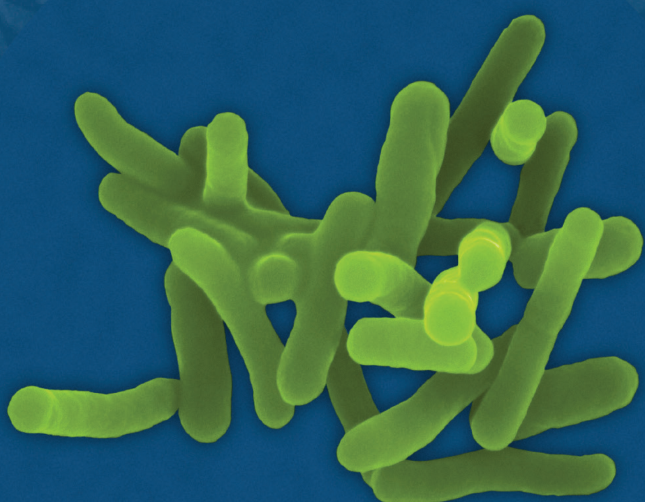
ISSN 1726-5274

Food and Agriculture Organization of the United Nations

World Health Organization

Microbiological hazards in spices and dried aromatic herbs

MEETING REPORT



27

MICROBIOLOGICAL RISK ASSESSMENT SERIES

27

MICROBIOLOGICAL RISK
ASSESSMENT SERIES

Microbiological hazards in spices and dried aromatic herbs

MEETING REPORT

Food and Agriculture Organization of the United Nations
World Health Organization

Rome, 2022

Required citation:

FAO and WHO. 2022. *Microbiological hazards in spices and dried aromatic herbs*. Meeting report. Microbiological Risk Assessment Series No. 27. Rome. https://doi.org/10.4060/cb8686en

FAO ISBN 978-92-5-135792-7
WHO ISBN 978-92-4-004518-7 (electronic version)
WHO ISBN 978-92-4-004519-4 (print version)

Contents

FIGURES

TABLES

Acknowledgements

The Food and Agriculture Organization of the United Nations (FAO) and the World Health Organization (WHO) would like to express their appreciation to all those who contributed to the preparation of this report through the provision of their time, expertise, data and other relevant information before, during and after the meeting. All contributors are listed on the following pages.

Appreciation is also extended to all those who responded to the calls for data that were issued by FAO and WHO and provided information that was not readily available in the peer reviewed literature or the public domain.

The preparatory work and expert meeting convened to prepare this report was coordinated by the Secretariat of the Joint FAO/WHO Expert Meetings on Microbiological Risk Assessment (JEMRA).

Contributors

EXPERTS

Ramasamy Anand, Microbiology Division, Quality Evaluation Laboratory, Spices Board, India

Paul Cook, Microbiological Food Safety Branch, Food Standards Agency, the United Kingdom of Great Britain and Northern Ireland

Ingrid Fiordaliso Candalino, Drogheria and Alimentari Spa, Italy

John Hill, British Pepper and Spice Co. Ltd., the United Kingdom of Great Britain and Northern Ireland

Greg Paoli, Risk Sciences International, Canada

Tom Ross, University of Tasmania, Australia

Jenny Scott, Food and Drug Administration, the United States of America

Ian Young, Public Health Agency of Canada, Canada

Jane Van Doren, Food and Drug Administration, the United States of America

RESOURCE PERSONS

Michael Batz, UF Emerging Pathogens Institute, the United States of America

Verna Carolissen, Joint FAO/WHO Food Standards Programme, Food and Agriculture Organization of the United Nations, Italy

Joni Munarso, Indonesian Center for Agricultural Postharvest Research and Development (ICAPRD), Indonesia

Marcel Zwietering, Wageningen University, the Netherlands

SECRETARIAT

Sarah Cahill, Food and Agriculture Organization of the United Nations, Italy

Haruka Igarashi, World Health Organization, Switzerland

Mina Kojima, World Health Organization, Switzerland

Jeffrey LeJeune, Food and Agriculture Organization of the United Nations, Italy

Masami Takeuchi, Food and Agriculture Organization of the United Nations, Italy

Kang Zhou, Food and Agriculture Organization of the United Nations, Italy

Declaration of interests

All participants completed a Declaration of Interests form in advance of the meeting. None were considered to present any potential conflict of interest.

All the experts participated in their individual capacities and not as representatives of their countries, governments or organizations.

Abbreviations and acronyms

ID_{50}	The dose of an infectious organism required to produce infection in 50 percent of the exposed individuals
CAC	Codex Alimentarius Commission
CCFH	Codex Committee on Food Hygiene
CFU	Colony forming unit
DALY	Disability-Adjusted Life Year
FAO	Food and Agriculture Organization of the United Nations
GHP	good hygiene practices
GMP	good manufacturing practices
HACCP	hazard analysis and critical control points
JEMRA	Joint FAO/WHO expert meetings on microbiological risk assessment
WHO	World Health Organization

Executive summary

A number of different pathogens have been found in spices and dried aromatic herbs on the market. An increased concern and attention to the safety of spices and dried aromatic herbs prompted the Codex Committee on Food Hygiene (CCFH) to request FAO and WHO to undertake a risk assessment on microbiological hazards in these food commodities. FAO and WHO initiated a series of activities that culminated in an expert meeting of the FAO/WHO Joint Expert Meeting on Microbiological Risk Assessment (JEMRA) on 7–10 December 2014.

The meeting considered the global evidence on the burden of illness, prevalence and concentration of selected microbial hazards with respect to various spices and dried aromatic herbs, and interventions aimed at controlling them in these commodities. Based on a structured review and analysis of information, the meeting agreed that *Salmonella* spp. and the spore-forming organisms *B. cereus* and *C. perfringens* should be considered foodborne pathogens of particular concern with respect to spices and dried aromatic herbs. To assess the health risks related to the commodity-pathogen combinations, a number of spice and dried aromatic herb commodities was selected, and a ranking approach was developed, considering key variables influencing risk of microbial contamination for a spice and dried aromatic herb and its relevant production and processing conditions. Using this approach, irrespective of the specific spice or dried aromatic herb, poor controls and practices together with no treatment predicted a high risk with few exceptions. Also, it was noteworthy that all 15 highly ranked (high-risk) scenarios were associated with *Salmonella* spp. Despite the expectation that some microbial inactivation is expected to occur during drying and storage, validated microbial reduction treatments are usually required for control of *Salmonella*. When used in conjunction with good hygiene practices (GHP), good manufacturing practices (GMP), and hazard analysis and critical control points (HACCP), these treatments play a critical role in the safety of these products, particularly if spices and dried aromatic herbs are subsequently added to foods that would support the growth of pathogens or to those that are consumed without further heat treatment.

In considering microbiological criteria for spices, the meeting noted that the microbiological safety of food is principally achieved through the implementation of control measures throughout the production and processing chain. The experts assessed the performance of the existing Codex sampling plan for *Salmonella* against several contamination scenarios (FAO and WHO, 2018). The sampling plan had some value when all lots were tested, and yet when only a small portion of lots were tested, the likelihood of detection dramatically reduced. The meeting considered establishing a microbiological criterion indicator which would reflect the production and processing conditions to which a particular commodity had been exposed, but at the time of the meeting, there were insufficient data to establish appropriate limits.

