredients. Results of weighing nitrite portions
Preparation and injection of curing brine **CCP**	Physical, chemical biological	Brine temperature at injection ≤+4°C	Check brine temperature	No utilization of curing brines failing temperature and purity requirements	Record conditions encountered
Tumbling	Biological	Room temperature ≤+4°C, time ≤ 8 hours	Check temperature/ time	Adjust room temperature if too high	Temperature/ time recording
Packaging, moulding	Biological	Cleanliness of synthetic materials, tightness of enclosure by clip or seal	Check quality of materials and clipping/ sealing.	Reject unsuitable synthetic bags, correct clipping/ sealing failures	Record on packaging material, equipment
Cooking **CCP**	Biological	Internal cooking temperature (core temperature) ≥+70°C. Temperature of cooking media +78°C	Check core temperature by electronic temperature measurement	Increase cooking temperature or prolong cooking time until required core temperature is reached	Record temperature of production batch. Record any deviation in temperature
Cooling (in water)	Biological	Cooling to +15°C core temperature in ice water	Check core temperature / time. Check cooling water temperature	Add ice if cooling water temperature too high	Time/ temperature record of cooling period
Storing (chiller)	Biological	Temperature of cooling room ≤+4°C	Check temperature daily	Adjust temperature as the case may be	Record of cold chain temperature

CCP = Proposed Critical Control Point

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[1)] pH to be measured at topside (Musc. gracilis)

[2)] Alternatively: check meat and decide on further utilization for processing into hygienically less sensitive products.

Table 18: HACCP plan for Fresh Frozen Beef Burger

HACCP PLAN

Product: **Fresh Frozen Beef Burgers (extended, with salt and spices, vacuum packed)**

Process steps	Hazard	Target level/ Critical limit	Monitoring Procedure	Corrective action if standards are not met	Records
Reception of raw meat materials (beef, boneless) **CCP**	Physical, chemical, biological	Internal meat temperature ≤+4°C, red meat colour, fresh slightly acidic odour, no visible contamination, no discoloration, not slimy, no other defects	Check purchase specification. Inspection of meat surfaces by random sampling. Check internal meat temperature	Reject delivery, if target levels not met	Physical characteristics of meat received, certificate of sanitary status and origin of meat. Meat temperature recordings
Storage in reception chiller	Biological	Room temperature ≤+4°C. Meat internal temperature ≤+4°C	Temperature control of chilling room and meat (internal)	Minor temperature deviation: Adjust chiller temperature Major temperature deviation: Reject meat[1]	Temperature/time recordings of chiller. Temperature recordings of meat
Weighing and composition of non-meat ingredients	Physical, chemical	Visibly clean non-meat ingredients (common salt, no curing salt to be used)	Check salt, spices and extenders for impurities	Reject suspected batches of non-meat ingredients	Record of status and expiration dates for non-meat ingredients
Prepare meat for grinding, effect grinding	Biological	Room temperature ≤+10°C. Period from delivery of meat from chiller to pass through grinder maximum 20 minutes. Meat free of grossly abnormal tissues and post-dressing contamination	Check period of product flow. Check for abnormal tissues and post-dressing contamination	Improvement in product flow. Discard meat parts with abnormal tissues, post dressing contamination	Product flow/ temperature recording
Mixing of meat with ingredients **CCP**	Biological	No further increase of contamination. Room temperature ≤+10°C. Period from grinding to completion of mixing/blending maximum 30 minutes. Temperature of meat/meat ingredients mix ≤+10°C	Check period of product flow. Check mix temperature	Minor deviations: Adjust time/temperature regime. Major deviations: Reject batch	Product flow/ temperature recording
Patty moulding	Biological	Carry out immediately after mixing. No significant product temperature increase	Temperature/time control	Increase process speed. Return mix to chiller if no immediate moulding process	Product flow/ temperature recording
Freezing **CCP**	Biological	Blast freezer at -35°C	Temperature control	Adjust freezer temperature	Record blast freezer temperatures
Packaging	Biological	Clean packaging materials	Check packaging failures	Adjust packaging machine in case of insufficient vacuum packaging	Results of packaging
Freezer storage	Biological	Temperature of storage freezer -18°C to -30°C	Continuous temperature check	Rise of temperature: immediate identification and correction of temperature problems, transfer to alternative storage freezer if long-term problem	Continuous freezer temperature records

CCP = Proposed Critical Control Point

[1] Alternatively: Check meat and decide on further utilization for processing into hygienically less sensitive products.

Remarks: In the processing of this product there is no heat treatment included to reduce microbial contamination. The necessary heat treatment immediately prior to consumption, which is not part of the manufacturing process, is the only relevant measure to control potential contamination with pathogenic microorganisms. In order to minimize the risk of pathogenic microorganisms, special advice on the handling of the products before heat treatment and on the intensity of heat treatment must be available on the package.

During processing, the nature of the product requires periodic microbiological testing as part of GHP and HACCP verification. Microbial testing of ground meat should take place once a week or more frequently in cases of suspected hygiene failures. Microbiological testing of finished mixes containing meat/non-meat ingredients mixes can be done on case-to-case basis.

The impact of microbial contamination on meat and meat products (Fig. 458)

Meat hygiene serves to minimize the impact of undesirable microorganisms and chemical residues on meat. While residue control is primarily the task of the competent authorities, control of microbial contamination is the responsibility of meat plants in the first place. Meat plant management and staff should therefore possess sufficient knowledge about **impact of microorganisms** on food and of basic rules on how to **prevent or minimize microbial contamination** (Fig. 453, 454, 455).

Microorganisms of relevance with regard to meat hygiene include parasites, moulds, bacteria and viruses. Within these groups **bacteria** play the most important role. Therefore, the focus of meat plant internal hygiene measures is mainly on bacteria, while **moulds and viruses** play a minor role but disinfection measures must also target them. The incidence of **parasites** should normally pose no major problems in meat which has passed meat inspection, or if efficient internal pest control programmes or measure are in place.

