Update
Le point

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Les articles de la rubrique Le point fournissent un bilan concis et fiable de la situation actuelle dans les domaines considérés, couvrant de nombreux aspects des sciences biomédicales et de la santé publique. La plupart de ces articles auront donc été rédigés par les spécialistes les plus autorisés.

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Foodborne listeriosis*

WHO WORKING GROUP[1]

Listeria monocytogenes *is widely distributed in the environment and may be transmitted to man through contamination of foodstuffs at any point from source to kitchen. Milk and dairy products, meat, poultry, vegetables, salads and seafoods have all been found to be contaminated. Unlike most other foodborne pathogens,* L. monocytogenes *can multiply in refrigerators (4–6 °C). Pasteurization reduces their numbers in raw milk to levels that do not pose an appreciable risk to human health.*

The infection has relatively low morbidity but a high case fatality. At greatest risk are pregnant women and the unborn child, alcoholics, drug abusers, diabetics, patients receiving treatment which alters their natural immunity, AIDS patients, and the elderly. Surveillance systems in countries should monitor sporadic cases and outbreaks of human listeriosis, with the support of a network of reference laboratories for sero-, phage- and other forms of typing at local, national and international levels.

The Working Group made recommendations for action by public health authorities and by the food industry in order to control and prevent these infections.

NATURE AND EXTENT OF THE PROBLEM

Epidemiology

Of all *Listeria* species, only *Listeria monocytogenes* has been regularly implicated as being pathogenic to humans and animals. Most other recognized species are harmless, though it is possible that *L. ivanovii* is responsible for occasional human disease.

Listeriosis has been recognized and studied mainly in the industrialized countries. While sporadic cases and occasional outbreaks of human listeriosis and examples of food contamination have been detected in other countries, the reported prevalences in Africa, Asia and South America are non-existent or low. Whether this is a result of different consumption

* This article is based on the report of a WHO Informal Working Group on Foodborne Listeriosis, which met in Geneva on 15–19 February 1988. Requests for the full report (document No. WHO/EHE/FOS/88.5) or for reprints of this article should be sent to Food Safety Unit, World Health Organization, 1211 Geneva 27, Switzerland. A French translation of this article will appear in a later issue of the *Bulletin*.

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patterns and dietary habits or represents a lack of available reference facilities is not known. Listeriosis remains, however, a worldwide problem and, with increasing urbanization, social evolution and changes in dietary habit, may assume greater significance in developing countries.

The Working Group reviewed recent data on human listeriosis and concluded that foodborne listeriosis is predominantly transmitted by non-zoonotic means. While soil may often be the source of the organism, transmission to man is primarily from the environment to animals and food surfaces. *L. monocytogenes* is therefore an environmental microorganism whose primary means of transmission to humans is through foodstuffs contaminated during production and processing.

The basic epidemiological pattern of human listeriosis, as seen in the industrialized countries, shows endemic sporadic cases with superimposed outbreaks of disease. This is the picture in countries where the surveillance for listerial infection is laboratory-based and passive (e.g., United Kingdom) or "semi-active" (e.g., France). A special active surveillance project in the USA has given much useful information. The more sensitive the surveillance system, the easier it is to distinguish outbreaks from sporadic cases; however, since outbreaks result in overall disease rates of only 10 to 50 cases per million, they may still be difficult to detect even with good surveillance.

Four major outbreaks of listeriosis have been described in the literature—in Nova Scotia (Canada) in 1981 (*1*), Boston (USA) in 1983 (*2*), Los Angeles (USA) in 1985 (*3*), and the Canton of Vaud (Switzerland) in 1983–87 (*4*). In Nova Scotia, Los Angeles and Vaud an epidemiological link with supporting microbiological evidence was established with a particular foodstuff (coleslaw, Mexican-style soft cheese and Vacherin soft cheese, respectively). In Boston, epidemiological evidence suggested whole milk, but there was no microbiological confirmation. These outbreaks have demonstrated clearly the association of human listeriosis with a number of foodstuffs and a variety of mechanisms of contamination. It is clear that not all possible causative foodstuffs, nor all possible mechanisms whereby these foodstuffs may become contaminated, have yet been satisfactorily elucidated.