1 Introduction

Spices and dried aromatic herbs impart flavour when added to food, and they may include many parts of the plant, including berries, flowers, leaves, roots and seeds. Spore-forming bacteria, including pathogens such as *Bacillus cereus* (*B. cereus*), *Clostridium perfringens* (*C. perfringens*) and *Clostridium botulinum* (*C. botulinum*), as well as non-spore-forming vegetative cells such as *Escherichia coli* (*E. coli*) and *Salmonella* spp. have been found in spices and dried aromatic herbs. The safety of spices and dried aromatic herbs depends on maintaining good hygienic practices along the entire food chain from farm to table, during primary production, processing, packing, retail and at the point of consumption. There have been several outbreaks of illness associated with spice and seasoning consumption, with most being caused by *Salmonella* spp. that have raised concerns regarding the safety of spices and dried aromatic herbs as a whole. The complex supply chain has made it difficult to identify the point in the food chain where contamination took place in each outbreak, but evidence has demonstrated that contamination can take place throughout the food chain if proper practices are not followed.

A number of different pathogens have been found in spices on the market, especially *Salmonella* spp., *B. cereus* and *C. perfringens*. There have also been several disease outbreaks associated with spices and dried aromatic herbs. Infants and children have been the primary population impacted by 33 percent of the spice-attributed outbreaks, including the largest (~1 000 illnesses) outbreak (Koch, *et al.,* 2005; Lehmacher *et al.*, 1995; Sotir *et al.,* 2009; Laidley, 1974). The outbreaks attributed to herbs and spices are likely underreported. For instance, the United

States Centers for Disease Control and Prevention (CDC, 2010) estimated that there are 28 undiagnosed cases of salmonellosis for every documented case of the infection (Scallan, 2011).

Several additional factors influence the number of illnesses arising from pathogen -containing spices. Spices and herbs are widely used around the globe. For example, according to FAOSTAT, the total export value of spices and dried herbs in 2011 was approximately 15 billion US dollars. In addition, it was estimated that high consumption level (95th percentile) of these commodities was approximately 49 g/ day (FAO and WHO, 2022) though they may be added to foods after the final treatment with a microbiological lethality step in food preparation.

1.1 BACKGROUND TO THE EXPERT MEETING

With increased concern and attention to the safety of spices and dried aromatic herbs, the Codex Committee on Food Hygiene (CCFH) agreed to begin a new endeavour to revise the *Code of Hygienic Practice for Spices and Dried Aromatic Herbs (CAC/RCP 42-1995)*[1] at the 43rd Session of the Committee (December 2011). The 44th Session of the CCFH (November 2012) discussed the proposed draft *Code* and agreed to request that FAO and WHO to (FAO and WHO, 2012):

> "*…undertake a risk assessment to determine whether there is a significant public health risk from Salmonella associated with consumption of spices and dried aromatic herbs and to evaluate whether criteria for Salmonella are meaningful to ensure adequate consumer health protection…*"

and further proposed that FAO and WHO extend their call for data to any microbiological hazard associated with spices and dried aromatic herbs in order to identify any other foodborne pathogens of concern. In addition, the 44th Session also agreed that FAO and WHO should:

> "*…identify the range of spices to be covered in the Code, and the critical points for control of Salmonella and/or other foodborne pathogens.*"

FAO and WHO initiated a series of activities starting with an issuance of an international call for data and experts in December 2012 to raise awareness about

---

[1] The *Code* was revised in 2014.

data needs and invite all interested parties to provide both organizations with any relevant information and data, particularly that which may not be readily available in the public domain, and a structured review of the topic. An expert meeting on the topic was held on 7–10 December 2014. The meeting considered the global evidence on the burden of illness, prevalence and concentration of selected microbial hazards with respect to various spices and dried aromatic herbs, and interventions aimed at controlling them in these commodities. This was based on a structured review and analysis of information in the public domain, information submitted in response to a call for data and information, data from some regulatory authorities, food recall and port of entry rejection data, data from industry and the knowledge and expertise of the participants.

1.2 OBJECTIVES AND SCOPE OF THE EXPERT MEETING

The primary objective of the meeting was to respond to the request from CCFH to undertake a risk assessment to determine whether there is a significant public health risk from *Salmonella* spp. and other pathogens associated with consumption of spices and dried aromatic herbs and to evaluate whether developing a set of criteria for *Salmonella* spp. and other pathogens is meaningful to ensuring adequate consumer health protection. Specific questions that have been raised by CCFH include (FAO and WHO, 2012):

- Is there a significant risk associated with *Salmonella* or other identified foodborne pathogens in spices and dried aromatic herbs? If so, are there particular spices and dried aromatic herbs which present a greater risk than others?
- Are the criterion and the associated sampling plan for *Salmonella* in the draft Annex (CX/FH 12/44/8) meaningful for public health protection? What is the performance of the existing microbiological criterion and associated sampling plan, given the information on the prevalence and concentration of *Salmonella* in spices and dried aromatic herbs? Identify and consider an alternative microbiological criterion and associated sampling plans that could be effectively applied to the management of *Salmonella* (or any other identified pathogen) in spices and dried aromatic herbs, given the available information on prevalence and levels of contamination.
- How would the different levels of microbial reduction treatments impact public health? For example, a 2–5 log reduction of *Salmonella* provided to spices and dried aromatic herbs?

To address these specific questions, the meeting discussions focused on the following three key areas:

- identification of microbiological hazards in spices and dried aromatic herbs;
- risk prioritization/ranking of microbiological hazards and related food commodities; and
- establishment of effective microbiological criteria/sampling plan.

As to the relevant commodities to be covered, the meeting agreed to exclude tea (*Camellia sinensis)* from the scope, to make this report consistent with the Code of Hygienic Practice for Spices and Dried Aromatic Herbs (CAC/RCP 42-1995), and to give consideration to all other spices and dried aromatic herbs used for culinary purposes, including infusions and tisanes. As for the scope of the pathogens, though the meeting noted that viruses and parasites could also potentially be a concern, due to the dearth of epidemiological data on these hazards or information on their occurrence in these commodities to warrant their specific consideration, the meeting agreed to primarily focus on bacterial hazards of concern. In addition, although mycotoxins can be formed as a result of fungal growth in foods, they were not considered in the evidence gathering nor in the discussions since they fall outside the remit of CCFH.

2

Foodborne pathogens of concern: microbiological hazards associated with spices and dried aromatic herbs

A structured, comprehensive review of evidence in the public domain including an international outbreak database was conducted to identify and synthesize global evidence on the burden of illness, prevalence and concentration of selected bacterial hazards, and interventions to control them, in spices and dried aromatic herbs (FAO and WHO, 2022). In addition, information received from the "Call for Data" issued in December 2012[2] was considered. The review identified 28 outbreaks of foodborne illness implicating spices and dried aromatic herbs, including herbal infusions, causing a total of 2 228 reported cases, 134 hospitalizations and two deaths, between 1973 and 2012. Most illnesses were caused by *Salmonella* spp. (77 percent), followed by *B. cereus* (20 percent), and *C. perfringens* (3 percent). Outbreaks were generally small: median 20 cases (range 1–1 000). *Bacillus subtilis* and *Bacillus pumilus* were associated with two small outbreaks of foodborne illness in 1995 and 1997, with a total of four reported cases. Outbreaks associated with consumption of spices and dried aromatic herbs are assumed to be underreported, as these foods are usually consumed as minor ingredients in meals.

