Cleaning and disinfection practice in the meat industries of Europe

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Summary: The application and efficacy of cleaning and disinfection methods are reviewed, together with the relevant European and French legislation. European Commission Hygiene Directive 93/43/EEC of 14 June 1993 proposes the adoption of hazard analysis and critical control points (HACCP) for the meat industry, and this includes cleaning and disinfection.

It is necessary to organise a team for washing, cleaning, rinsing, disinfection and final rinsing; three different types of organisation are compared. Application of HACCP and its contribution to the shelf life of products and their contamination with Listeria monocytogenes is discussed in the light of practical experience with poultry meat and cured pork products.

Various means of verifying the efficacy of cleaning and disinfection (turbidimetry, adenosine triphosphate assay and macroscopic observation) are compared with the techniques of conventional microbiology.

The authors conclude that cleaning and disinfection are essential for application of HACCP to the meat industry.


INTRODUCTION

Cleaning and disinfection are currently regarded as the most effective means available to the food industry for controlling the multiplication of microorganisms in products of animal origin.

Current production methods cannot guarantee that live animals, which constitute the raw material for the food industry, are free from pathogenic bacteria. Under these conditions, effective procedures for cleaning and disinfection are necessary to restrict contamination to a given carcass or a batch of carcasses, particularly by reducing the risk of cross-contamination.
 Few regulations deal specifically with cleaning and disinfection, and the only regulation in force in France, up to development of the ‘new approach’ to food hygiene, was Article 10 of Decree No. 73-138 of 12 February 1973 (2).

This regulation required users of materials or objects which come into contact with foods to ensure that these materials and objects are kept clean. This implied daily cleaning and disinfection, and other possible measures as required, applicable to mobile equipment (vehicles for transport of live animals and carcasses, trolleys, knives, gloves, aprons, etc.), fixed equipment (slaughter line, cold storage line, machines, conveyor belts, etc.) and premises (walls, ceiling, floors).

The general approach to hygiene in the food industry has been changed considerably by the publication of European Economic Community (EEC) Directive 93/43/EEC of 14 June 1993 (10) concerning food hygiene, known as the Hygiene Directive. Article 3 of this directive proposes the adoption of a new approach to quality control in the food industry, taking into account hazard analysis and critical control points (HACCP) (10).

HACCP is a quality assurance method which is particularly suitable for food products. It was developed in around 1970 in the United States of America, for use by companies which supplied food for special projects of the National Aeronautics and Space Administration (NASA), in order to avert potential risks from contamination of these products by pathogenic microorganisms.

As a quality assurance system, HACCP provides a procedure for identifying and evaluating the risks associated with various stages of a process, and for defining the steps to be taken to control these risks (12). It does not provide scientific or technical information, but it has the virtue of being a coherent system to assist analysis and decision making, taking account of all the operators in a processing chain. HACCP can thus be a tool for management and for building greater responsibility among personnel. With the help of HACCP, the quality of a manufactured product may be controlled through the manufacturing process, and in this way HACCP complements Standard ISO 9002 of the International Organisation for Standardisation (ISO), which governs the entire enterprise. HACCP is least costly to implement when only a small number of products is produced, but one person is still required to lead the HACCP team.

Application of HACCP is based on seven steps, as follows (12):

a) Identify the risks associated with food processing at all levels, from raw materials to consumption. Evaluate the possibility of occurrence of these risks. Identify the preventive measures necessary for control.

b) Determine the critical control points (CCP): these are points, procedures or operational stages which have to be mastered in order to eliminate or reduce a risk. Points where risks may be eliminated are called first-order points (CCP1), while those where a risk may be reduced but not eliminated are called second-order points (CCP2).

c) Determine the critical limits (which separate acceptable from unacceptable risks) and establish new targets and/or tolerances to ensure that the CCP is reached.

d) Establish a surveillance system based on programmes of testing, measurement or observation.

e) Establish corrective actions to be taken if surveillance shows that a CCP has not been completely controlled.

LEGISLATIVE BASIS FOR CLEANING AND DISINFECTION
f) Establish verification procedures, including additional tests, which demonstrate that the HACCP system is applied and is effective (audits and automatic checks).

g) Establish a documentation system for all procedures or all records concerning points a) to f) and their application.