How does bacterial contamination of meat occur ?

In live animals, the muscle meat is virtually **sterile**. However other parts of the animal such as skins, hooves and intestines contain enormous numbers of bacteria. Depending on the slaughter hygiene, these bacteria find their way to the carcass or "**contaminate**" the meat during slaughterhouse operations. Skinning, scalding, evisceration, dressing and carcass transport are common contamination points. Most bacteria reach the carcass via butchers' hands, tools, contact with equipment or through water, air, etc. The bacterial contamination of meat is not stopped after slaughtering. It is ongoing during the operations following the slaughter process, such as meat cutting and meat processing (Fig. 452).

It is quite normal and unavoidable to find bacterial counts of "total plate count" (TPC, see page 335) of the order of **several thousands** per cm^2 on meat surfaces in commercial slaughtering and meat handling. However, the principle must be to keep bacterial counts as low as possible through adequate hygienic measures. Total plate count numbers exceeding 100,000 per gram (**10^5 per cm^2**) on fresh meat are not acceptable and alarm signals and meat hygiene along the slaughter and meat handling chain must be urgently improved (Table 19).

Table 19: Recommended microbiological criteria for fresh meat

	Good microbiological standard	Critical microbiological condition	Not acceptable
Total plate count[1] per cm^2	Less than 10000 $<10^4$	Between 10000 and 100000 $>10^4$ - $<10^5$	More than 100000 $>10^5$
Enterobacteriaceae[2] per cm^2	<100	>100 - <1000	>1000

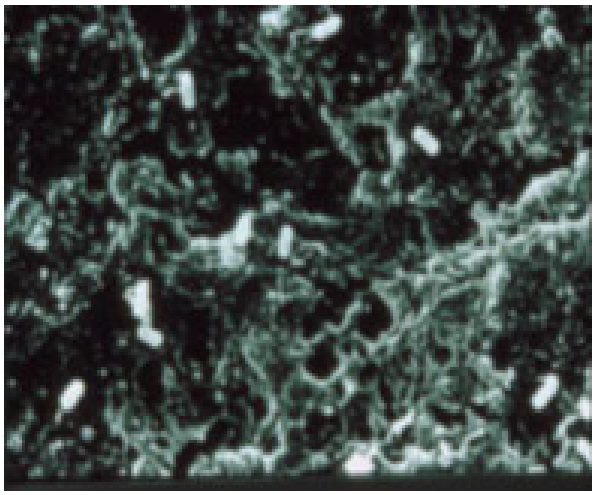

Fig. 453: Bacteria (white rod shaped) in comminuted meat mix (3,000-fold enlarged)

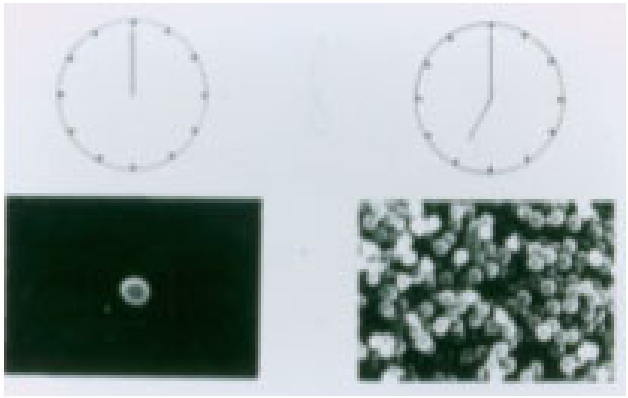

Fig. 454: Bacterial growth in 7 hours (from one bacterial cell to more than 2 million). Multiplication through periodic partition of bacterial cells.

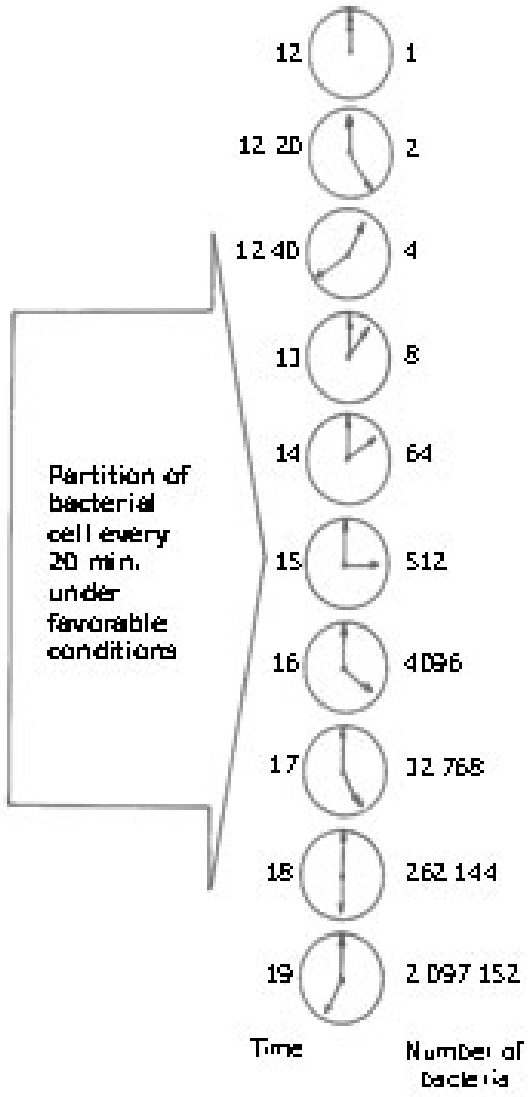

Fig. 455: Microbial growth starting

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1) "Total plate count" is the total number of bacteria comprising all microbial groups (page 336).