Although other bacterial hazards have been reported in spices and dried aromatic herbs (e.g. *Cronobacter* spp. and *Staphylococcus aureus*), no spice-associated outbreaks or cases of foodborne illness were identified due to these hazards. In addition, neither the review nor the meeting identified any information on the presence of pathogenic *E. coli* and *Listeria monocytogenes* in spices and dried aromatic herbs.

---

[2] Available at http://www.fao.org/fileadmin/templates/agns/pdf/jemra/Call_for_data_and_experts_on_spices_Final_20121220.pdf.

In conclusion, the meeting agreed that *Salmonella* spp.and the spore-forming organisms *B. cereus* and *C. perfringens* should be considered foodborne pathogens of particular concern with respect to spices and dried aromatic herbs.

Public health risk from *Salmonella* spp. associated with consumption of spices and dried aromatic herbs

Estimating the public health risk associated with a specific pathogen in a particular food is challenging and can involve a detailed risk assessment requiring large amounts of data. Due to the diversity of the commodities categorized as spices or dried aromatic herbs and the limited data available, a full quantitative risk assessment was not considered to be feasible. However, the meeting considered that under the typical conditions of production and processing of spices and dried aromatic herbs, there is a significant potential for contamination with a range of pathogens. In some cases, subsequent growth of these organisms could occur when spices and dried aromatic herbs are added to high-moisture foods. Despite the expectation that some inactivation will occur during drying and storage, validated microbial reduction treatments are usually required for control of *Salmonella* spp. When used in conjunction with good hygiene practices (GHP), good manufacturing practices (GMP) and hazard analysis and critical control points (HACCP), these treatments play a critical role in the microbiological safety of these products, particularly if spices and dried aromatic herbs are subsequently added to foods that would support growth of pathogens. When pathogens are present, the cooking, preparation, storage and consumption practices of consumers are important factors in relation to the potential risk to public health.

Impact of microbial reduction treatments for spices and dried aromatic herbs on public health

Contamination of untreated spices and dried aromatic herbs with *Salmonella* spp. occurs with regular frequency. The prevalence and levels found will depend strongly on the methods of production, harvest and processing of these commodities. Much of the international spice and dried aromatic herb industry relies on GHP, GMP, and HACCP, including microbial inactivation treatments, for product safety. Given the diversity of products and processes involved, it is not possible to generalize the impact of different levels of microbial reduction treatments on public health.

3

Spices and dried aromatic herbs of greatest concern

3.1 APPROACH AND METHODS

In general, the spice and dried aromatic herb industry is supported by millions of small farmers around the world. Given the production and processing practices employed, there is great potential, with few exceptions, for spices and dried aromatic herbs to be contaminated with bacterial pathogens at levels that can present an unacceptable risk to public health. Due to the global nature of the industry and the extensive number of stakeholders involved with these products, it is difficult to characterize the risk associated with an individual spice or dried aromatic herb. To overcome this, the ranking approach developed by the expert meeting included the identification of several production and processing practices which strongly influence the prevalence and level of microbial contamination of spices and dried aromatic herbs by bacterial pathogens. Additionally, individual characteristics of pathogens were considered.

Changes in pathogen levels in response to production, handling and processing, together with likelihood and severity of illness associated with specific pathogens, were explicitly considered in an estimation of relative risk. The factors, parameters and functions needed to develop a deterministic mathematical model to calculate risk from farm to fork were established (Table 1). Additional details of the factors and their categorization are provided in Annex 1. The categorization and the numerical score value of parameters were used to capture the scale of the differences between the different descriptors. The model could be implemented in different software to facilitate systematic consideration of the factors identified as relevant for risk ranking.

TABLE 1 Key variables influencing risk of microbial contamination for a spice/dried aromatic herb, the relevant production/processing conditions, parameters and functions for the deterministic semi-quantitative model

Factors	Description	Parameters	Functions
Agricultural	Amount of contamination of the selected organism at pre-harvest considering agriculture inputs and environmental factors but not inputs from human handling	AgC	Baseline Contamination, BaseC = log (10^AgC + 10^HaC)
Handling	Changes in contamination or growth during harvest and post-harvest	HaC	
Drying	Changes in contamination during drying, potential for microbiological growth or inactivation, increase in concentration of contaminants due to dehydration	DryGrow, potential for microbial growth or inactivation DryRec, addition of recontamination	The drying contamination, DryC = log(10^(BaseC + DryGrow) + 10^DryRec)
Post-drying	Changes in contamination after drying, potential for microbiological growth after drying due to incomplete drying	EvaR, drying evaporation ratio (concentration of the hazard as water evaporates and product loses weight) PostDryGrow, growth during handling, storage and treatment PostDryRec, recontamination during handling, storage and transportation	The post drying contamination, PostDryC = log(10^(DryC + PostDryGrow + log(EvaR)) + 10^PostDryRec)), or if PostDryC > 9+ log(EvaR), then PostDryC = 9+ log(EvaR).
Treatment	Whether pathogen reduction treatment is applied, reduction achieved	TreFac, Treatment factor	Treatment leve, TreLev = PostDryC + TreFac
Post-treatment	Changes in contamination after treatment, potential for microbiological growth after treatment	PostTreFac, post treatment factor	Post treatment level, PostTreLev = log(10^TreLev + 10^ PostTreFac).

(cont.)

Factors	Description	Parameters	Functions
Food (preparation and storage prior to consumption)	Growth or inactivation during preparation of food and during storage of prepared food prior to consumption	FooPre, food preparation	Level at consumption, LevCons = PostTreLev +FooPre, or if LevCons > 9+ log(EvaR), then LevCons = 9+ log(EvaR).
Pathogen	Sources, infectivity of pathogen (ID_{50}), disease severity, growth and survival characteristics, resistance to heat treatment	Path, pathogenicity factor	Illness rate = LevCons +Path
The Risk = Illness rate +log(SevFac), where Severity Factor (SevFac) is obtained from the DALYs.			

The model first estimates the likely contamination and change in contamination levels of *Salmonella* spp., *B. cereus* and *C. perfringens* on spices and dried aromatic herbs in the field (Agricultural), through harvest (Handling) and processing and distribution (Drying, Post-drying, Treatment and Post-treatment) to end use in meals (Food) for different, user-specified scenarios (Figure 1). Then, the approximate ID_{50} values for each organism (Pathogenicity) as a measure of likelihood of illness, as well as DALY values (Severity Factor) for each of the three pathogens to model disease severity are considered to ultimately produce a measure of risk for each pathogen for each scenario which will serve as the basis for relative ranking (Table 2).

