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Review

Decontamination of meat and poultry carcasses

N.M. Bolder

The decontamination of meat and poultry carcasses can help to reduce human foodborne infections. However, process hygiene to prevent contamination should never be neglected. Some examples of methods to decontaminate carcasses and meat products are discussed in this article.

Consumers demand safe food products and are unwilling to accept health risks that could be reduced by additional precautions being taken in the kitchen. For the future, dependable and safe production methods require developments in product and process safety. Thus, meat products must be safe, have a low spoilage rate, and have the right composition, packaging, colour, taste and appearance. This means that a lot of effort must be put into the production of live animals, to ensure these requirements are economically and easily met. Improving product quality (i.e. the microbial safety of a product) is often not possible during food production; the most that is possible is to consolidate or minimize the loss of certain quality aspects.

Recent problems associated with bovine spongiform encephalopathy (BSE) and *Escherichia coli* O157:H7 in beef production have resulted in a lot of pressure on consumers to avoid its consumption, whereas pork and poultry consumption seem to have increased, despite intrinsic problems in these products with *Salmonella* spp., *Campylobacter* spp., etc.

The food industry and the European Union (EU) are showing their awareness of the importance of product safety through their efforts to implement hazard analysis and critical control points (HACCP) systems in the food industry, and this includes the meat processors.

Hygiene problems start during animal slaughtering, that is, with the 'raw material' – the live animals. Those that have systemic infections will be condemned by the veterinary inspectors; thus meat tissue is usually free from the causative organisms. However, animals may arrive at the processing plant with a huge heterogeneous load of bacteria, both externally and intestinally, including potential pathogens such as *Salmonella* spp., *Campylobacter* spp., *Listeria* spp., *E. coli* O157:H7 and staphylococci.

Because there is as yet no generally accepted and applicable method to reduce this bacterial load drastically, slaughterers must prevent such contamination from spreading. Slaughter equipment is supposed to limit cross-contamination, and manufacturers are doing their utmost to produce machines that will prevent it. However, compromises must be made owing to a conflict of interests: performance and economy against safety and public health[1].

The possible formation of difficult-to-remove biofilms on machine surfaces has to be considered, and adequate methods for cleaning and disinfecting equipment, both during and after the processing periods, must be employed.

The implementation of a HACCP system will force meat producers to study their production process and find, monitor and control the critical points[2]. Together with improvements in meat processing equipment, this should help to control product safety. Another means of controlling or even improving the safety of food products is to decontaminate the carcasses or products during or at the end of the production line. This article presents some examples of methods to decontaminate meat and poultry carcasses.

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PII: S0924-2244(97)01040-6

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Hygiene intervention in the process alone does not lead to safe products, owing to the constant flow of bacteria entering the processing plant and unavoidable cross-contamination. The absolute elimination of pathogens from the live animals would be the only solution. The eradication of pathogens in the livestock or the rearing of animals that are 'specified pathogen free' (SPF) might make relevant contributions. However, the SPF system is currently too expensive, and despite all efforts, the complete eradication of pathogens in animal husbandry is unlikely to occur in the near future. Decontamination of carcasses or meat products therefore seems to be the only possibility for the production of pathogen-free products. Moreover, the SPF husbandry approach generally deals only with pathogens, offering no solution for spoilage microflora.

The effective removal of bacterial contamination is difficult or even impossible, although contamination levels normally decrease throughout the slaughter process.

The decontamination strategy should not, however, be the method of first choice to eliminate bacteria during or after processing, because it may tempt producers to neglect process hygiene.

Many decontamination treatments have been described, which can roughly be divided into three types: chemical, physical and combinations of the two. The processes (Box 1) have been studied both at the laboratory scale and under practical conditions.

Not all of the treatments are applicable in the meat industry, nor will some of them directly decontaminate carcasses; a brief summary is given of the most relevant applications for decreasing or controlling carcass or meat contamination.

A general problem is that chemical or physical treatments of carcasses are not allowed in Europe according to certain EU regulations, yet they are approved in the USA.