In addition, outbreak phenomena have been observed in many countries where, by epidemiology and/or microbiology, a common source could not be established, e.g., Denmark in 1986 (W. Frederiksen, personal communication), and Philadelphia (USA) in 1987 (C. V. Broome, personal communication). These remain, however, highly probable examples of foodborne outbreaks.

An implication from all these observed outbreaks is that if listeriosis is caused by foodborne transmission in epidemic situations, it may also be caused in part (even the larger part) by such transmission in sporadic cases. This conclusion is supported by anecdotal case reports in the literature associating listeriosis with isolation of the same phage type from an ingested foodstuff.

No single strain has been repeatedly found to be associated with different outbreaks. Outbreaks observed to date have been associated with a range of serovars and lysovars. Available evidence from France and the United Kingdom suggests that the distributions of serovars and lysovars isolated from foodstuffs and from humans are different. Whether this is the result of a sampling bias or reflects a real phenomenon is as yet undetermined and warrants further investigation.

Apparent increases in the incidence of listeriosis have been noted, particularly after publicity about the disease. These are, perhaps, due more to increased awareness, followed by more frequent diagnosis and compliance with reporting systems, than to real increases in incidence. The establishment of stable monitoring systems is thus essential for the assessment of such changes over time. Even allowing for differences in reporting systems and effectiveness of surveillance, the range of reported incidences in countries with surveillance systems is worthy of note, e.g., those from France, Scandinavian countries, United Kingdom, and USA range from less than 2 to 11.3 per million. Whether this reflects different dietary habits, consumption patterns, diagnostic routines or surveillance methods remains speculative.

Natural history of infection

Risk groups. Pregnant women and their fetuses or newborn children are at particularly high risk; in the United States active surveillance project, 120 sporadic cases occurred per million births (C. V. Broome, personal communication). Other well-characterized groups at increased risk of listerial infection include those whose immune system is compromised or incompetent because of a wide variety of reasons, and narcotic addicts whose resistance to infection is diminished. The role of gastric defences against infection or colonization remains unclear.

A proportion of cases also occurs among previously healthy persons in whom no predisposing cause could be found. The role of intercurrent infection in changing from a carrier state to clinical illness by decrease of resistance or through some other mechanism needs further exploration, as does the question of differences in dietary factors and therefore different exposures in different risk groups.

It must be recognized that the rising proportions of immunocompromised and elderly persons in many populations are increasing the numbers of those at risk from listerial disease.

Infectious dose. Virtually nothing is known about the infectious dose of *L. monocytogenes* in man, nor is there reliable quantitative information on the amount of contaminated foodstuff ingested in relation to the risk of acquiring the disease. It is likely that the infectious dose may be related to host susceptibility. Another possible influence worthy of investigation may be related to the food substrate.

Incubation period. Evidence from Switzerland and the USA (personal communications presented at the meeting), in those instances where data on both ingestion of the contaminated foodstuff and onset of illness could be reliably determined, suggests an incubation period in adults of one to several weeks. Here too it is possible that the clinical illness is triggered in a carrier by some factor such as intercurrent viral infection; much has therefore still to be learned concerning the incubation period.

Clinical spectrum. Septic abortion, newborn and adult septicaemia, and meningitis or meningoencephalitis are the major clinical manifestations of listerial infection. There is, however, conflicting and inconclusive evidence on the varieties of clinical disease expressed in different risk groups. In general, clinical expression does not seem to differ in outbreak situations from that in sporadic cases; this, perhaps, lends support to the possibility that many sporadic cases are also associated with foodborne transmission. No association has yet been demonstrated between particular serovars or lysovars and particular clinical illnesses.