TABLE 2 The pathogenicity and severity factors for *C. perfringens*, *B. cereus* and *Salmonella*

	C. perfringens	***B. cereus***	***Salmonella* spp.**
Pathogenicity factor: ID_{50} (Teunis *et al.*, 2010)	-8	-8	-1.6
Severity factor: DALYs (Havelaar *et al.*, 2012)	0.0032	0.0023	0.049

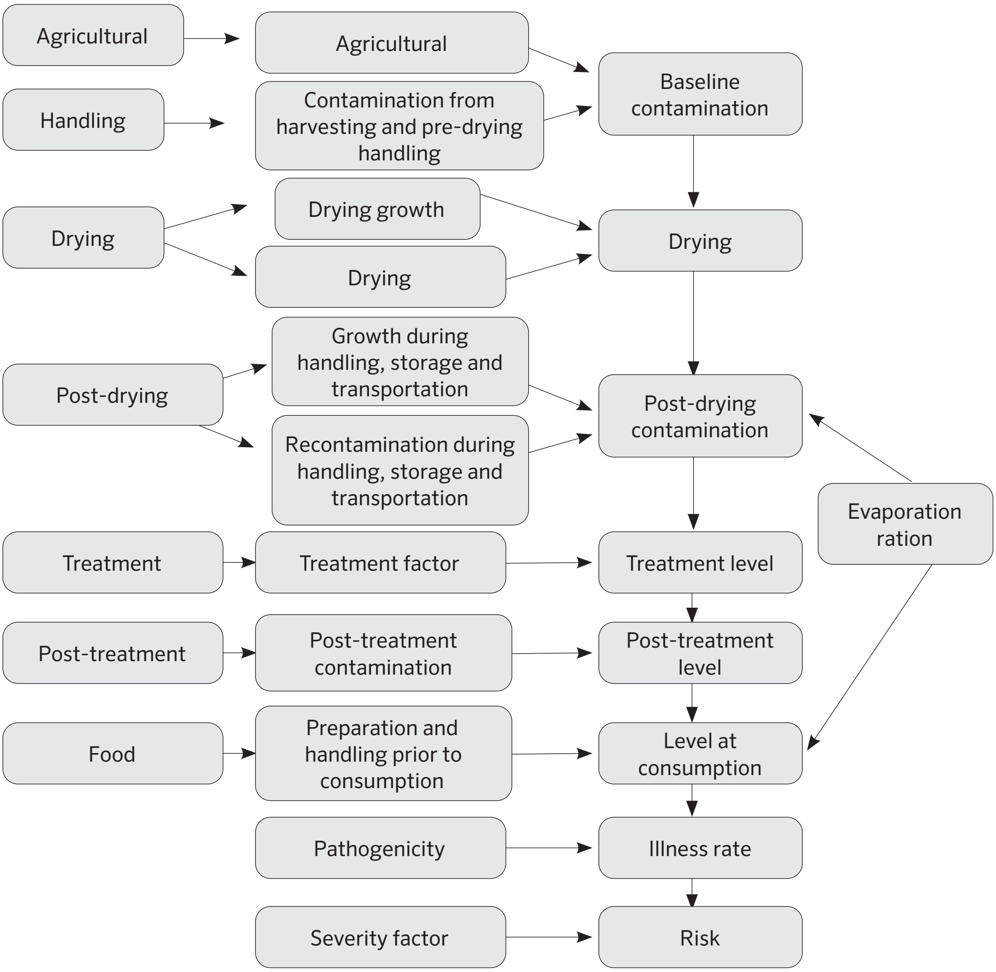


FIGURE 1 The process of the semi-quantitative model to determine the risk

The meeting grouped spices and dried aromatic herbs by plant part, as this characteristic was considered to influence potential sources of contamination. A number of examples were selected to reflect the range of spices and dried aromatic herbs that are available on the market (Table 3). The experts provided specific comments to the general production conditions and usual handling practices on each specific spice or dried aromatic herb.

TABLE 3 Different categories of spices and dried aromatic herbs based on plant parts, relevant experts' comments on hygiene challenges associated with their production and processing, and decisions about whether to include them in the ranking or not

Plant Part	Example	Agricultural contamination condition	Experts' comments	Common use and consumption pattern	Ranking inclusion
Pistil	*Crocus sativus* (saffron)	Almost sterile (Level 0)	Saffron involves a unique and highly hygienic production and process practice due to its delicate features and monetary value. In almost every case, the handling process is well controlled, otherwise the product cannot be sold.	Cooked	Yes
Inner bark	*Cinnamomum* spp. (cinnamon)	Lightly contaminated (Level 1)	Cinnamon can be sold in sticks or in powder, and both require manual handling and processing. There is no treatment that can be applied to its stick form, and for the powder form, there is a validated treatment method available after the drying process, though the treatment must be the one for delicate products, so that the cinnamon does not lose its aroma.	Cooked (ground cinnamon)	Yes
Fruit/ berry	*Capsicum* spp. (chilli/red pepper)	Highly contaminated (Level 3)	For both whole and ground chilli, water quality can be an issue. In the poorly controlled processing conditions, drying is often done on the ground with no cover. Validated sporicidal treatment methods are available.	Usually cooked, ground chilli occasionally used fresh	Yes
	Piper nigrum (black pepper)	Moderately contaminated (Level 2)	For both whole and ground black pepper, validated sporicidal treatment methods are available. However, some processing plants use steam treatment to keep the product's quality, even though the method is not validated. Water quality can be an issue.	Often non-cooked (sprinkled)	Yes
Seed	*Cuminum cyminum* (cumin)	Highly contaminated (Level 3)	For both whole and ground cumin, validated sporicidal treatment methods are available. Water quality can be an issue.	Cooked	Yes

(cont.)

Plant Part	Example	Agricultural contamination condition	Experts' comments	Common use and consumption pattern	Ranking inclusion
	Coriandrum sativum (coriander seed)	Highly contaminated (Level 3)	Generally processed in open-air conditions and dried on the ground with no cover (poorly controlled). Validated treatment methods for delicate products are available.	Cooked	No. The data obtained on coriander did not specify if it was about coriander leaf or seed, and as different conditions and practices would apply, coriander is not to be included in the ranking.
	Myristica fragrans (nutmeg)	Lightly contaminated (Level 1)	For ground nutmeg, validated sporicidal treatment methods are available. No treatment can be applied to whole nutmeg. If unpeeled, the seed in the whole nutmeg shell is often well protected from contamination.	Cooked	Yes
Leaf	*Origanum vulgare/onites* (oregano)	Moderately contaminated (Level 2)	Validated treatment methods for delicate products are available. Water quality can be an issue. Processing is very often moderately or well controlled (usually it is not too poorly handled), as the colour is an important selling factor.	Fresh or cooked	Yes
	Ocimum basilicum (basil)	Very highly contaminated (Level 4) – leaf is sensitive and vulnerable to contamination	Validated treatment methods for delicate products are available. Water quality can be an issue.	Normally not cooked	Yes
	Rosmarinus officinalis (rosemary)	Moderately contaminated (Level 2)	Validated and sporicidal treatment methods are available.	Cooked	Yes

(cont.)

Plant Part	Example	Agricultural contamination condition	Experts' comments	Common use and consumption pattern	Ranking inclusion
Rhizome (root)	*Curcuma longa* (turmeric)	Very highly contaminated (Level 4) – direct contact with soil	Validated and sporicidal treatment methods are available for whole turmeric. Validated treatment methods for delicate products are available for ground turmeric, for keeping its strong colour.	99% cooked	Yes. Both whole and ground turmeric are included in the ranking to see the differences.
Bulb	*Allium sativum* (garlic)	Very highly contaminated (Level 4) – direct contact with soil	No validated treatment methods are available and heat/steam treatment is not a suitable treatment as the final product will become too sticky (quality issue). Some processing plants use chlorinated water when peeling. Garlic is known to have some level of natural anti-microbial properties. Some countries allow processors to irradiate dried garlic.	Mainly cooked	No. While garlic's very highly contaminated agricultural condition is considered in the model, the impact of the extensive peeling process as well as its possible natural anti-microbial properties are not considered in the model. If the current model is applied to garlic, the results would be biased and confusing.