Box 1. Product decontamination treatments

Chemical:

- Chlorine (hypochlorite, ClO_2)
- Organic acids (lactic acid, acetic acid, buffered lactic acid, gluconic acid, etc.)
- Inorganic phosphates (trisodium phosphate, polyphosphates)
- Organic preservatives (benzoates, propionates)
- Bacteriocins (nisin, magainin)
- Oxidizers (hydrogen peroxide, ozone)

Physical:

- Water (rinse, spray, steam)
- Ultrahigh pressure
- Irradiation
- Pulsed-field electricity
- Ultrasonic energy
- UV light

Combinations of the above chemical and physical applications can also be used

Chlorine

Chlorinated water is used in some countries to control microbial grow-out, cross-contamination or contamination[3,4]; however, the EU does not allow the addition of chlorine to process water during poultry and meat processing. The chlorine levels do not normally exceed 50 ppm, which results in a reduction in microbial load of just 1 log cycle[5]. Application of 200 mg/l chlorine appears to reduce bacteria substantially on poultry, pork and beef, but in the case of low initial counts on beef carcasses, treatment with 200 mg/l chlorine resulted in no change in bacterial levels either immediately after treatment or after 8 d of storage. *Salmonella* spp. were effectively eradicated from poultry carcasses by treatment with 300–400 ppm of chlorine[6] but not by 50 ppm (Ref. 7). Thiessen *et al.*[8] used 1.33 mg/l ClO_2 to control *Salmonella* spp. in poultry chiller water and found practically no reduction (<0.5 log cycles) in bacteriological counts on the skin. Application of Salmide®, a complex mixture of chlorine-based components, alone or in combination with EDTA, lauryl sulphate or trisodium phosphate (TSP) effectively reduced the level of *Salmonella* spp. on poultry skin[9].

The effectiveness of chlorine for bacterial reduction can be improved by combining it with organic acids such as acetic acid, or by raising the temperature of the solution[10].

Organic acids

The application of organic acids should, as with other decontaminants, form part of a hygiene programme[11]. Organic acids are legally allowed as a surface (including meat) decontaminant in the USA; the US Department of Agriculture permits the use of lactic acid for pre-evisceration rinsing of carcasses. In the EU, there is no consensus in this respect; some countries allow the application of organic acids (Belgium and Germany), some do not permit their use (France, The Netherlands and Luxembourg), whereas other countries have yet to decide[12].

The natural content of lactic acid in meat is ~10 g/kg; it contributes to the flavour of meat and owing to its antimicrobial effects affects keeping quality.

A variety of organic acids, applied as a spray or dip for decontamination purposes, have been studied extensively and appear to constitute an effective bactericidal or bacteriostatic surface treatment, which also effectively prevents the attachment of Gram-negative spoilage microorganisms[10].

The use of lactic acid solutions at concentrations of 1–2% reduces the bacterial counts on poultry carcasses immediately after slaughter and during storage, without affecting organoleptic characteristics such as colour and flavour[13,14]. Bautista *et al.*[7] tested the efficacy of a 1.24% lactic acid spray and found a significant reduction in the total number of aerobic bacteria (2.4 log cycles) on turkey carcasses.

Both the concentration of an acid and the pH of the solution are essential factors in determining its antibacterial effect[15,16]. Furthermore, the bactericidal effect of organic acids can be augmented by increasing the time and temperature of the acid treatment[17], or by treating the animals soon after they are killed[18]. However, this is not true for all acids. For example, a 3% solution of succinic acid, when used as a surface disinfectant for poultry skin at a temperature of 60°C, did not result in the elimination of *Salmonella* spp.[19] Similarly, a low dose of acetic acid (10 mg/l), used at 4°C on beef carcasses, was ineffective as a decontamination treatment[20]. The efficacy may be further influenced by the type of surface to which the bacteria attach; lactic acid removes bacteria from lean pork meat surfaces more effectively than from fatty substrates[21]. The point at which contamination occurs during the slaughter process may also influence the degree of bacterial adherence to the skin[22]. Thus, microorganisms may be easier to remove from poultry meat (lean) than from fatty skin. Hwang and Beuchat[16] treated chicken skin samples with both lactic acid and sodium benzoate and found that spoilage flora were controlled well during storage; furthermore, the inactivation of *Salmonella* spp., *Campylobacter* spp. and *Listeria* spp. was accelerated.

The combination of treating carcasses with acid and packaging them in a modified atmosphere extends the shelf life for poultry[11] and meat[12], mainly because it increases the lag phase of the microorganisms.