Although the EEC Hygiene Directive contains few specific stipulations, it places responsibility for quality control on the food industry, and provides (in an Appendix) general rules for premises, equipment and transport vehicles, particularly with regard to ease of cleaning and disinfection.

Conditions under which this new approach can be implemented – particularly procedures for verifying and measuring the quality of cleaning and disinfection – will be considered below.

However, no current legislation specifies the procedure for cleaning and disinfection. Products used for this purpose in France must appear in an approved list (2, 3, 4).

IMPLEMENTATION OF CLEANING AND DISINFECTION PROCEDURES

Cleaning and disinfection team

The following types of organisation are possible, depending on scale and the preference of the producer:

- Some or all of the personnel perform the operations at the end of the working day; this system has the advantage of personal involvement, but these operations are often regarded as a chore.

- An independent team, forming an integral part of the enterprise, operates in the evening or a few hours before the end of daily operations (in this way, the cleaning and disinfection team is not completely segregated from the production team).

These first two solutions can be combined: general cleaning and maintenance of work stations are entrusted to members of the production team, while cleaning and disinfection are performed by a designated team.

- A team employed by an outside servicing company conducts operations as specified in a contract between the two partners.

This third solution is becoming increasingly popular, as it enables the task to be precisely defined. Members of the production team may be made responsible for preliminary cleaning of their work stations to maintain the motivation for good hygienic practice. It is also desirable to have a united team, with the team leader permanently present on-site, and to incorporate the measurement of certain objective criteria of quality (microbiological assay, adenosine triphosphate [ATP] assay) into the contract.

Procedures for cleaning and disinfection

Design of premises and materials

Concern for hygiene at workplaces should be integrated into the fundamental design of premises. A number of criteria are stipulated in various regulations (1, 10) and the most important of these criteria are as follows:

- Buildings must be permanent structures and so designed that cleaning, washing and disinfection can be performed easily and effectively.
Angles between walls and between the walls and floor should be rounded.
- Walls and doors should be provided with a smooth, shock-resistant covering and painted with washable, light-coloured paint.

In addition to these regulatory requirements, the following architectural features may also facilitate hygiene in buildings:
- underground channels for evacuation of waste materials (5);
- concealment of ducts, pipes and girders by a false ceiling which can be washed easily;
- sufficient space to facilitate dismantling and maintenance of machinery, and to provide optimum hygienic and working conditions;
- provision of a special area for cleaning and disinfecting small objects, trolleys, crates, etc.

This planning stage must include the design of materials. A considerable degree of automation is being incorporated into slaughter and processing. New machinery, of increasingly high performance, ought to be easier to clean and disinfect effectively (by virtue of the materials used, ease of dismantling, watertight electrical compartments, possibility of continuous washing or disinfection, etc.). Manufacturers are now more aware of this aspect of machine design, and the French standards institutes AFNOR (Association française de normalisation) and GAMAC (Groupement pour l'amélioration du matériel destiné à l'alimentation collective) award a special 'food hygiene' label.

**Technique and products used**

**Preliminary cleaning**

Preliminary cleaning is an important operation, particularly where meat is handled, and is aimed at achieving 'visual cleanliness' of the workplace. For this purpose, the production and/or maintenance team (or the cleaning and disinfection team) must perform the following tasks:
- place materials to be used the next day (carcasses, raw materials, etc.) in cold storage;
- dismantle equipment;
- store utensils (trolleys, gloves, etc.) in the appropriate place;
- remove waste materials (meat, viscera, etc.) on floors, walls and equipment by scraping, brushing, sweeping, or washing down with a low-pressure hose.

When this stage is complete, a large part of the work has been accomplished, as elimination of all these materials also eliminates the support for dependent microorganisms.

**Cleaning**

The actual cleaning stage must remove organic matter on equipment, floors and walls. The 'visual cleanliness' achieved earlier has not dealt with remnants of meat still present in gaps or crevices, or the greasy layer which might coat floors and machines.