In conclusion, the expert meeting agreed to focus on the following spice/dried aromatic herb commodities: *Capsicum* spp. (**chilli**/red pepper), *Cinnamomum* spp. (**cinnamon**), *Curcuma longa* (**turmeric, whole and ground**), *Cuminum cyminum* (**cumin**), *Piper nigrum* (**black pepper**), *Origanum vulgare/onites* (**oregano**), *Myristica fragrans* (**nutmeg**), *Rosmarinus officinalis* (**rosemary**), *Crocus sativus* (**saffron**) and *Ocimum basilicum* (**basil**).

The experts then developed scenarios considering the combinations of (1) commodity, (2) state of the commodity (whole or ground) as applicable, (3) type of treatment applied (or not applied) and (4) pathogen. The full scenarios of ranking the risk are shown in Annex 1 and Annex 2. The example scenarios for *Capsicum* spp. (chilli/red pepper) and their respective scenario codes are shown in Table 4.

TABLE 4 Example combination scenarios for *Capsicum* spp. (chilli/red pepper) with its hygiene control levels, treatment types and concerned pathogens

Scenario Code	Hygiene control during processing and handling	Treatment	Pathogen
Chilli PCNT CP	Poorly Controlled (PC)	No Treatment (NT)	*C. perfringens* (CP)
Chilli PCNT BC			*B. cereus* (BC)
Chilli PCNT SA			*Salmonella* (SA)
Chilli PCVST CP		Validated Sporicidal Treatment (VST)	*C. perfringens* (CP)
Chilli PCVST BC			*B. cereus* (BC)
Chilli PCVST SA			*Salmonella* (SA)
Chilli WCNT CP	Well Controlled (WC)	No Treatment (NT)	*C. perfringens* (CP)
Chilli WCNT BC			*B. cereus* (BC)
Chilli WCNT SA			*Salmonella* (SA)
Chilli WCVST CP		Validated Sporicidal Treatment (VST)	*C. perfringens* (CP)
Chilli WCVST BC			*B. cereus* (BC)
Chilli WCVST SA			*Salmonella* (SA)

A similar coding was applied for other focused spice/dried aromatic herb commodities, and a total of 129 scenarios were developed. It should be noted that the expert meeting identified saffron as one of the rare examples of a spice that is expected to have a very low level of contamination because of its particular handling and processing practices. The final list is available in Annex 2. Apart from the coding symbols shown in Table 4, additional codes such as VDT for “Validated Treatment for Delicate Products”, NVT for “Non-Validated Treatment”, W for “Whole” and G for “Ground” have been used (Table 5).

TABLE 5 Coding symbols

Codes	Explanation
PC	Poorly Controlled
WC	Well Controlled
NT	No Treatment
VST	Validated Sporicidal Treatment
VDT	Validated Treatment for Delicate Products
NVT	Non-Validated Treatment
W	Whole
G	Ground
CP	*C. perfringens*
BC	*B. cereus*
SA	*Salmonella*

3.2 RESULTS

Based on the model described in 3.1 and the expert elicitation of the different scenarios for different products and pathogens (Annex 1 and Annex 2), the risk ranking of all the scenarios were developed (Annex 3). Figure 2 shows the 15 highest-risk scenarios identified from the results, which each have a risk ranking value higher than 2.0.

The results above illustrate that irrespective of the specific spice or dried aromatic herb, poor controls and practices together with no treatment combinations pose a high risk with a few exceptions. It also shows that all 15 scenarios are associated with *Salmonella* spp. Generally speaking, the results indicate that the risk may be reduced when microbial reduction treatments are applied. However, the success of a microbial inactivation treatment in eliminating and reducing the contamination depends on treatment efficacy and production and processing practices. Pre-treatment pathogen levels can exceed the capabilities of process treatments, particularly when significant pathogen growth has occurred. Posttreatment re-contamination or growth can erase the reductions achieved by a processing