2) "Enterobacteriaceae" is a specific bacterial group, which indicate contamination by faecal and related materials (page 339).

Meat spoilage through micro-organisms

Meat spoilage bacteria will grow if temperatures are not kept in the cooling (-1°C to +4°C) or freezing (below -1°C) range. Not all bacteria which contaminate meat will behave in the same way. Some may multiply already at temperatures at around 10°C, others at higher temperatures, for example 30°C. Most bacteria can optimally grow in the range between 30°C and 37°C (Fig. 456 and Fig. 457). Some may attack the protein portion of the meat resulting in the production of very unpleasant putrefactive odours, others may break down carbohydrate components in particular in processed meats causing intensive sour taste or acidity. Others may attack the fats, producing rancidity (Fig. 458; table 20). These various bacterial impacts result in **meat spoilage** or **decomposition**. Spoilage of meat and meat products causes serious financial losses for the meat industries as such products, due to their sensory changes exposed through unpleasant smell and taste are unfit for human consumption. But spoiled meat, if accidentally ingested, is usually not the cause for illness in consumers.

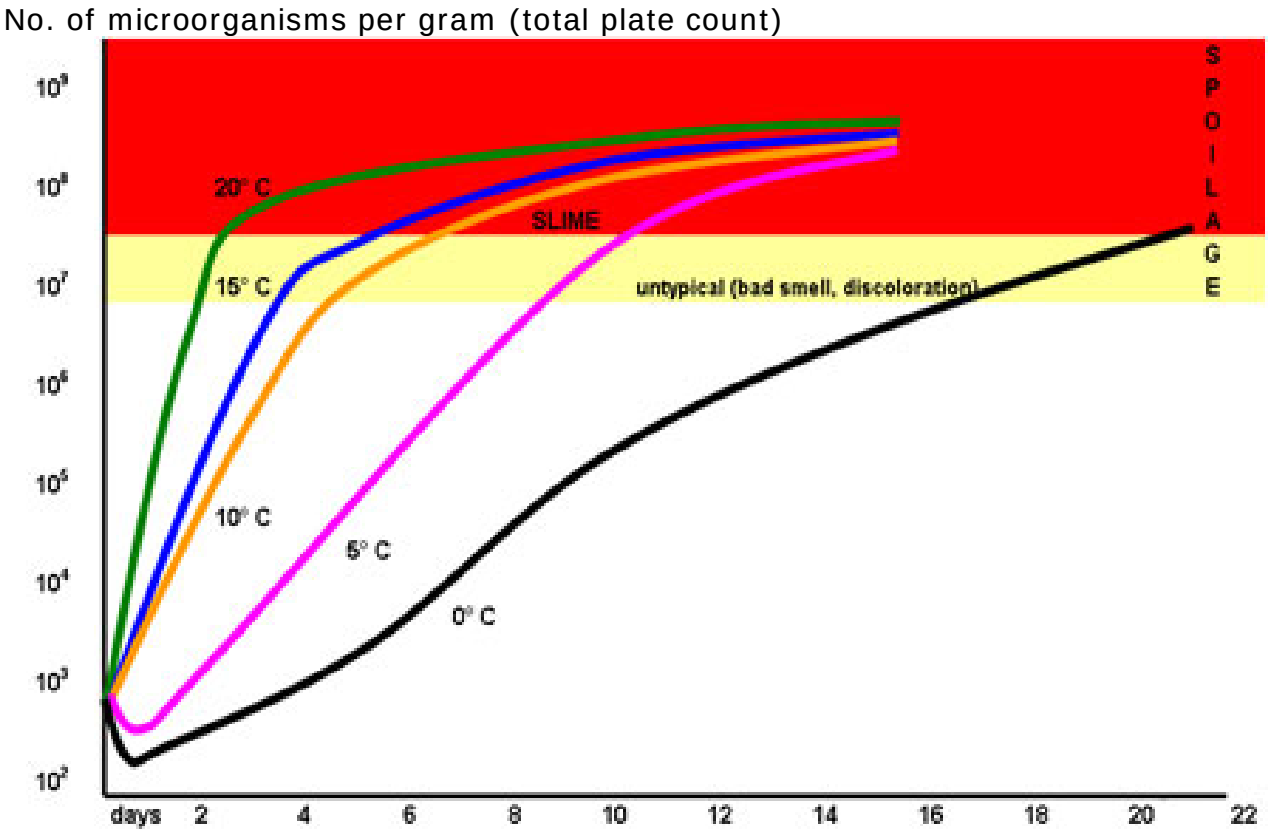

Fig. 456: Growth of microorganisms on meat (starting from same initial bacterial loads/approx. 1000 per gram meat , but different storage temperatures, 0°C, 5°C, 10°C, 15°C). At 20°C spoilage on the second day at 0°C spoilage after more than 20 days.