Carriage. The existence of a carrier state, perhaps related to foodborne transmission, and its relationship with disease have long been the subject of speculation.

The question of immunity to listerial infection is poorly understood; a major reason for this is the continuing lack of definitive serology for *Listeria* and the possibility that cell-mediated immunity may be more important. The ratio of clinical to subclinical cases is also not known because specific serological techniques are not available.

Surveillance

In order to monitor the occurrence of human listeriosis and to detect outbreaks, it is crucial that countries establish a surveillance system. The two major indicators defining an outbreak are an increase in the number of cases over that expected and the isolation of a common strain from the majority of such cases. Detection of the former requires a sensitive and stable system for monitoring listerial infection, and the latter requires access to effective laboratory facilities for phage-typing, isoenzyme typing or subtyping by gene restriction methods. For both these requirements, there is a fundamental need for a strong network of reference laboratories at local, national and international levels.

The method used for identification of a specific strain will vary depending on the aims. If the object is the detection of a common (epidemic) strain different from other strains in the area, any method capable of effectively performing such discrimination is adequate. If the aim is to test the associated virulence of particular strains, then the method must be amenable to international standardization. Similarly, evaluations of the efficacy of different methods require international standards.

Effective surveillance should not only identify outbreaks and changes in the background pattern of disease but also generate action based on this information. Resources must therefore be made available for the rapid investigation of outbreak phenomena as well as other changes in the disease pattern. The strategies in France, Switzerland, United Kingdom, and the USA for establishing and improving surveillance systems include providing resources for the investigation of outbreaks based on the collection and finer identification of isolates.

Presence of L. monocytogenes *in foods*

Isolations from dairy products. *L. monocytogenes* has been isolated from raw milk, up to 5% of samples in some surveys containing the organism at levels of $\leqslant 10$ cells per ml. Contamination of the milk is mainly from faeces; several studies have confirmed a link between faecal excretion of the organism and the condition of silage fed to the cows. Infected cows with mastitis have been reported to shed *L. monocytogenes* in numbers of approximately 10^3 per ml in their milk, but these reports are infrequent. The organism may occur intracellularly and this may be difficult to detect. Raw milk from goats and ewes is often used for cheese production but there are only limited data on the occurrence of *L. monocytogenes* in these milks.

The reported incidence of contamination of cheeses varies greatly between different surveys. Of all foods, cheeses have been found to be frequently contaminated with *Listeria* and associated with human disease. Soft-ripened cheeses (especially with white mould and red-smeared surface) appear to be the most suitable for both contamination and growth of *L. monocytogenes*. This may be due to the higher

pH of these cheeses in the later stages of ripening. Surveys show that from 1% to 5–10% of the product may be contaminated. When contaminated, certain cheeses are capable of supporting growths up to 10^4–10^7 organisms per gram. Knowledge of the sampling time is critical in interpreting these numbers. Variations in manufacturing practices can lead to post-process contamination. In theory, cheeses manufactured from contaminated raw milk are more likely to be ultimately contaminated, but only a low percentage of contaminated raw milk has been reported. Surveys in the Federal Republic of Germany, Switzerland and France strongly suggest that cheeses made from pasteurized milk are as frequently contaminated with *L. monocytogenes* as cheeses made from unpasteurized milk, the contamination occurring during manufacturing and handling.

The risk of contamination of other dairy products depends on many factors. Acidified dairy products (e.g., cottage cheese) are, in principle, free of *L. monocytogenes*. Post-process contamination of ice cream has been reported. Quantitative data are limited, with levels varying from less than 1 to 15 organisms per gram of food product, the incidence of contamination varies from zero to approximately 5.5% of the products tested, according to surveys.