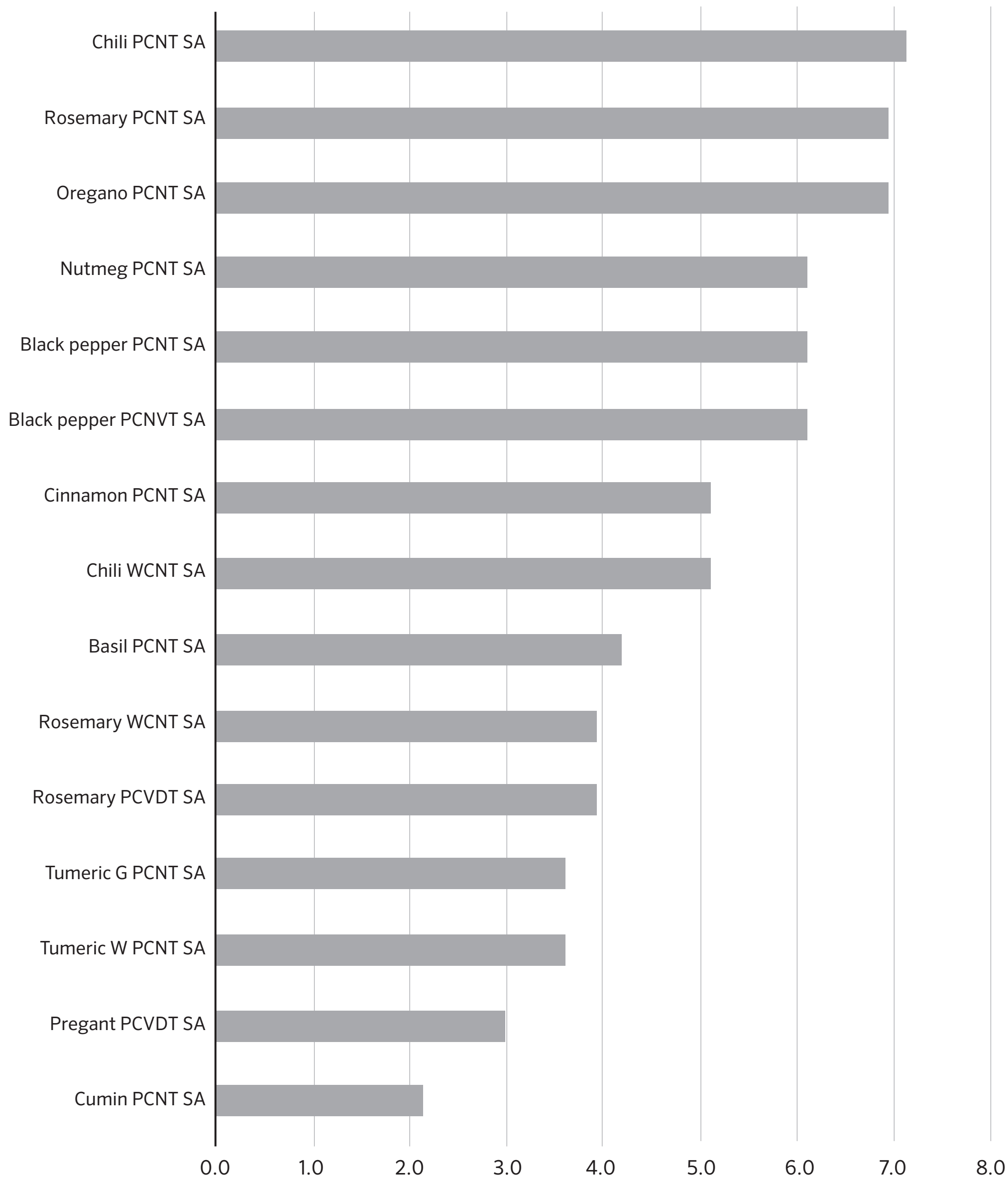


FIGURE 2 15 high-risk scenarios using the ranking model

treatment. In addition, it was observed that when poorly controlled or no treatment is applied, rosemary and oregano scored high in the ranking; however, during the scoping review, no information and data was found on *Salmonella* outbreak associated with leafy herbs. It is possible that pathogens with these herbs are inactivated through a full cooking process (i.e. baking and grilling for rosemary), or these herbs are added to food immediately before consumption and provide no time for *Salmonella* to grow (i.e. oregano). Therefore, how the particular commodities are commonly prepared in food and how they are consumed are also significant factors in estimating the eventual risks.

Table 6 shows the ranking results by different pathogens. Note that no scenario in the lists for *C. perfringens* and *B. cereus* have a positive score and only the list for *Salmonella* includes 17 scenarios with positive scores (higher risks).

TABLE 6 Worst 10 risk ranking of the scenarios by pathogens

Ranking (from the worst)	Scenarios by pathogens		
	C. perfringens	***B. cereus***	***Salmonella* spp.**
1	Rosemary PCNT	Chilli PCNT	Chilli PCNT
2	Rosemary PCVDT	Rosemary PCNT	Rosemary PCNT
3	Chilli PCNT	Rosemary PCVDT	Oregano PCNT
4	Black pepper PCNT	Oregano PCNT	Nutmeg PCNT
5	Black pepper PCNVT	Oregano PCVDT	Black pepper PCNT
6	Oregano PCNT	Nutmeg PCNT	Black pepper PCNVT
7	TurmericW PCNT	Black pepper PCNT	Cinnamon PCNT
8	TurmericG PCNT	Black pepper PCNVT	Chilli WCNT
9	Nutmeg PCNT	Rosemary WCNT	Basil PCNT
10	Oregano PCVDT	Rosemary WCVDT	Rosemary WCNT

Although the health-risk scenarios for spore-forming bacteria did not show significantly high risks in the full ranking, there are some outbreaks of *C. perfringens* and *B. cereus* in the reported spices. This means the presence of these bacteria could themselves pose a significant health risk if there is a failure in food preparation (i.e. temperature abuse), and so ensuring appropriate food preparation becomes as equally important as well-controlled processing and handling.

4

Microbiological Criteria (MC) and their role in ensuring consumer health protection

The safety of foods is principally achieved through the implementation of control measures throughout the production and processing chain, which the risk ranking results from this report also confirm. Such controls are based upon the consistent application of GHP, GMP and HACCP, including the application of validated microbial inactivation treatments where appropriate. This preventive approach offers much more control than reliance on microbiological end-product testing, which is limited by the number of samples tested, the available methodology, the cost and can only provide a specified degree of confidence in the result. In a modern food safety management system, microbiological testing is optimally used for assessing adherence to GMP/GHP and the suitability of a food or ingredient for its intended purpose, while end-product testing is only a final verification that the measures put in place are effective in producing safe products.

The value of end product testing for *Salmonella* spp. or any other pathogens in terms of ensuring consumer health protection is difficult to quantify. As noted above, the most relevant application of testing is in the context of a preventative approach where it is one of many factors contributing to consumer health protection. However, in some cases when information on the history of a product or commodity is not available and there is the potential to have high degree of contamination, testing and rejecting positive lots of products may have a direct positive impact on consumer health. However, the efficacy of testing is also closely linked to the stringency of the microbiological criteria and associated sampling plan. As average contamination decreases, the value of the sampling and testing as a means of removing contaminated product from the market diminishes.

4.1 PERFORMANCE OF THE EXISTING CODEX MC AND ASSOCIATED SAMPLING PLAN FOR *SALMONELLA* IN THE CONTEXT OF DIFFERENT CONTAMINATION SCENARIOS AND DIFFERENT RATES OF SAMPLING

The current Codex sampling plan for spices and dried aromatic herbs (n = 10 (×25 g) c = 0) is intended to be applied to ready-to-eat spices and dried aromatic herbs at points in the food chain after any microbial reduction treatment has been applied and prior to use by consumers. The performance of this plan was assessed using *Salmonella* sp. contamination data available for *Capsicum* spp. from port of entry testing in the United States of America (Van Doren *et al.*, 2013), and the FAO/WHO microbiological sampling tool (http://www.fstools.org/sampling/). The Operating-Characteristic (OC) curve from this sampling plan and two variations are presented in Figure 3. This illustrates the probability of acceptance of the tested lot according to the microbial load.

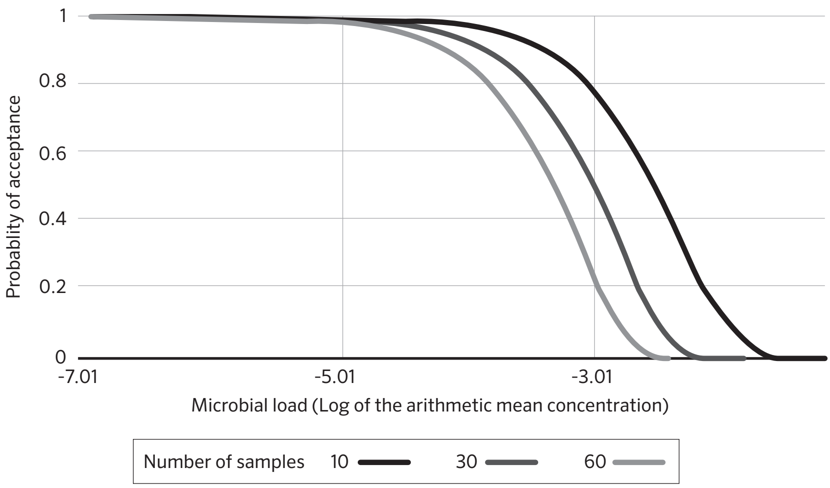


FIGURE 3 OC-curve for Salmonella sampling plans with c = 0 and (a) n = 1, (b) n = 30 and (c) n = 60; sample size = 25 g (within lot standard deviation = 0.5)

The current sampling plan (10 samples of 25 g) will detect, with 95 percent probability for lots tested, those with approximately an (arithmetic) mean concentration of one *Salmonella* in 62 g of product.[3] The performance of the plan, in comparison to testing 30 and 60 samples and with application to 1 percent and

[3] The within lot standard deviation is assumed to be 0.5 log cfu/g.

100 percent of lots is presented in Table 7. With the same contamination scenario, increasing the number of samples to 30 will enable the sampling plan to detect approximately one *Salmonella* in 224 g of product, while increasing to 60 samples will enable the sampling plan to detect approximately one *Salmonella* in 468 g of product. The OC curves for a sampling plan with 30 and 60 samples respectively are also presented in Figure 3. The figure illustrates that increasing the number of samples taken (while sample weight remains constant) increases the probability of rejecting a lot at lower levels of contamination, i.e. the OC-curve moves to the left.