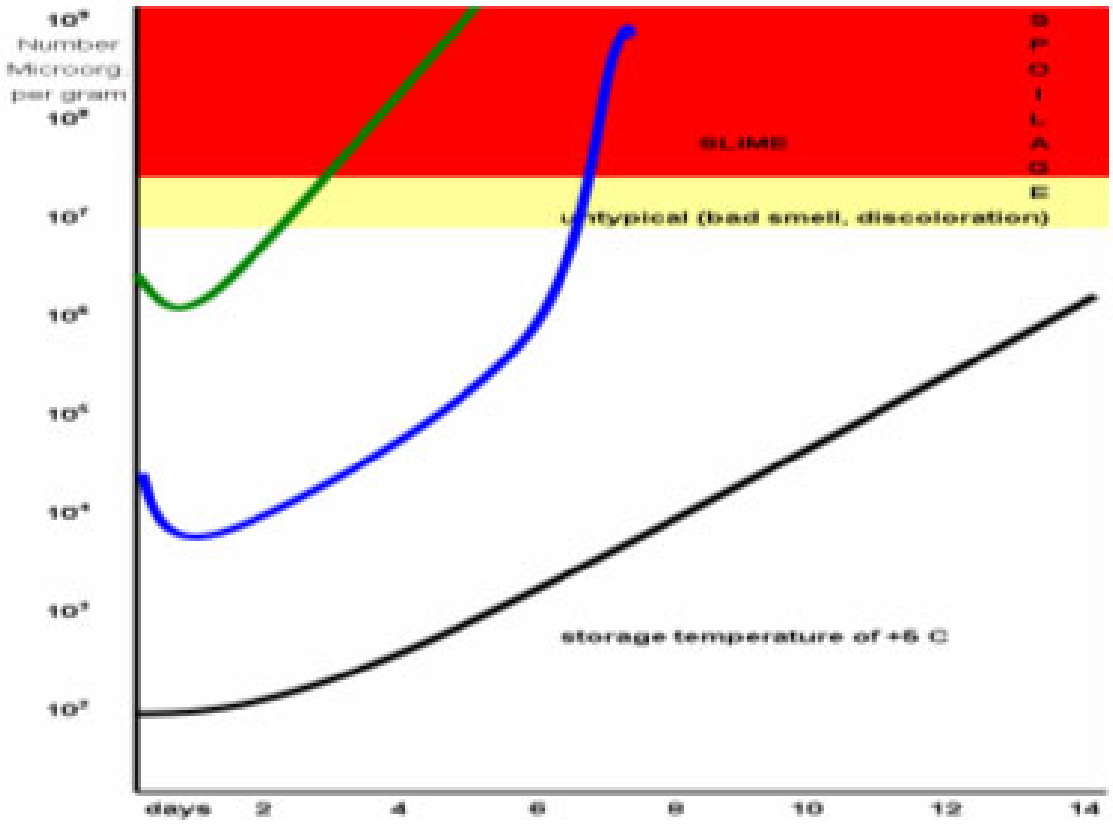

Fig. 457: Growth of mMicroorganisms on meat (starting from different initial bacterial loads/100, 10000 and 500 million per gram, but same storage temperature

Fig. 458: Impact of bacteria on meat

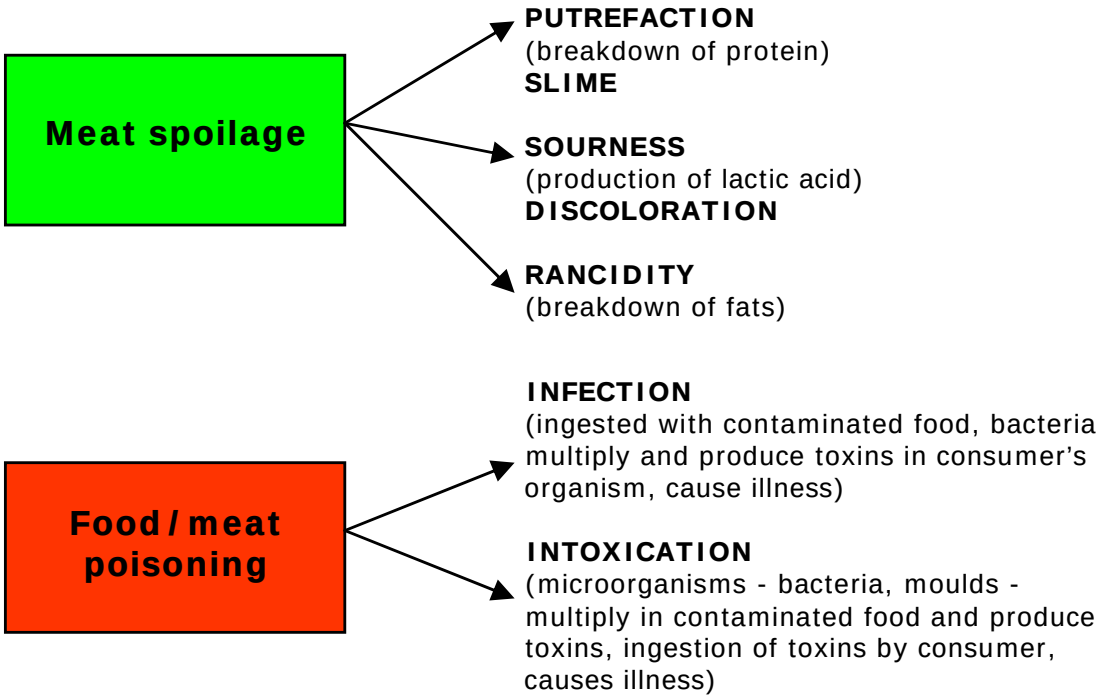

Table 20: Microorganisms causing microbiological spoilage of meat

Putrefaction	Pseudomonas ("Cold room flora"), Proteus, Clostridium (Fig. 459)
Souring	Lactobacillus, Enterococcus, Pediococcus ("Lactic acid bacteria")
Fermentation[1]	Yeasts (Saccharomyces), Enterobacteriaceae, Lactic acid bacteria
Turbidity (cloudy brine in meat juice)	Lactic acid bacteria, Enterobacteriaceae (e.g. vacuum packed meat, sausage slices)
Greenish discoloration	Lactic acid bacteria (Fig. 461)
Slime formation	Pseudomonas, Streptococcus, Enterobacteriaceae (on open meat), Lactic acid bacteria (on vacuum packed meat and meat products), Yeasts (on raw fermented products such as raw hams) (Fig. 460)
Rancidity of fats	Mainly due to presence of oxygen, but certain microorganisms are also capable of causing fat deterioration.
Mould growth	Penicillium, Aspergillus, Mucor (Fig. 462.)