This operation involves the use of a product with detergent action, approved for cleaning with food-contact surfaces. This product must detach, dissolve and inhibit redeposition of organic and mineral soilings. It facilitates the removal of debris from gaps and crevices. The choice of cleaning product depends on the principal type of soilings.
present and the equipment used. Such products may be divided into the following broad categories (11):

- Alkalis (sodium, potassium, etc.) are active against organic soiling, as they saponify fats and dissolve proteins. Consequently, these products are frequently used in the meat and poultry industries.

- Acids are used mainly to eliminate calcium deposits (from hard water) and to restore stainless steel surfaces.

- Organic (surface-active) products are often incorporated into the alkali and acid preparations mentioned above. These products have the ability to reduce the surface tension of water, inhibiting the tendency for droplets to form on cleaned surfaces (increase in wetting power) (9).

Certain products referred to as 'detergent-sanitisers' combine an (alkaline) detergent action with an active principle which has a disinfectant action (e.g. chlorine). Although such a formulation destroys microorganisms (in the disinfectant phase), this microbicidal activity may be inadequate, as it will be inhibited by any organic matter still present at this stage.

Once a product has been chosen, the recommended mode of application must be strictly observed, paying attention to the following fundamental principles:

a) The final concentration of the product must be monitored for the following reasons:

- the product will not exert its full action in a sub-optimal concentration;
- it is wasteful to use a higher concentration, as no increase in efficacy results, and there may be a risk from toxic residues.

The ideal concentration varies between 1% and 5%, depending on the product (13), and this concentration can be maintained by incorporating a dosing pump in the circuit.

b) The temperature of the detergent solution at the moment of use must also be controlled, partly as temperature affects the rate of chemical reactions (13), and partly because the solvent action may thus be enhanced. However, high temperature alone must not be relied on for disinfection, as it has been demonstrated that cleaning by steam jet at 130°C produces a temperature of no more than 80°C just 15 cm from the jet. Moreover, when such a jet is applied to a metallic surface, the temperature of this surface will reach only 35°C one minute after application and 50°C after two minutes (9). In addition, some types of materials may be damaged by such an increase in temperature.

Temperatures usually employed at this stage of cleaning range from 45°C to 60°C for preparing the solution, but may reach 70°C during mechanised application.

c) Duration of application is important, as the chemical reaction between the product and the soiling requires a minimum time for completion. Two distinct aspects are involved in the timing of product application, as follows:

- The time required for personnel to apply the product to all surfaces depends mainly on the use of efficient techniques and rational organisation of the work.

- The contact time necessary for a chemical reaction varies with products used, materials and soiling, but once defined it has to be observed scrupulously (approximately 20 min). Reducing this time accidentally will diminish efficacy, and will subsequently eliminate substances which are still active, leading to economic losses. The use of a foam-
forming support can extend the contact time, particularly by slowing run-off from vertical surfaces.

d) A mechanical action is obtained by using a brush or a water jet with detergent solution and a foam enhancer. This action ensures mixing at the molecular level, produces repeated contact between the product and soiling, and detaches the most tenacious soiling.

In abattoirs and processing premises, the surfaces of equipment have numerous fissures, interstices and corrosion points, and the preliminary cleaning may have been inadequate. The same applies to conveyor belts made of synthetic material intended for food use, and working surfaces made of high-density polyethylene, on which fissures are accentuated during use. Consequently, this stage of cleaning must be performed thoroughly to dissolve all organic matter (e.g. blood, coating of fat) present on the various surfaces, and to reach interstices by lowering surface tension.

**Intermediate rinsing**

Rinsing after the application of cleaning products detaches the most tenacious soiling by the use of high pressure, and removes the mixture of detergent, foaming agent and soiling from surfaces. Another important stage of cleaning is accomplished, as the surfaces now look and feel clean. Rinsing can also remove resistant biofilms. The cleaning and rinsing stages remove a large proportion (approximately 90%) of microorganisms trapped by attachment to organic particles and by the formation of a suspension with the detergent. This decrease in bacterial count greatly assists the next stage.

**Disinfection**

The aim of disinfection is to eliminate the microorganisms still present on surfaces, adhering to anchorage points. Some bacteria become attached a few nanometres from the surface, while others produce substances which result in an adhesion that is difficult to break down (biofilm) (6).