Meat and meat products. Up to 30% of raw, ready-to-eat meat products have been reported to contain *L. monocytogenes*. In sausages subjected to listericidal heat treatment, post-processing manipulations (e.g., slicing) appear to be responsible for contamination. Quantitative studies on these products are lacking, although in prospective studies on cooked poultry an inoculum of 50 organisms yielded populations of 10^7 within 2 weeks at 4.4 °C storage temperature.

Not surprisingly, given the faecal carriage of *L. monocytogenes* by many mammals and birds and the opportunity for contamination in abattoirs, numerous isolations from raw meats and poultry have been reported. The organism has been isolated from raw beef and pork, lamb, ground or minced meat, and various poultry. Up to 30% (usually 15–20%) of minced meat samples have yielded *L. monocytogenes* in some surveys, the reported numbers ranging from less than 20 to 10^3 per gram. About 15–80% of retail poultry have been reported to be contaminated, depending on the sampling method (i.e., surface, whole carcass wash, swab). The numbers of organisms in refrigerated, retail poultry have been observed to increase during storage by up to 2 $\log_{10}$ in 10 days; freezing appears to have no detrimental effect on the organism.

Fermented sausage products have also been surveyed and the incidence of contamination varies greatly and may be up to 20%. The numbers of *L. monocytogenes* have generally been lower in these products than in non-fermented ready-to-eat cooked meats. When the organism is present in cooked, ready-to-eat meats, surveys have strongly suggested recontamination after cooking.

Other foods. Although the data are limited, recent surveys suggest that cooked fish and other seafoods may also be contaminated with *L. monocytogenes*. About 4–8% of cooked crabmeat and 3–4% of shrimp samples may yield the organism on analysis. One study on frozen, butterfly shrimp using a genetic probe suggested that 200 organisms per gram may be present. It is likely that game animals may also be contaminated, but survey data are lacking. Neither internal nor external contamination of eggs has been reported.

Salad vegetables have been surveyed and found to be contaminated with *L. monocytogenes*. Pre-cut, packaged salad vegetables have also been reported to be contaminated. Certain vegetables, once cut, support the growth of the organism, but the numbers of samples are at present too small to determine the incidence of contamination. Fruits have thus far been free of contamination.

Heat resistance of L. monocytogenes *in food, with particular reference to pasteurization of milk*

Many studies to evaluate the effect of heat treatment on inactivation of *L. monocytogenes* in milk have reported conflicting results, which can be explained by differences in the experimental procedures used to assess thermal resistance. Early studies on contaminated milk in test tubes, which were only partially submerged in a water-bath during the heat treatment, indicated that the organism could survive a pasteurization treatment at 61.7 °C for 35 minutes. Other studies of heat treatment of milk in sealed containers, which were totally submerged in a water-bath, revealed that the organism was readily inactivated at 62 °C ($D_{62\,°C}$=0.1 to 0.4 min); this did not happen with partially submerged containers, a method considered to be inaccurate for measuring the rate of thermal inactivation.

Later studies, with *L. monocytogenes* added to milk and heated in sealed tubes at 71.7 °C for 15 seconds, revealed *D*-values of 0.9 second. These results indicate that high temperature short time (HTST) pasteurization (71.7 °C, 15 seconds) is sufficient to kill 10^{15} organisms per ml of milk. However, this study did not take account of intracellular organisms, i.e., those with leukocytes in milk from cows with a *Listeria* infection. This point was addressed by a study in which milk from cows inoculated with *L. monocytogenes* was heated in a commercial-type HTST pasteurizer at 72 °C (minimum) for 15 sec-

onds. Surviving organisms were occasionally detected by extensive testing of such heat-treated milk using enrichment procedures, but consideration must be given to the fact that an unusually large number of intracellular organisms (10^3 to 10^4 cells/ml) were present in the milk. This is an extreme condition since recent studies of raw milk supplies revealed that only a small percentage (less than 5%) is contaminated and the number of listeriae present is $\leqslant 10$ cells per ml.