Fig. 459: Putrefaction of lower part of beef quarter

Fig. 460: Slime formation on sausage surface and attached to packaging film

[1] This refers to undesirable fermentation processes. For some meat products (raw-fermented hams and sausages) controlled fermentation is wanted and necessary (see page 124 and 177).

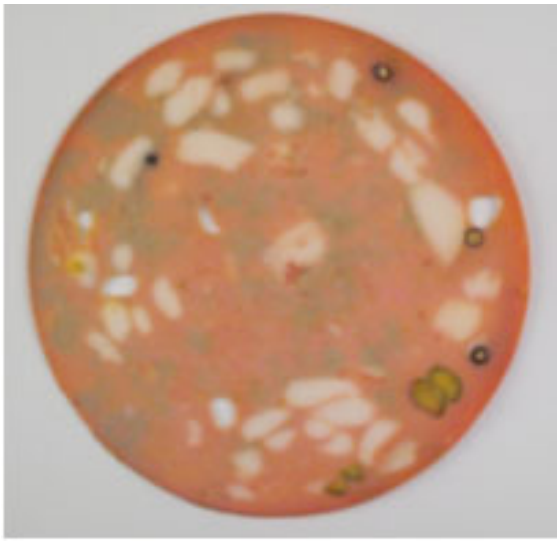

Fig. 461: Greenish discoloration (sliced mortadella)

Fig. 462: Mould growth

Meat poisoning through micro-organisms

Harmful microbes may have little adverse effect on carcasses or meat in terms of visible alterations and spoilage (smell and taste), but can have severe negative effects on consumers called **food** or **meat poisoning**. After consumption of meat contaminated with food poisoning bacteria, food poisoning results in severe illness with consumers needing intensive and costly medical treatment.

The impact of food poisoning **bacteria**, depending on the species of microorganisms, is either as a

- food borne infection or
- food borne intoxication.

Bacteria that cause **food borne infections**, must first multiply to high infectious numbers in rich protein foods such as meat and have to be ingested by consumers. They cause sickness through microbial metabolic substances i.e. toxic substances released by the living microorganisms inside the human digestive tract. The best known examples of food borne infections are those caused by Salmonella bacteria (Fig. 463). In some instances relatively high numbers of bacteria are needed to make people severely sick. For example, it is estimated that 10^5/g of Salmonella bacteria are needed in ingested food to cause Salmonellosis. In other cases, for example in the case of a recently emerged very pathogenic form of the normally harmless E.coli bacteria (entero-pathogenic form, mostly type O157 H7 residing in faecal material, on skin of animals), only a few hundred bacteria per gram food can cause severe illness with **gastro-intestinal symptoms** and **fever** and even **death**.

Microorganisms causing **food borne intoxications** produce and release the poison during their multiplication in the food. Upon ingestion by consumers of such food, which was heavily intoxicated outside the human body, severe gastro-intestinal food poisoning symptoms (**vomiting**, **diarrhea**, **abdominal pain**, **fever**) occur.

Food borne intoxications are frequently caused by Staphylococcus aureus (Fig. 464, 467, 468). These bacteria are present in purulent wounds an frequently in the respiratory system of healthy people. When they get into meat, which is not sufficiently refrigerated, they multiply rapidly and produce toxins, which cause severe gastro-intestinal symptoms only a few hours after ingestion by consumers. Another bacteria, Cl. botulinum, in the absence of oxygen e.g. in canned food or deep layers of raw-fermented hams, is capable of producing one of the strongest toxins known. Intoxication, if not treated immediately, can be fatal to consumers.

Bacteria are the most common food poisoning microorganisms. Apart from bacteria, moulds can also play a role in the incidence of food poisoning.

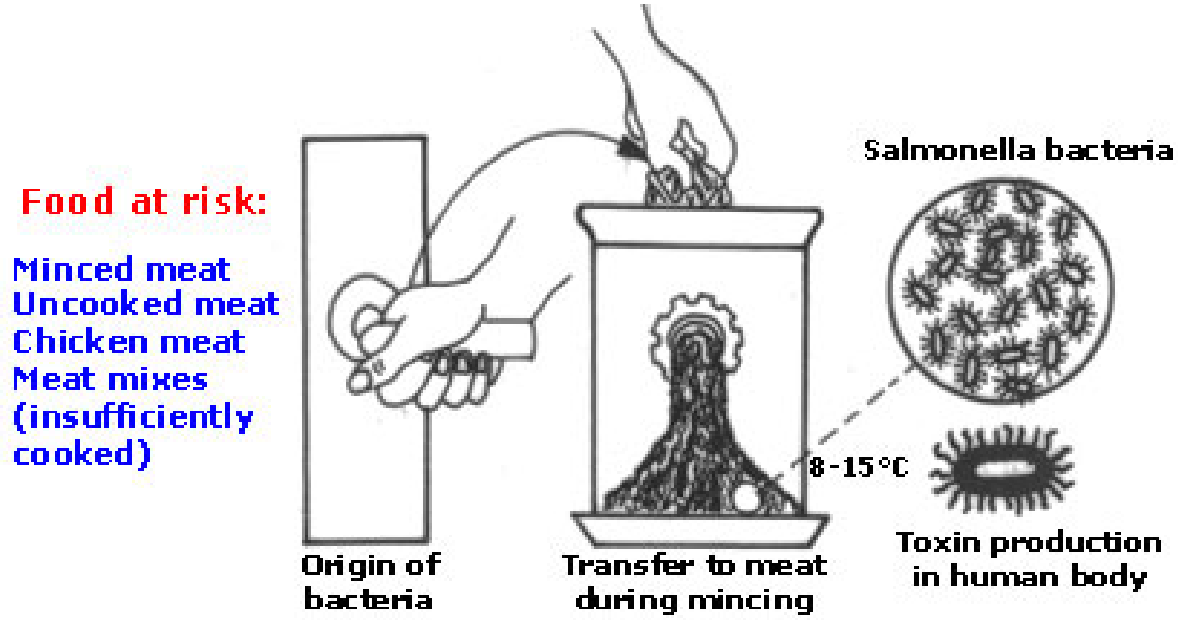

Fig. 463: Food infection by Salmonella
Deficient toilet hygiene, human carrier of Salmonella contaminates food (minced meat)