This stage consists of applying an approved disinfectant. In order to be effective, the product must reach all the places where bacteria may be persisting (requires good wetting action), and must be capable of destroying the bacteria present, either by upsetting the electrostatic and electrodynamic forces of adhesion, or by attacking a vital constituent of the cell (lethal action or inhibition of development).

The concept of 'sanitation' is often evoked by the food industry, implying appropriate measures to eliminate food contaminants and potentially pathogenic microorganisms, with the understanding that it is impossible to eliminate all microorganisms present on working surfaces and utensils used in this industry.

Chemical disinfectants fall into the following main categories:

a) Halogen derivatives may be further sub-divided into chlorine- and iodine-based products, as follows:

- Chlorine products are used widely in the meat industry. They act by oxidising cell material and have a wide range of bactericidal activity. Chlorine products can be used in alkaline medium (pH 8.0) and can be combined with other chemical compounds, such as surfactants. Such products are usually cheap but have the disadvantage of being very sensitive to the presence of organic matter, requiring thorough cleaning prior to use.

- Iodine compounds (iodophors) have an identical mode of action and also possess considerable bactericidal activity. They are little used in the food industry as they can stain certain materials and are relatively unstable.
b) Quaternary ammonium compounds (QACs) are capable of reducing the surface tension of water (wetting action) and become adsorbed to cell walls, disturbing the physiology of bacteria. QACs are particularly effective against Gram-positive bacteria, yeasts and moulds. However, these disinfectants are relatively expensive, are sensitive to the presence of proteins, and possess little activity against Gram-negative bacteria.

c) Amphoteric compounds have a structure similar to that of amino acids, which is probably the origin of their disinfectant ability (interfering with cell function by substitution).

d) Aldehydes (e.g. formaldehyde) have a wide range of bactericidal activity but their action is relatively slow. Disadvantages of products based on formaldehyde include an unpleasant smell and irritant effect, and the fact that they cannot be used at low temperatures (e.g. in cold stores).

The mode of application of a product is governed, as in the case of cleaning, by the following main criteria:

a) The final concentration at which a product is used is very important, as excessive dilution renders the product ineffective; a slightly lower dilution might reach a threshold at which the disinfectant even encourages the growth of microorganisms. Concentrations above this threshold but below that recommended by the manufacturer have an inhibitory effect on the growth and multiplication of microorganisms; such a level may lead to the phenomenon of habituation or adaptation of the bacteria to sub-lethal doses of the product. When this occurs, the more resistant bacterial strains can continue to develop and to invade the substrate. The optimum concentration has a microbicidal action, destroying bacterial cells. Higher concentrations are no more effective and constitute economic wastage.

The importance of controlling this parameter requires not only a system for continuous determination of concentration but also a means of monitoring the actual efficacy of the product. Consequently, one must be aware of the entire process of cleaning and disinfection in order to avoid, for example, antagonism between two chemical products used (e.g. traces of an anionic detergent could react with cationic disinfectants).

b) Recommendations for the temperature at which a disinfectant solution is used must be respected, as this provides for optimum efficacy; use temperature is usually between 20°C and 30°C.

c) The time of contact between the product and a surface can be adjusted. The bactericidal action of the product increases with length of contact. Consequently, a contact time of one to two hours or more would be useful, although it is necessary to avoid the product drying out (and thus leaving traces behind).

d) Mechanical action (e.g. brushing, foam formation, low-pressure jet) improves contact between the solution and microorganisms. Of course, any utensils used (brushes, brooms) must be disinfected prior to use.

The surfaces onto which disinfectants products are sprayed or sprinkled should be ‘clean’, to enhance the efficacy of the disinfectants. Addition of a foaming agent improves mechanical action, increases contact time, and facilitates monitoring of the operation.

Premises and equipment can also be disinfected by applying aerosols to the ambient air; this cannot be performed in the presence of personnel, but might be suitable at the end of a working week.
Final rinsing

The final rinsing is an obligatory step to remove all traces of substances used, or other residues which might enter food. Rinsing is also necessary to remove the complex of disinfectant and destroyed or inhibited bacteria present on equipment, walls and floors. This rinsing is performed using a jet of potable water, at low pressure (to avoid splashing) but at sufficient flow rate to remove all traces of the substances (particularly after a prolonged period of contact).