Treatment with an effective dosage of organic acids such as lactic acid sometimes causes colour disorders; this can be prevented by using buffered lactic acid instead[23]. Effectiveness is governed by the undissociated acid molecules rather than by low pH.

The lethality of an acid can be increased by pretreating surfaces with chemicals such as NaCl or sucrose, which alter the osmotic pressure[10].

In conclusion, organic acids, especially lactic acid, seem to have promising potential as meat surface decontaminants.

Inorganic phosphates

The treatment of carcasses with TSP reduces the levels of Gram-negative bacteria such as *Salmonella* spp. In the USA, treatment with 10% TSP (AvGard™, Rhône Poulenc, France) is patented and based on the removal of fat together with bacteria from skin surfaces by the alkaline solution; TSP treatment is officially accepted and implemented in the poultry slaughter process. It does not cause undesirable sensory effects that are detectable by the consumer[24]. Treatment of carcasses with TSP should not be interrupted by washing or rinsing[25]; thus, in the case of immersion chilling of poultry, TSP treatment should preferably be applied after chilling. However, Gorman *et al.*[26] sprayed beef carcasses with 12% TSP and found that a subsequent water spray of 74°C did not affect the efficacy of the TSP treatment.

Although the main goal is a reduction of *Salmonella* contamination levels in products, laboratory trials have shown that the numbers of *E. coli* and *Pseudomonas* spp. were also reduced significantly on poultry skin samples after treatment with TSP or other phosphates[27].

Rodriguez de Ledesma *et al.*[28] treated chicken wings with a combination of TSP and hot water and found a 3-log reduction in the number of spoilage bacteria after 7 d at 4°C. Although the hot water treatment led to a temporarily abnormal appearance of the product, which disappeared after a few days of storage, it did not affect the internal temperature of the product. These authors also suggested that the TSP treatment could be modified into a TSP dip at 95°C, followed by quick chilling in a blast freezer. Slavik *et al.*[29] also found no susceptibility of *Campylobacter* spp. on chicken carcasses towards TSP treatment at low temperature (12°C).

Dickson *et al.*[30] found TSP treatment was more effective for *Salmonella* spp. on lean beef than on fatty adipose tissue but could not demonstrate any temperature effect. The inadequacy of TSP to inactivate microorganisms on fatty tissues might explain why the application of TSP as a spray treatment on turkey carcasses (which have an outer fatty skin layer) caused neither a reduction in *Salmonella* levels nor a significant reduction in coliform counts (<1.8 log cycles)[7].

Application of an aqueous acidic sodium pyrophosphate product in poultry chiller water (1.5%; pH 2.8) led to a significant reduction of viable coliform and *E. coli* counts in the water[31]. Although the application of water chilling is decreasing in poultry processing in Europe, this product could be considered for other applications such as its addition to scald water.

Other organic preservatives

The other commonly used chemical preservatives are sorbates and benzoates, respectively derived from sorbic acid and benzoic acid, both of which are organic acids with known antimicrobial capacity. After a potassium sorbate treatment, pathogens such as salmonellae and staphylococci were suppressed and the shelf life of poultry was extended. Temperature affected the lethality of potassium sorbate towards salmonellae on chicken carcasses.

Treatment of beef carcasses with potassium sorbate in combination with other preservatives including potassium sorbate, sodium acetate, sodium citrate and NaOH showed that inhibition of growth depended on both the temperature and the type of microorganism, but also produced sensory defects[10].

Although the use of such products may be effective, the presence of residues on products will limit their use in the meat industry.

Bacteriocins

Microbial metabolites sometimes have an antagonistic (lethal or bacteriostatic) effect on other related microorganisms. Lactic acid is one such metabolite, but lactobacilli also produce specific antimicrobial proteins that are known as bacteriocins. The bacteriocin nisin is produced by *Lactobacillus lactis* subsp. *lactis* and is effective against Gram-positive bacteria. Yang and Ray[32] reported that bacteriocin-producing microorganisms are generally present in meat, and are therefore consumed regularly with no known adverse effects. Nisin is considered to be a non-toxic non-immunoallergenic preservative for dairy products that is active against *Clostridium* spp. and *Listeria* spp. and has been approved by the World Health Organization as a preservative with GRAS (generally recognized as safe) status for food[33]. Nisin is a small hydrophobic protein that directly attacks the outer membrane of microbial cells and causes cell lysis. Gram-negative cells have an outer cell membrane that protects them against this mode of action.