Recent studies using sealed tubes or slug-flow heat-exchange methods in conjunction with more sensitive recovery procedures for detecting heat-injured *Listeria* revealed $D_{71.7\,°C}$ of 2.75 to 3.1 seconds for organisms added to milk and 4.1 seconds for those within bovine leukocytes. Other studies with milk from *Listeria*-infected cows did not detect any surviving organisms. Furthermore, milk before pasteurization is often homogenized which disrupts the leukocytes and frees the organisms.

Based on this information, the Working Group concluded that pasteurization[a] is a safe process which reduces the number of *L. monocytogenes* occurring in raw milk to levels that do not pose an appreciable risk to human health. It was also the consensus of the group that further research on the pasteurization of milk is not necessary, but additional studies are needed to determine the heat resistance of this organism in other foods such as meat products. It was generally felt that dairy products and most other foods may be recontaminated after pasteurization by *L. monocytogenes* from environmental sources.

Methods for the detection of L. monocytogenes *in foods*

A careful review of the many existing methodologies for detecting *L. monocytogenes* in foods readily convinced the Working Group that while many were inadequate, some held promise and several appeared to be quite effective. Direct plating procedures that require selective formulations to recover low numbers have generally been unsuccessful. Single-step enrichments that employ low temperatures with or without inhibitory constituents are now inordinately time-consuming for routine work and may fail to resuscitate sublethally injured cells. The Working Group felt that serial enrichment procedures, employing a less selective primary medium followed by a selective secondary enrichment and a differential isolation agar, are currently more promising than either of the above methodologies for isolating foodborne *L. monocytogenes*.

The Working Group strongly recommended that investigators who have developed improved detection procedures should submit them for evaluation by rigorous collaborative studies conducted according to the guidelines promulgated by such international bodies as the International Dairy Federation (IDF), International Standardization Organization (ISO), Association of Official Analytical Chemists (AOAC), and the International Commission on Microbiological Specifications for Foods (ICMSF). Sampling procedures, size, and microbiological limits can only be given when a satisfactory method has been approved. To this end, the guidelines laid down in the general principles for the establishment and application of microbiological criteria for foods should be strictly followed.[b]

Because of the urgent need for more Listeria Reference Laboratories to provide mainly sero- and phagetyping for confirmatory and epidemiological usages, the establishment of new laboratories and the continuation of existing ones should be encouraged.

CONTROL OF CONTAMINATION OF FOOD WITH *L. MONOCYTOGENES*

Owing to its widespread occurrence in nature *L. monocytogenes* has become part of the microbial ecosystem of food production and processing environments, from where it contaminates various foods and comes into contact with man. The use of raw fertilizers in vegetable production is a contributing factor for contamination. The presence of the organism in processed foods and packaged processed foods after listericidal treatment indicates post-processing contamination from the environment.

Survival, growth and transmission of L. monocytogenes

The critical issues are to control the survival and growth of the organisms and to minimize the recontamination of processed foods from the environment. Survival and growth are determined by the food substrate (its pH, water activity and salt concentration), the time–temperature relationship of the heating process, and the effectiveness of other listericidal processes. Cut vegetables and soft cheeses are favourable substrates owing to the combination of conditions including pH, moisture, salt concentration, and nutrients; the surfaces of meats are also suitable substrates to support growth of *L. monocytogenes* after contamination from the environment. Unlike most foodborne pathogens, growth of this

[a] As defined in *Recommended international code of hygienic practice for dried milk* (unpublished document CAC/RCP31-1983, prepared by the Codex Alimentarius Commission). Rome, FAO/WHO, 1983.

[b] *Microbiological criteria for foods — summary of recommendations of FAO/WHO Expert Consultations and Working Groups 1975–1981*. Unpublished WHO document No. WHO/VPH/83.54, 1983.

organism is not completely inhibited at refrigeration temperatures (4–6 °C). Hence extended storage times should be discouraged.