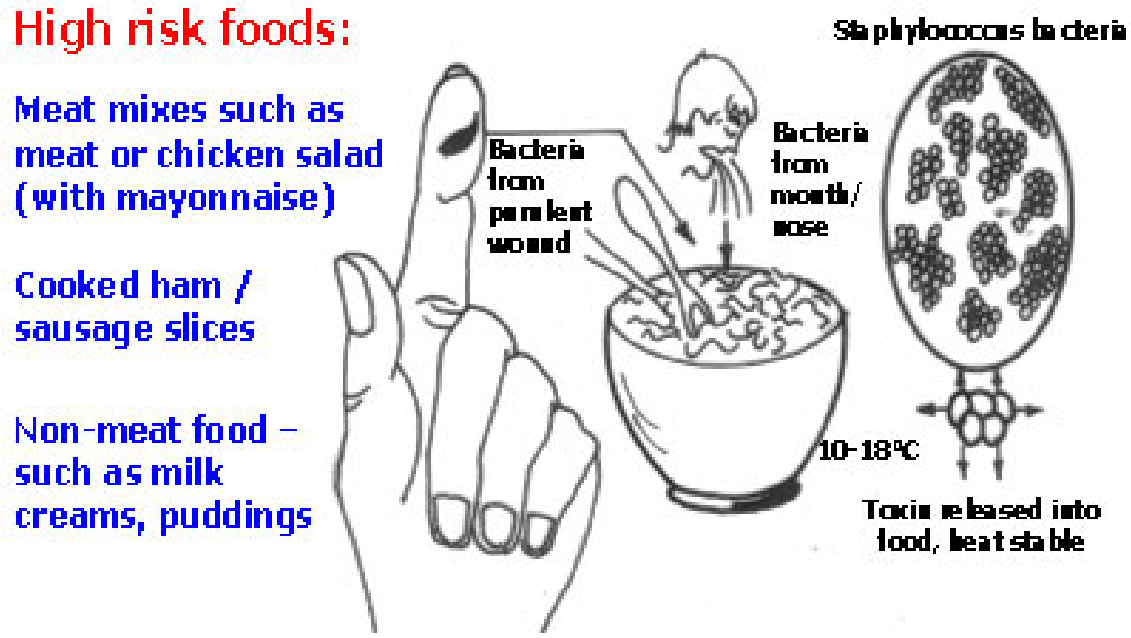

Fig. 464: Food intoxication by Staphylococcus aureus
Source of bacteria may be from purulent wound or mouth/nose.

Moulds (Fig. 465) are sometimes found on the surface of meat products after prolonged storage. Growth of moulds (see page 124) on meat can have two undesirable effects. Firstly, strong growth of moulds can spoil the affected meat parts. Secondly, and this is a more serious issue, certain types of moulds produce toxins which are released into the food. If consumed in food or feed they can, in the long term, have carcinogenic effects.

Aflatoxins are strongly carcinogenic, in particular hepatotoxic, i.e. cause liver cancer through long term impact (Aflatoxin = toxin of Aspergillus flavus). **Ochratoxin** is strongly nephrotoxic, i.e. it causes kidney disease, in particular kidney enlargement and kidney failure (Ochratoxin = toxin of Penicillium vividicatum).

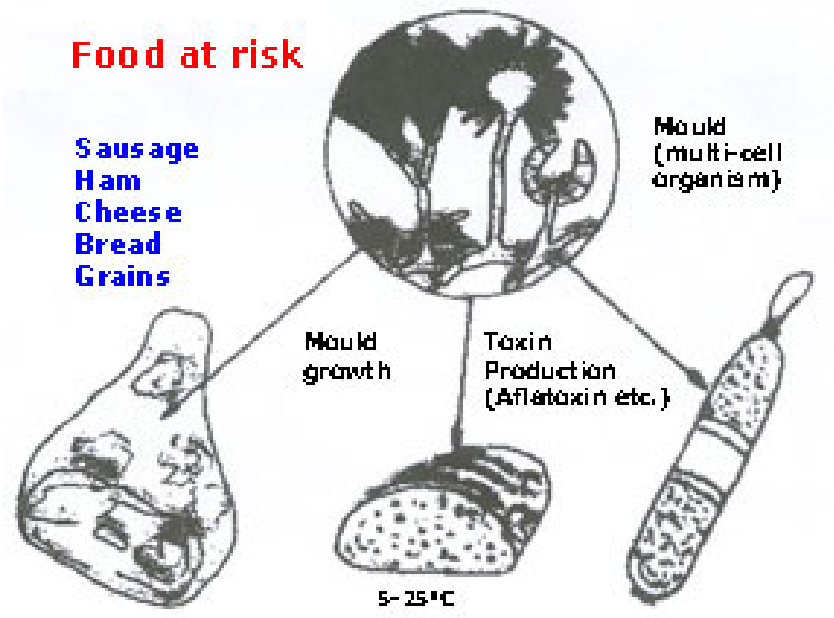

Fig. 465: Food intoxication by moulds
Potential production of mould toxins on dried ham, dry fermented sausage and bread.

Viruses were always suspected to cause food infections. In the last years it has been shown that in particular the **Norovirus** group can be responsible for food infections with similar, mainly gastro-intestinal symptoms, as bacterial food infection agents.