Bacteriocins can be applied either directly by adding it to the product or by growing a bacteriocin-producing microbial culture as a competitor on the product surface. The latter method of application does not seem to be very effective because the level of production of bacteriocin *in vivo* is very low, although, according to Yang and Ray[32], highly productive strains might increase bacteriocin production to levels that are economically viable. Bacteriocins, being proteins, will be inactivated by proteolytic enzymes or other food components[34]. Furthermore, bacteria may lose or not express their ability to produce bacteriocins, or the target microorganisms may become resistant.

Because nisin does not inhibit the attachment of Gram-negative bacteria to meat surfaces[35], the application of this bacteriocin as a carcass decontaminant is appropriate only when additional treatments are also used to inhibit the growth or attachment of Gram-negative bacteria such as *Salmonella* spp. or *E. coli*. A combination of nisin and chelators such as EDTA or citric acid inhibited the growth of *Salmonella* spp. and other Gram-negative microorganisms[36], and its effect on the microbial quality of poultry skin was even better than that of 20 ppm chlorine in water[37]. In combination with lactic acid, nisin prevented the attachment of both Gram-positive and Gram-negative microorganisms on beef[38], and Rayman *et al.*[39] successfully used a combined nisin and nitrite treatment for the control of the microbial contamination of meat. Meat products that were treated with nisin and then vacuum packaged had an increased shelf life and lower number of *Listeria innocua*[40].

Sheldon[41] mentioned another promising application of nisin: to form part of packaging materials for food products. A preliminary study showed a reduction of *Salmonella* spp. contamination on poultry skin packed in a nisin-containing material.

The application of lactobacilli or lactococci as a starter culture for meat products seemed to enhance the growth of lactic acid bacteria, which compete with the Gram-negative spoilage bacteria *Brochothrix* spp. and *Listeria monocytogenes* on meat surfaces[42]. On poultry carcasses, however, Gram-negative spoilage microflora were not inhibited by a *Lactobacillus* strain[43].

Certain *Pseudomonas* spp. appear to produce bacteriocin-like products that have an antagonistic effect against other *Pseudomonas* spp.[44] or *Listeria* spp.[45] However, this effect could not be confirmed in a preliminary study on broiler carcasses *in vivo*.

Hydrogen peroxide

Hydrogen peroxide has a bactericidal–bacteriostatic effect that is mainly based on the formation of radicals that damage nucleic acids, proteins and lipids[46]. Hydrogen peroxide as a poultry carcass decontaminant showed a minimum effective dose of 0.5% (w/v) in water, which leads to temporary bleaching and bloating of the carcasses and excessive foaming of chiller water, because of the catalase activity of the skin and blood producing oxygen gas[15,47]. Fletcher *et al.*[48] applied a combined spray treatment of sodium bicarbonate and hydrogen peroxide, which resulted in a slightly longer shelf life in poultry. The exposure time in these experiments appears to be an important factor. Preliminary experiments on broilers and ducks that were dipped in a solution of up to 5% (v/v) of a commercially available product containing hydrogen peroxide, stabilized with glycerol, did not reveal any reduction in total bacterial counts, or levels of Enterobacteriaceae, *Pseudomonas* spp. or *Salmonella* spp.

Cabedo *et al.*[49] treated beef with a hydrogen peroxide solution and found that bacteria were more resistant the longer they had been attached to the tissue.

The application of hydrogen peroxide for carcass decontamination seems to be an effective and safe method to control the spread of pathogens.

Ozone

Ozone generators are sometimes used in storage rooms for food, to control the growth of microorganisms. The application of ozone as a beef carcass washing agent improved the bacteriological quality of the product[50]. Sheldon and Brown[51] chilled poultry carcasses in ozonated water and demonstrated neither visual defects to the carcasses, nor sensory off-flavours. However, the reduction of bacterial counts was poor (<1 log cycle) for both total counts and psychrotrophs; furthermore, there was no increase in shelf life. Carcass spraying with water followed by a spray treatment with ozonated water resulted in an effective bacteriological sanitation method for beef[26].

Modern ozone generators can be controlled better, but nevertheless because of its low minimal-acceptable-concentration value, ozone represents a public health hazard, especially when it is applied in production areas.