TABLE 7 Overview of the performance of a range of sampling plans for *Salmonella* in spices and dried aromatic herbs when 100 percent or 1 percent of lots are tested, using a contamination profile based on port of entry testing data for capsicum[3]

Number of samples	Sample mass	Detectable microbial load*	Probability of accepting 1 cell per 1 000g	% lots tested	% of load remaining**	% load removed**	Log removal from the overall supply	% of lots rejected**
10	25 g	1 cell/62 g	79%	100%	14	86	0.85	22
30	25 g	1 cell/224 g	48%	100%	7	93	1.15	36
60	25 g	1 cell/468 g	23%	100%	4	96	1.36	46
10	25 g	1 cell/62 g	79%	1%	99	1	0.004	0.22
30	25 g	1 cell/224 g	48%	1%	99	1	0.004	0.36
60	25 g	1 cell/468g	23%	1%	99	1	0.004	0.46

*Intra-lot distribution is lognormal distribution in Van Doren *et al*., 2013; within lot standard deviation set to 0.5 log cfu/g. Performance of sampling plan is slightly improved when the within lot standard deviation is reduced.

** Assumes a between lot distribution, log-normally distributed, a geometric mean of 3.5 log units and a standard deviation of 0.5 log.

As illustrated in Table 7, applying such a sampling plan (n = 10) to 100 percent of lots, with a contamination profile based on port of entry testing data for capsicum[3,] would remove 86 percent of the contamination from the supply through the approach of removing the most contaminated lots. This would have the effect of reducing the amount of *Salmonella* spp. in the supply by just under one log (i.e. by a factor of ten). When 30 or 60 samples are taken, 93 percent and 96 percent respectively of the contamination is removed from the supply. This reduction is entirely driven by assumptions regarding the level and variability of contamination among lots[3,4]. While this illustrates what a sampling plan can achieve, in reality it will drive the producer and processer towards achieving a lower level of contamination in order to ensure that a large percentage of lots are not rejected in this way.

As noted above, the level of contamination assumed here was based on port of entry data for *Capsicum*[3], which may or may not have been heat treated. The mean amount of contamination was assumed to have a geometric mean (or median) concentration of 3 cells per 10 000 g, with a standard deviation (on the $\log_{10}$ scale) of one, and with an arithmetic average concentration of 1 cfu per 250 g. In the case of one spice-attributed outbreak (paprika, *Capsicum* spp.), in which the level of contamination in the paprika was estimated to be 2.5 MPN/g, the current sampling plan (n = 10) would have rejected all lots with this level of contamination. Another scenario was considered where the contamination of the product was slightly greater than in the case of *Capsicum* (median concentration of 1 cell per 1 000 g, average of 1 cell per 80 g) (Table 8). Results for this scenario emphasize that sampling is more likely to detect, and as a consequence remove, contaminated product when the mean concentration of contamination of the lots increases.

TABLE 8 Overview of the performance of a range of sampling plans for *Salmonella* spp. in dried spices and aromatic herbs when 100 percent of lots are tested based on an average contamination of 1 cfu/1 000 g

Number of samples	Sample mass	Detectable microbial load*	% lots tested	% of load remaining**	% load removed**	Log removal from the overall supply	% of lots rejected**
10	25 g	1 cell/62 g	100%	7	93	1.1	36
30	25 g	1 cell/224 g	100%	3	97	1.4	53
60	25 g	1 cell/468 g	100%	2	98	1.7	64

* The within lot standard deviation is 0.5 log cfu/g; performance of the sampling plan is slightly changed when the within-lot standard deviation is reduced, i.e. detection is more likely when the lot is more homogeneous.

** Assumes a between lot distribution, lognormally distributed, a geometric mean of 3 log units and a standard deviation of 1 log.

Several of the above scenarios assume 100 percent of lots of a commodity are tested. However, in reality, at least in the context of port of entry testing, sampling may only apply to, for example, approximately 1 percent of lots. In this case, using the same contamination scenario (Table 7) only 1 percent of the microbial load would be rejected as a result of testing. This clearly illustrates the value of testing in the regulatory context where only a small fraction of product is tested, and not as a mechanism to detect and remove contaminated product from the supply chain. It provides an incentive to producers and processors to ensure their product meets the required specifications. Some industry organizations currently test one sample of 75 g for *Salmonella* spp.. While on an individual lot basis, testing one sample of 75 g for *Salmonella* spp. is not as sensitive as the current Codex sampling plan. Based on a contamination profile based on port of entry testing data for *Capsicum*.[3] The current Codex sampling plan applied to 100 percent of lots would remove (by lot rejection) 76 percent of the microbial contamination from the overall supply.

The expert meeting also examined the probability of detecting one *Salmonella* spp. in 1 000 g of product (Table 8). With the current Codex sampling plan (n = 10), there is a 79 percent chance of accepting a lot with an average level of contamination of one *Salmonella* cell per kilogram of product. In the case of 30 and 60 samples, this decreases to 48 percent and 23 percent, respectively. If we consider that typical serving sizes of spice or dried aromatic herb range from 0.2 g to 2.5 g per person per meal, and that a typical average serving size is 0.5 g per person, per meal, a spice lot with one *Salmonella* cell per kilo of spices would mean that one in every 2 000 servings will be contaminated. If we further assume, for simplicity of calculation, a 1 in 100 chance of illness as a result of exposure to one *Salmonella* spp., this equates to one illness for every 40 000 servings of spices consumed. Considering the use of the spice, i.e. whether it is consumed directly or added to a food that is subsequently cooked, this figure will in some cases be dramatically lower. Attributing illnesses to spice consumption is complicated because these commodities are only minor ingredients in foods, single lots can be dispersed to a large number of end users, and the shelf life of spices is such that ingredients from a single batch can be added to foods anytime over a year or more.

4.2 CONSIDERATION OF OTHER MICROBIOLOGICAL CRITERIA FOR SPICES AND DRIED AROMATIC HERBS

Apart from *Salmonella* spp., the expert meeting considered the value of establishing additional microbiological criteria for spices and dried aromatic herbs. Consideration was given to *B. cereus*, generic *Escherichia coli*, aerobic plate counts and *Enterobacteriaceae*. Further information about these microorganisms was considered to be potentially useful to risk managers in informing the safety of these products, as their presence and numbers could potentially be used to reflect the manner in which these commodities were produced or if they had been subjected to an adequate microbial inactivation treatment.

Based on the systematic review, *B. cereus* was the second most important bacterial pathogen associated with spices and dried aromatic herbs (FAO and WHO, 2022). While high levels of *B. cereus* can be found in spices and dried aromatic herbs, the distribution of contamination can be highly variable, and in some cases the organism may only be present in very low numbers. This variability suggested that *B. cereus* may not be the optimal indicator of overall product safety or, when detected in low numbers, as an indicator that a spice has been subjected to a validated microbial inactivation treatment. Nevertheless, considering the potential of this organism to grow and produce toxins when present in certain high moisture foods, it was considered important that the organism be present in low numbers in spices and dried aromatic herbs. Data available from one spice processer in Europe indicated, based on almost 7 000 samples of a range of spices[4] in the past year, that 93 percent of samples had *B. cereus* at levels ≤100 cfu/g and 99.8 of samples had levels ≤500 cfu/g (British Pepper and Spice Co. Ltd., personal communication, 2014).