The sources and vectors for environmental contamination during processing and distribution, or in retail food establishments and homes include drains, conveyor belts and other equipment, cutting surfaces and knives, water supplies, condensates, aerosols, humans, insects and rodents.

Control measures

In food processing environments, as well as in retail food establishments and homes, appropriate control measures against listeriosis include (*a*) separating non-contaminated foods from contaminated foods, (*b*) limiting the potential for growth by elimination of unnecessary use of water and by application of adequate sanitation principles, and (*c*) limiting the vectors for *L. monocytogenes* transmission. General guidance on good manufacturing practices (GMPs) and hygienic principles is available.[c] Codes of practice for some specific commodities are also available as part of the Codex Alimentarius. A systematic approach to the assessment and control of hazards within the processing environment is termed the Hazard Analysis Critical Control Point system (HACCP). General guidance on GMPs and HACCP is also available (*5*).[d,e]

Cross-contamination should be eliminated from the environment through suitable design of equipment and appropriate sanitation procedures, and contamination from contact surfaces should be minimized. Raw and cooked products must be kept separate to avoid cross-contamination by food-handlers, contact surfaces and other transmission vectors. Listericidal processes (e.g., pasteurization, cooking procedures), when applied correctly, will eliminate *L. monocytogenes* from food and recontamination can be prevented by maintaining good hygienic practices.

RECOMMENDATIONS

Research needs

Although considerable research has been done on the association of *L. monocytogenes* with cases of illness and on the role of food in the transmission of the organism, several unresolved questions requiring further research remain. The Working Group made several suggestions for studies in epidemiology, virulence/pathogenicity, and methodology, and concerning contamination of raw and processed foods, effects of processing, effects of extrinsic and intrinsic factors, and the role of other *Listeria* species as an indicator of contamination. Details will be found in the full report.[f]

Recommendations to national public health authorities

The object of these recommendations is to: (1) reduce the incidence of foodborne listeriosis; (2) limit, or eliminate, where technologically feasible, the burden of *L. monocytogenes* in the food supply; and (3) enhance consumer confidence in the safety of the food supply.

The Working Group recommended that public health authorities should:

(1) actively promote research to determine ways in which (*a*) *L. monocytogenes* can be reduced or eliminated from the raw food supply and, (*b*) the contamination of processed food in areas of greatest public health impact (e.g., delicatessens and restaurants) can be lessened;

(2) commence or continue public education programmes to help consumers to protect themselves from *L. monocytogenes* in raw foods (plain or mixed with other ingredients) and processed foods which are subsequently handled;

(3) ensure that consumers are not given a false sense of security about the safety of raw or processed foods;

(4) ensure that foods in intact packages which have received a listericidal process at any point in their production are free of *L. monocytogenes* during the product's normal shelf-life and as long as the packaging remains undamaged;

(5) encourage the use of ionizing radiation for the elimination of *L. monocytogenes*, particularly for foods which are highly susceptible to contamination and growth of this organism, and for any packaged food, processed or raw;

(6) consider the removal from the market of processed foods in intact packages (e.g., pasteurized milk, dairy products and cooked meats in sealed containers) that are found to be contaminated with *L. monocytogenes*;

(7) withdraw from the market any foods which have been demonstrated to be causally associated with human cases of listeriosis;

[c] CODEX ALIMENTARIUS COMMISSION. *Recommended international code of practice — General principles of food hygiene* (document CAC/Vol. A–Ed. 1). First revision (1979). Rome, FAO/WHO, 1983.

[d] *Guidelines on prevention and control of salmonellosis*. Unpublished WHO document No. WHO/VPH/83.42, 1983.

[e] *Prevention and control of foodborne salmonellosis through the application of the Hazard Analysis Critical Control Point system*. Report of an ICMSF *Ad hoc* Committee. Unpublished WHO document No. WHO/CDS/VPH/86.65, 1986.

[f] See footnote with an asterisk on page 421.