Table 21: Major meat poisoning organisms

Salmonella	Food borne infection
E. coli (enteropathogenic type)	Food borne infection
Listeria monocytogenes	Food borne infection
Campylobacter jejuni	Food borne infection
Yersinia enterolytica	Food borne infection
Staphylococcus aureus	Food borne intoxication
Clostridium botulinum	Food borne intoxication
Mycotoxin producing moulds	Food borne intoxication
Norovirus	Food borne infection

Good Hygienic Practices in meat processing

Microbial meat spoilage or food poisoning through meat can be prevented if the microbial load/bacterial contamination, which occurs during slaughtering and meat handling, is kept as low as possible. The key for achieving this is strict meat hygiene including an uninterrupted cold chain throughout the entire meat production and handling chain.

Meat hygiene is a complex field, based on regulations by competent authorities and meat plant internal hygiene programmes, to be supervised by the plant management (see page 341). Those programmes will only be successful if meat plant staff are familiar with and active in observing basic hygiene requirements. In order to facilitate the application of hygiene requirements, it has proven useful to differentiate between:

a. **Personal hygiene**
b. **Slaughter and meat processing hygiene**
c. **Hygiene of slaughter and meat processing premises**
d. **Hygiene of slaughter and meat processing equipment**

The topics a-d are of equal significance. Negligence in any of the four areas may give rise to hazards, which can cause economic losses and affect consumers' health.

Some key requirements for **meat processing plants** are listed below. More detailed hygiene requirements are laid down in national regulations and in international codes, such as FAO/WHO CODEX ALIMENTARIUS Code of Hygienic Practice for Meat (CAC/RCP 58-2005). Guidelines on slaughter hygiene or meat transport and storage hygiene are not included hereunder. However, as meat is the primary material for processed meat products, the application of hygienic practices in slaughterhouses and throughout the cold chain is equally important. Principles of sanitation of premises and equipment are described in a separate chapter (page 369).

Principles of personal hygiene

- Wear clean protective clothes (Fig. 405, 406)
- Washing hands before starting work (Fig. 466)
- Repeatedly washing hands during work
- No finger rings, watches, bracelets
- Access to production areas with working clothes only
- Cleaning/disinfection of hands/tools/clothes if there was contact with highly contaminated subjects or abnormal animal parts likely to contain pathogens.
- Fresh wounds through knife cuts etc. must be covered by a water tight bandage. Workers with purulent wounds are not allowed to work with meat. (Risk of spread of Staph. aureus bacteria, see Fig. 464, 467, 468).
- Strict toilet hygiene must be observed (removal of apron, hand washing and hand disinfection). Toilets must be kept clean and must not have direct access to production areas. (Risk of spread of Salmonella, see Fig. 463).
- Periodic medical examination of staff

Fig. 466: Handwashing with liquid soap, pedal, paper towel.

Fig. 467: Fresh non purulent wound, to be protected by impermeable bandage.

Fig. 468: Purulent wound, working with meat prohibited.

Basic hygiene of meat processing

- Ideally meat cutting/deboning should be carried out in climatized rooms (approx. + 10°C) with low air humidity. Meat should be brought in progressively and not accumulate on work tables.
- If visual contamination of manufacturing meat occurred, do not try to wash it off but remove it with knives by cutting off superficial meat parts in the case of minor contamination. Discard the meat in case of heavy contamination.
- Do not hose down floor and wall areas or equipment next to meat processing operations or final products with a power hose. (Risk of contamination by aerosol/droplets, see Fig. 469).

Fig. 469: Cleaning with pressurized water must be avoided in rooms where meat is present

- Never take meat pieces, which accidentally had contact with the floor or other contaminated surfaces, back onto working tables or into meat processing machines (Fig. 470).
- Containers for meat, fat, or semi–or fully processed meat products must not be placed directly on the floor but on hygienic stands, pallets etc. (Fig. 471).

Fig. 470: Meat which falls accidentally onto the floor, must not be taken, goes to waste.

Fig. 471: Meat containers must not be placed directly on the floor

Hygiene of meat processing premises

(Hygienic requirements for lay-out and construction of slaughterhouse and meat processing buildings)

Meat processing facilities must meet the following basic hygienic standards in order to ensure and maintain clean and hygienic working conditions:

- Adequate rooms for personnel must be available including sections for changing clothes and for personal hygiene.
- Wall windows must be positioned at a sufficient height from the floors in order to allow profound washing and disinfection of floors and walls. Wall windows for processing plants must be at their lowest part at least 2 m

Fig. 472: Hygienically good finishing of premises. Wall tiles and wall windows 2 meters high, for easy cleaning.

high over floor level. Window frames should be of non-corrosive material e.g. aluminium or similar and must not be painted (Fig. 472).

- Walls in all rooms, where meat and by-products are handled, must have smooth and easily washable surfaces up to a minimum height of 2 m in processing plants. Walls should preferably be covered with wall tiles or at least with washable paint (Fig. 472, 475).

Fig. 473: Hygienically good finishing of premises. Easy to clean surfaces, left floor with drain and wall with coved junction, right plastic door for refrigerated room.

- Floors in the mentioned sections must be impermeable for water and reasonably smooth for good cleaning, but anti-slip for workers safety. They are usually made of fat-resistant concrete. Additional covering by epoxy substances or floor ceramics are possible (Fig. 473, 475).
- In order to facilitate proper cleaning, the junction between floor and walls must be coved, i.e. rounded (not rectangular), which can be achieved by extending the floor concrete up to an height of 10-50 cm alongside the walls. If the concrete layer alongside the wall is

Fig. 474: Proper cleaning/sanitation not possible. Crack in junction wall/floor.

Fig. 475: "Cleaning friendly". Smooth floor and wall tiles, cove at junction wall/floor.

sufficiently thick (approx. 10-20 cm), it serves also as shock absorber and protects the walls against damage by transport vehicles, such as trolleys, fork lifts etc. Appropriate coves at wall-floor junctions can also be achieved by using special curved wall tiles (Fig. 475).