Water

The removal of microorganisms by plain water can sometimes be effectuated using a rinse, spray, immersion bath or steam treatment. Only small reductions in bacterial load can be achieved by carcass rinsing with pure water[52]. During immersion chilling, a substantial decrease in contamination levels of broiler carcasses can be expected[53], and the variation in bacterial load of individual carcasses will be reduced. The effectiveness of spraying carcasses with cold water is not affected by the water pressure[10]; it does not decontaminate carcasses, and aerosols may even spread microbial contaminants[54].

Rodriguez de Ledesma *et al.*[28] used hot water (95°C) for the surface decontamination of poultry skin and found a significant reduction in the microflora. Lower water temperatures (65.6°C) reduced the bacterial load by 1 log cycle[55]. In the case of beef carcasses, Davey and Smith[56] found a linear regression between water temperature and reduction in *E. coli* numbers, but at temperatures above 74°C the appearance of the carcasses was damaged permanently. Gorman *et al.*[26] also found water spraying at 74°C to be the most useful decontamination treatment for beef carcasses when compared with chemical intervention; however, chemical treatments such as ozone, hydrogen peroxide or TSP should preferably be applied at a lower temperature (16–35°C).

The decontaminating effect of a hot water spray is partly caused by a lethal effect, and partly by the detachment of bacteria or removal together with melted softened fat. However, this treatment hardly increases the shelf life of poultry products, probably because of ineffective treatment of the body cavity and because removal of the epidermal skin layer makes the carcass more susceptible to bacterial growth.

Bacteria that are attached to poultry skin surfaces might be more heat resistant than those that are not attached[10]. Cabedo *et al.*[49] reported a similar effect on beef tissue.

Thus, in a poultry processing line, a hot water spray could easily be introduced at the end of the evisceration line where carcasses are washed both inside and outside, removing or killing the non-attached bacteria.

High-pressure washing of pig carcasses with cold water resulted in improved microbiological quality[57]. Shackleford[58] used this technique to wash poultry carcasses before evisceration and found a significant reduction in total counts. Although only a small amount of moisture was taken up by the carcasses, bacteria might be driven into the meat by high pressure[10]. Other applications of high-pressure washing in poultry processing are not known, but it could be applied as a final carcass wash. However, the formation of contaminated aerosols may occur, thus negating the positive effects.

Steam can also be used for surface decontamination. The advantages of steam are the efficient heat transfer, lack of residues and an intense additional cleaning of the surfaces. Disadvantages are the difficulties of application in a continuous production process and the extremely short possible application time before damage occurs to the product. Morgan *et al.*[59] described an experimental device for carcass treatment with superheated steam (126–139°C). The system resulted in a reduction of 3 log cycles of *L. innocua* counts on poultry. Dorsa *et al.*[60] have reported promising results using steam treatment for the control of *E. coli* O157:H7 on beef surfaces.

An effective application of water or steam has no regulative constraints, as long as certain limits such as the level of water uptake and the appearance of the product are taken into account.

Ultrahigh hydrostatic pressure

Killing bacteria by ultrahigh-pressure treatment is a physical approach. A pressure of up to 600 MPa is necessary to kill Gram-positive bacteria. Being a batch process, its application in the meat industry, especially for beef or pork carcass decontamination, is not very likely, although equipment with chambers that have a capacity of up to 1000 litres is available. Small carcasses, such as poultry, or sausages, hams and other meat products or ground meat such as mechanically deboned poultry meat or surimi-like slurries can be treated with this technique. However, discoloration of the products may occur[17].

Other applications of this technique, such as decontamination of process water, can be envisaged.

Gamma irradiation

Food irradiation is an effective process for the decontamination of the final product. In the USA, a recent consumer survey revealed that consumers were less concerned about food irradiation than other 'hazards' such as food additives, residues of pesticides or drugs, hormones and microorganisms. Nevertheless, 30% of those surveyed considered irradiated food to be radioactive[61]. Bruhn[62] discussed strategies for informing the public about radiation facts, but consumer activists still try to convince consumers not to buy irradiated food. Lagunas-Solar[63] suggested possible ways of changing consumer attitudes by education and by proving the economic viability of the process.