Equipment

A specially designated area should be equipped with washing machines which contain many compartments, or are capable of performing several washing cycles, and are provided with dosing pumps for adding the various products. These machines can be used for washing small movable equipment (knives, crates, etc.).

Other equipment needs special attention, as follows:

- Cutting boards require thorough cleaning, with mechanical action (scrubbing) to remove particles from the numerous crevices, followed by disinfection (e.g. by immersion) using the maximum possible contact period (for example, two sets of boards may be provided per person, thus one set can be used while the other is being disinfected).

- Gloves and protective aprons, which act as traps for meat debris, should also be correctly cleaned and then disinfected by immersion.

An important part of a hygiene programme is to arrange for all movable equipment (crates, trolleys, etc.) to be taken to a separate area to pass through a special and obligatory cycle of cleaning and disinfection after each use. This also applies to aerial conveyors and hooks which may not be the responsibility of a team, and therefore tend to be overlooked or forgotten. Obligatory passage through a special machine after each use will maintain the equipment in a good state of cleanliness. Special equipment is now available for cleaning armoured gloves and knives.

**IMPORTANCE OF CLEANING AND DISINFECTION IN THE MANAGEMENT OF MICROBIOLOGICAL RISKS**

Regulations for cleaning and disinfection are well established in the food industry, but awareness of the importance of such regulations among industrialists is relatively recent.

A survey of thirty poultry abattoirs conducted in 1981 and 1982 by CNEVA (National Centre for Veterinary and Food Studies) in Ploufragan, France revealed that all establishments practised daily preliminary cleaning, while only 18 used a detergent for cleaning (7). Nineteen performed disinfection, but only 12 of these establishments practised final rinsing. This study found poor results in abattoirs which failed to apply disinfection, but even application of the complete process of cleaning and disinfection failed to guarantee satisfactory results. In fact, the results were completely satisfactory in only five of nine abattoirs which used the full procedure for plucking machines, although better results were achieved for eviscerating machines.

The efficacy of cleaning seemed to depend as much on the thoroughness of the procedures used as on the type of machinery treated.
It is important to monitor contamination of machines after cleaning and disinfection, as certain types of contamination can be traced to surface contamination. Some examples from field observations demonstrate the importance of cleaning and disinfection in preventing microbiological risks.

**Influence of cleaning and disinfection on the storage life of products**

This example (14) concerns an abattoir where poultry carcasses could be safely kept for only four to five days, compared with eight days for most other abattoirs. A microbiological audit of the slaughter chain showed that contamination with *Pseudomonas* was greatest after the plucking stage (Fig. 1), so it was necessary to seek the source of contamination before this stage. Analysis of product-contact surfaces (plucking digits, basins, skirts) after cleaning and disinfection (Fig. 1) showed that the biofilm which covered these surfaces was probably responsible for most of the contamination.

Effective cleaning and disinfection reduced carcass contamination to an acceptable level, enabling the product to achieve its optimum storage life (seven days) without difficulty (Fig. 2). Daily surveillance of this critical point ensured continuation of this status. This example clearly demonstrates the important role of cleaning and disinfection in preventing microbiological risks.

![Diagram](image)

**Fig. 1**

Evolution of poultry carcass contamination by *Pseudomonas* when the plucking machinery is poorly cleaned and poorly disinfected
Evolution of poultry carcass contamination by *Pseudomonas* when the plucking machinery is properly cleaned and disinfected

Preventing the risk of *Listeria* contamination

**At a poultry abattoir**

An investigation was conducted to determine the source of *Listeria monocytogenes* contamination of carcasses from a certain poultry abattoir (17). At the initial visit, *L. monocytogenes* was isolated from surfaces throughout the premises used for evisceration and grading. The procedure for cleaning and disinfection was then reviewed by the producer. Contamination was reduced, but it persisted at various earlier stages. By changing a number of worn conveyor belts and by ensuring more thorough cleaning and disinfection, residual contamination was confined to the rubber digits of the plucking machine and the cooler trolleys, both of which are frequently covered with a biofilm. This demonstrates the difficulty of completely suppressing *L. monocytogenes* by cleaning and disinfection, and indicates the important role of biofilm formation in the survival of *Listeria*. 