- All wet rooms must have floor drains, which should be covered by non-corrosive metal plates or grills (Fig. 473). The covers should be easily removable for proper cleaning of the drains. Drain sinks must be of the siphon type (anti-smell).

Fig. 476: Minced meat and vegetable in same chiller - risk of cross-contamination

Fig. 477: Rusty meat hooks

- Provisions must be made to channel waste water from hand-wash facilities, cool room evaporators, tool sterilizers, etc. by means of water pipes or similar directly into effluent drains without contaminating the floor.
- Rooms for meat processing should have sufficient ventilation. Air conditioning is only required in meat cutting/deboning rooms (10 - 12°C).
- Supply systems for electrical wiring and pipes for hot and cold water as well as for compressed air should not hamper cleaning operations and be out of reach of possible dirt contamination (Fig. 478). Insulations for hot water pipes must have smooth surfaces and be washable.
- Openings for ventilation must be bird- and insect-proof.

Fig. 478: Supply systems for electrical

Hygiene of meat processing equipment

(Hygienic requirements for design and construction of machinery, working tables and tools)

In production lines in the meat industries equipment and hand-tools should be used, which enable workers to perform all operations according to Good Hygienic Practices. It is the responsibility of the meat plant management to provide adequate equipment for all working places. For equipment manufactures, directives have been issued as to proper design and construction of meat processing equipment. Designs must allow easy and profound cleaning and avoid any accumulation of difficult to remove organic matters (negative examples see Fig. 476, 477, 479, 480).

Fig. 479: Corroded meat grinder (hygienically obsolete)

Fig. 480: Old fashioned meat processing equipment with red paint (should be stainless steel)

As a principle in modern meat industries it is commonly accepted that tools and surfaces in contact with meat should be made of food grade stainless steel or synthetic materials. **Stainless steel** must be used for working tables, meat hooks (at least their parts contact in meat), blades of knives, saws, cleavers and axes. All parts of machinery in contact with meat, fat, sausage mixes and meat ingredients must be of stainless steel such as frozen meat cutter, grinder, meat mixer and tumbler, meat emulsifier, sausage stuffer, brine injector etc. The bowls of bowl cutters are nowadays also mostly made of stainless steel. All the stainless steel parts must be smooth, easily accessible for cleaning and without hidden spaces, where particles of meat materials may accumulate (Fig. 481, 482).

Fig. 481: Adequate material for refrigerated rooms: Overhead galvanized rails and beams, stainless steel meat hook

Fig. 482: Stainless steel equipment and tools for meat processing

Galvanized steel or food-grade aluminium are useful materials in the meat industries as they are non-corrosive. Those materials should however not be in direct contact with meat, as they are not sufficiently smooth or may release unwanted substances. But they are very suitable materials for overhead rails and supporting structures, working platforms and frames for tables and machinery (Fig. 481).

Food grade synthetic materials are used for many types of meat containers and for handles of knives and other hand tools, for cutting boards and some internal parts of meat processing equipment such as washers, parts of valves etc. (Fig. 483, 484, 485, 486, 487).

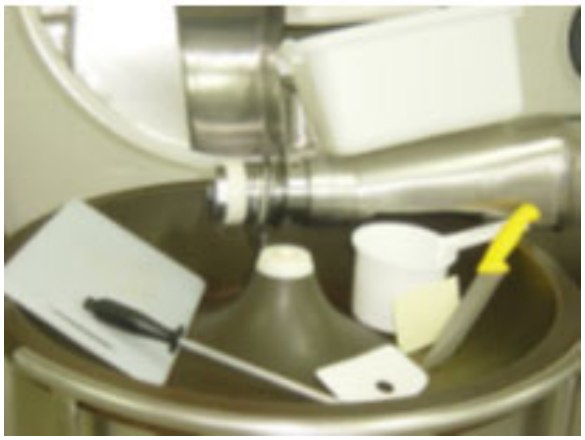

Fig. 483: Food grade plastic materials

Fig. 484: Meat cutting table, frame made of stainless steel, plastic boards removable for easy cleaning

Fig. 485: Wooden cutting board, knife incisions close up when wet and imbed bacteria (hygienically not acceptable)

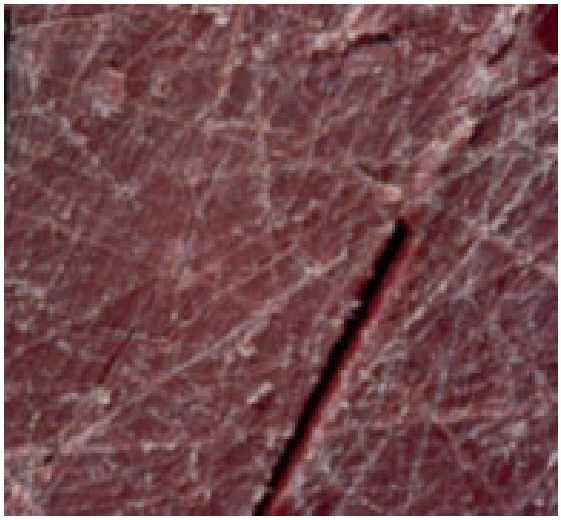

Fig. 486: Plastic cutting board, knife incisions remain open for profound cleaning

Fig. 487: Polishing plastic cutting board with shaver

In summary it can be stated that Good Hygienic Practices in meat processing requires efforts by both management and staff.

- It is the duty of the plant management to procure investments in **good quality premises and equipment** and in continuous **plant and equipment maintenance**.
- For the meat plant staff it is an obligation to observe during all meat processing operations **relevant hygienic rules**.

Such efforts will result in good storage life of attractive meat products with desirable appearance, flavour and taste.