(8) fully consider, when withdrawal of a food product from the market is indicated, all the ramifications and possible consequences prior to withdrawal (such a decision should be based on the best available scientific information and made only after careful risk analysis, in order to maintain consumer confidence in food supplies that cannot be made totally *Listeria*-free);

(9) work cooperatively with affected (or likely to be affected) segments of the food industry in order to prevent, limit, and (where possible) eliminate the presence of *L. monocytogenes* in foods;

(10) cooperate with the food industry, universities and research institutes to coordinate essential research on this organism;

(11) implement and maintain surveillance systems for all forms of human listeriosis in order to detect outbreaks, monitor progress towards their reduction, and provide epidemiological and microbiological resources for energetic investigation of outbreaks;

(12) when contributing to the WHO Surveillance Programme for Foodborne Infections and Intoxications in Europe, exchange data concerning foodborne listeriosis through the WHO Collaborating Centre in Berlin (West) coordinating the programme;

(13) educate all health professionals about the relatively new problem of foodborne listeriosis so that they can make appropriate recommendations to patients at high risk for the disease on the relative risks of foodborne listeriosis versus the benefit of consuming raw or processed or mixed foods.

It was recommended that WHO should act as a focal point for information exchange on foodborne listeriosis research and should facilitate the establishment of reference laboratories for *L. monocytogenes*.

Recommendations to the food industry

The general recommendations made by the WHO Consultation on prevention and control of listeriosis in 1986 are still valid in principle,[8] but certain points should be re-emphasized in the light of experience. The measures to be taken to reduce or limit the growth of *L. monocytogenes* on food contact surfaces in food factories are exactly the same as those for other pathogens. The fact that the former can grow at chill temperatures makes the reduction of their numbers or their elimination all the more important. Techniques that have been used against *Salmonella* spp., in meat processing for example, are also effective against *L. monocytogenes* if they are applied with great attention to detail (adequate washing and rinsing, disinfectant concentrations, and contact time). Since *L. monocytogenes* is particularly common in wet environments in food factories, the maintenance of a dry environment, wherever feasible, is one of the best ways of limiting the growth of this organism.

The HACCP approach has been recommended as the best way to assure safety and quality of foods, but it is not practised in all sectors of industry. Specific recommendations made by the Working Group to the food industry and/or commodity organizations, taking these factors into account, were that they should:

(1) promote the HACCP approach and ensure the safety of food products, by education and motivation of all those working in the food industry;

(2) apply the HACCP approach in order to: (i) identify pathogens associated with production environments and raw materials; (ii) identify critical sources of contamination and eliminate them where possible; (iii) identify vehicles of contamination and eliminate them; and (iv) identify opportunities for survival and growth of undesirable microorganisms in the factory, environment and product;

(3) concerning 2(iv), ensure (i) that bactericidal treatments (heat, irradiation, etc.) are adequate and result in the killing of *L. monocytogenes*, and (ii) that disinfectant concentrations and sanitization regimes are adequate for killing the organisms;

(4) carry out or promote research to seek new ways of eliminating or limiting the growth of *L. monocytogenes* in foods using natural or synthetic inhibitors;

(5) cooperate with regulatory agencies regarding the presence of *L. monocytogenes* in manufactured products and industry's efforts to eliminate the organism;

(6) collaborate closely with food processing equipment manufacturers to improve hygienic design;

(7) collaborate closely with regulatory/public health authorities to elaborate codes of hygienic practice for different sectors of food production;

(8) collaborate with international (e.g., WHO) and national organizations and universities to devise food microbiology curricula which include the HACCP approach;

(9) carry out research on new technological solutions to the problem of *L. monocytogenes* in products which do not undergo listericidal treatments before consumption, but which have traditionally been regarded as safe (e.g., raw foods mixed with other ingredients).

[8] *Report of the WHO Consultation on Prevention and Control of Listeriosis*. Unpublished WHO document No. WHO/CDS/VPH/87.69, 1986.

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