CFU: colony-forming units

**FIG. 2**

disinfection in storage life of a product. Another investigation of a chain for automated segmenting of chickens (15) showed that thorough cleaning of equipment and machinery (residual mesophilic aerobe count of less than 10 bacteria/cm²) yielded a final product of good microbiological quality, provided that the carcass was of satisfactory quality at source.
At a pork products factory

Investigations conducted in 1992 at five pork products factories showed that the results of disinfection procedures could be deceptive when decontamination was applied to surfaces covered with a biofilm or calcareous deposit. *L. monocytogenes* was recovered from 17.5% of samples from the area where raw meat was handled, and from 7.5% of samples collected from areas where cooked meat was handled (16, 18). However, *L. monocytogenes* was not particularly resistant to disinfectants (19), provided that adequate cleaning was performed prior to disinfection.

As in the case of the poultry abattoir, trolleys, knives, conveyor belts, basins for transporting meat, and machines with difficult access were generally the most contaminated objects after disinfection. However, this investigation showed that in premises which applied thorough cleaning and disinfection, *Listeria* was eliminated more readily.

Thus cleaning and disinfection occupy a prominent place in the quality management of foods. Thorough use of these procedures ensures that the quality of the final product reflects the quality of the raw materials, rather than the result of contact with soiled surfaces. Moreover, only such procedures can ensure complete separation between two working days, averting the recurrence of microbial contamination.

A guarantee of the efficacy of cleaning and disinfection procedures before a processing chain begins to operate is therefore an important part of daily quality assurance management for the producer. Consequently there is a need for rapid techniques to evaluate the efficacy of these procedures.

**ASSESSMENT OF THE EFFICACY OF CLEANING AND DISINFECTION IN QUALITY ASSURANCE SYSTEMS**

The adoption of quality assurance systems, particularly the HACCP system, requires the recording of certain parameters which provide objective information on the correct operation of a manufacturing process in relation to product quality (8). An essential requirement in a recording system for quality assurance is rapidity of response. Any delay in obtaining information about a failure in quality means that the quality of batches produced during the waiting period cannot be guaranteed, and these batches will have to be dealt with in a different way.

Adoption of measuring methods which provide an immediate result, even though some of the techniques may lack precision, means that frequent breakdowns of conformity are averted. Such methods enable a preventive diagnosis to be made.

Of the methods available for verifying the quality of cleaning and disinfection which provide immediate results, human observation is often overlooked. There should be general adoption of the strategy of using a well-trained employee to judge the quality of cleaning and disinfection of a machine or workplace. The employee would fill in a form providing information on objective parameters of cleaning and a visual assessment of the outcome. When correctly applied, this system enables decisions (corrective action) to be taken immediately.

However, it is risky to rely solely on subjective appraisal. Regular verification and 'calibration' of such observations are needed.
Various levels of validation and calibration may be used for this purpose, as follows:

- Every three days, some swabs are taken from test surfaces for examination by turbimetric analysis (the result of which is proportional to the amount of organic matter) or ATP assay (which yields more accurate information on the microbiological status of the sample). These measurements are then compared with the observations of the operator.

- Once a week, one or more swabs are submitted to a microbiological laboratory, and the results (which provide reference values) are compared with the results of the above tests and the observations of the operator.

In this way, both techniques for assessing the quality of cleaning and disinfection can be calibrated and verified.

This example illustrates the ideas behind quality assurance methods, and it is important to note that in numerous cases – notably in industries which handle raw meat – such recording of the efficacy of cleaning and disinfection is the only course available for discovering that the critical point of a risk has been reached. It is therefore necessary to be particularly vigilant in the implementation and recording of the methods used, to ensure adequate documentation of the chosen quality assurance system.

**CONCLUSION**

The current approach to cleaning and disinfection in the food industry goes beyond the simple regulatory requirements.

Most industrialists use these tools as part of their contribution to producing food of high quality and maximum safety.

Thus, cleaning and disinfection – which have often been regarded merely as a regulatory constraint – have now become the central pillar of quality assurance systems in the food industry.

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**REFERENCES**