Yogasumdran[64] compared the efficacy of physical and chemical treatments to reduce *Campylobacter* spp. counts on broiler drumsticks. Irradiation with a low dose of γ-rays was the method of choice and appeared to be more successful than glutaraldehyde or chlorine treatment. R.W.A.W. Mulder [(1982) *Salmonella Radicidation of Poultry Carcasses* (PhD thesis), Agricultural University of Wageningen, The Netherlands] calculated the probability of survival of *Salmonella* spp. on poultry carcasses. He found hardly any undesirable side effects when an effective lethal dose for frozen products was used. However, colour changes may be caused by ionizing radiation[65].

Despite the reservations of consumers, there is no scientific reason not to use irradiation, and its application for foods that are intended for health-risk consumer groups such as the elderly or those who are immunosuppressed should be considered.

Electron accelerators do not require isotopes, but do need high energy levels up to 10 MeV, and permit an effective penetration of radiation into the product of only 1–2 cm (Ref. 66). This is insufficient for the decontamination treatment of carcasses, although superficial contamination will be eradicated.

Pulsed-field electricity

Pulsed-field electricity is currently used for the electrostimulation of carcasses in the beef industry. Research has shown that the treatment also causes a reduction in bacterial counts and prolongation of the lag phase of bacterial growth[67]. Application of electrical stimulation in the broiler industry is not practical, although it might be relevant for turkey carcasses.

Li *et al.*[68] treated poultry chiller water with salt or TSP and pulsed electricity, and successfully destroyed *Campylobacter jejuni.*

Ultrasonic energy

The application of ultrasonic energy to carcasses is possible when they are immersed in water; application is therefore suitable only for small carcasses, such as poultry carcasses, that can be immersed. The bactericidal effect is due to cell disruption, which can be amplified by altering the pH and temperature[69] or by chlorination[70]. The presence of fat may reduce the effectiveness of the technique. Sonification of scald water for decontamination treatment can be considered in the poultry and pork industry, but may be inhibited by the presence of organic material.

UV light

UV light is used for the decontamination of water used in the aquaculture of plants. The continuous use of UV light in meat storage rooms and processing areas controls the bacterial load carried by the atmosphere. However, its use in the decontamination of meat surfaces is probably not very effective because the skin surfaces are highly irregular, with hair and feather follicles causing shadow areas that cannot be reached by the UV light.

Conclusions

The control of process and product hygiene in poultry and meat processing plants is of the utmost concern from both a public-health and commercial point of view. Cleaning and disinfection operations in processing plants require product specialists, who advise and support the operational staff. Meat processing plants can contribute to hygiene by carrying out good operational practices such as correct use and adjustment of equipment and also by ensuring the adequate instruction and motivation of the operational staff[71].

Hygiene intervention in the process alone does not lead to safe products, owing to the constant flow of bacteria into the processing plant and the unavoidable occurrence of cross-contamination. The total elimination of pathogens from the live animals is the ultimate solution and this might be achieved by the eradication of pathogens in the stocks or by rearing SPF animals. However, the SPF system is too expensive at present, and despite all efforts complete eradication of pathogens in animal husbandry is unlikely to occur in the near future. For now, the decontamination of carcasses or meat products therefore seems to be the only possible intervention technique.

However, the decontamination strategy should not be the first choice to eliminate bacteria during or after processing, because producers may be seduced into neglecting process hygiene.

Modern slaughter equipment, especially that for poultry processing, is often very complicated, although designers are paying increasing attention to the hygiene aspects of construction and to the importance of cleanability, for example by cleaning in-place operations.

Product decontamination during or at the end of the process can be carried out by chemical or physical methods or combinations of the two types. It can inhibit bacterial growth or extend shelf life. A decontamination treatment of choice must have no adverse effect on product appearance or on any other sensory aspect, must pose no unacceptable risks to humans, the product and the environment, and must be a low-cost application.

Technical interventions can be applied during meat processing, but must never be the ultimate correction mechanism for improper product or process hygiene.

It is essential to prevent bacteria from adhering to carcasses or tissues, thus the treatment should be applied as soon as possible during or after the process, and can be improved by combining applications.

Particular applications should be considered for the production of food for health-risk consumer groups, especially those who depend on institutionally prepared food.

The information given to consumers and cooks about some of the hazardous aspects of food preparation should be increased and put into perspective with the possible risks of decontamination procedures.

Future research on decontamination treatments should focus on safe applications that do not result in residues on products, thereby facilitating consumer acceptance.

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