Generic *E. coli*, aerobic plate counts or *Enterobacteriaceae* were also considered as possible indicators of process hygiene, particularly in the case of those commodities that are not typically subjected to pre-consumer microbial inactivation treatments (e.g. garlic and onions). One of the challenges of establishing microbial limits for these indicators is the need for a good understanding of the amounts present in spices and dried aromatic herbs before and after inactivation treatments. Very few of such data are available in the public domain; however, the industry indicated that they do collect such data, for both heat-treated spices and spices which cannot be heat treated. Data available from two spice processors in Europe indicated similar results, based on sampling a range of spices in the past year. One processer reported that 92 percent of samples[4] had ≤10 cfu/g coliforms (n = 5 747) and over 99 percent of samples had ≤10 cfu/g *E. coli* (n = 6 556) (British Pepper and Spice Co. Ltd., personal communication, 2014), with another processer reporting 91 percent of samples had ≤10 cfu/g coliforms (n = 10^3) and 100 percent of samples had ≤10 cfu/g *E. coli* (n = 10^4).[5]

With regard to aerobic plate counts, data from industry indicated 35 percent of 6 485 samples had ≤1 000 cfu/g, 36 percent of samples had 1 001–10 000 cfu/g and 27 percent of samples had 10 001–100 000 cfu/g. Data on total viable count at 30 °C indicated that 48 percent of samples (n = 98) had ≤100 cfu/g, 20 percent of samples had 101–1 000 cfu/g, 9 percent of samples had 1 001–10 000 cfu/g, 21 percent of samples had 10 001–100 000 cfu/g and 1 percent had 100 001–1 000 000 (Drogheria & Alimentari Spa, personal communication, 2014).

The expert meeting considered it could be useful to provide guidance on potential limits for one or more of these organisms as an indicator of either implementation of good practices or whether adequate inactivation treatment had been applied where appropriate. However, further consideration of the available data, as well as data from the broader spice and dried aromatic herb industry, was considered necessary before any specific guidance on potential limits could be provided.

---

4 Heat-treated cumin, heat-treated black pepper, heat-treated oregano, heat-treated basil, heat-treated turmeric, heat-treated ground nutmeg, whole nutmeg (not heat treated), garlic powder (not heat treated), onion powder (not heat treated), and cinnamon bark (not heat treated).

5 Treated oregano, treated black pepper, delicate-treated black pepper, treated chilli, and garlic (only heat treated during the production process).

5

Conclusions

The meeting took into consideration that under typical conditions of production and processing of spices and dried aromatic herbs, there is significant potential for contamination with a range of pathogens, including *Salmonella* spp.. With certain uses of spices, there also exists the potential for subsequent growth of these organisms to occur. Given the global nature of the spice and dried aromatic herb industry, and the diverse ways in which spices and dried aromatic herbs are produced, processed and used, it is difficult to characterize the risk associated with an individual spice or dried aromatic herb. Instead, the approach developed by the expert meeting included the identification of several production and processing practices which strongly influence the estimated level of contamination in spices and dried aromatic herbs. Then, the probability and severity of infection were incorporated in the ranking production and processing scenarios for a range of spices and dried aromatic herbs.

The expert meeting grouped spices and dried aromatic herbs into a series of categories based on plant parts reflecting similarities in production and processing. The ranking approach considered the microbial pathogens *Salmonella* spp., *B. cereus* and *C. perfringens,* the full range of production and processing practices that might affect the level of contamination, and a set of representative spices and dried aromatic herbs that illustrate the diversity of these commodities. The scenarios examined highlighted the importance of production and processing methods on potential contamination and growth of pathogens in spices and dried aromatic herbs. These scenarios also illustrate the importance of mitigation and control measures throughout the supply chain and demonstrate that while microbial inactivation treatments are critical, these treatments must be combined with other mitigations and controls as part of GHP, GMP and HACCP to ensure the safety of spices and dried aromatic herbs.

In considering microbiological criteria for spices, the meeting noted that the microbiological safety of food is principally achieved through the implementation of control measures throughout the production and processing chain. The performance of the existing Codex sampling plan for *Salmonella* was assessed against several contamination scenarios. While the sampling plan was seen to have some value when 100 percent of lots are tested, this value was dramatically reduced when only a small portion of lots are tested. The meeting recognized the value of having an indicator microbiological criterion which would reflect production and processing conditions to which a particular commodity had been exposed, but at the time of the meeting, there were insufficient data to propose either an appropriate indicator or threshold limits.

Despite the expectation that some inactivation is expected to occur during drying and storage, validated microbial reduction treatments are usually required for control of *Salmonella* spp. When used in conjunction with GHP, GMP, and HACCP, these treatments play a critical role in the safety of these products, particularly if spices and dried aromatic herbs are subsequently added to foods that would support the growth of pathogens.

References

Centers for Disease Control and Prevention (CDC). 2010. Salmonella Montevideo infections associated with salami products made with contaminated imported black pepper and red pepper – United States, July 2009-April 2010. *MMWR. Morbidity and Mortality Weekly Report, 59(50): 1647–1650.*

FAO & WHO. 2012. *Codex Alimentarius. Report of the forty-fourth session of the Codex Committee on Food Hygiene.* REP13/FH. Rome, FAO.

FAO & WHO. 2018. Codex Alimentarius. Code of hygienic practice for low-moisture foods. CXC75-2015. Rome, FAO. (also available at: https://www.fao.org/fao-who-codexalimentarius/sh-proxy/en/?lnk=1&url=https%253A%252F%252Fworkspace.fao.org%252Fsites%252Fcodex%252FStandards%252FCXC%2B75-2015%252FCXC_075e.pdf)

FAO & WHO. 2022. Ranking of low-moisture foods in support of microbiological risk management: meeting report and systematic review. *Microbiological Risk Assessment Series* No. 26. Rome, FAO.

Havelaar, A. H., Haagsma, J. A., Mangen, M. J., Kemmeren, J. M., Verhoef, L. P., Vijgen, S. M., Wilson, M., Friesema, I. H., Kortbeek, L. M., van Duynhoven, Y. T. & van Pelt, W. 2012. Disease burden of foodborne pathogens in the Netherlands, 2009. *International Journal of Food Microbiology*, 156(3), 231–238. https://doi.org/10.1016/j.ijfoodmicro.2012.03.029

Koch, J., Schrauder, A., Alpers, K., Werber, D., Frank, C., Prager, R., Rabsch, W., Broll, S., Feil, F., Roggentin, P., Bockemühl, J., Tschäpe, H., Ammon, A. & Stark, K 2005. *Salmonella* Agona Outbreak from Contaminated Aniseed, Germany. *Emerging Infectious Diseases,* 11(7): 1124–1127.

Laidley, R., Handzel, S., Servers, D. & Butler, R. 1974. *Salmonella weltevreden* outbreak associated with contaminated pepper. *Epidemiological Bulletin,* 18(4): 62.

Lehmacher, A., Bockemühl, J. & Aleksic, S. 1995. Nationwide outbreak of human salmonellosis in Germany due to contaminated paprika and paprika-powdered potato chips. *Epidemiology and Infection,* 115(3): 501–511.

Scallan, E., Hoekstra, R.M., Angulo, F.J., Tauxe, R.V., Widdowson, M.-A., Roy, S.L., Jones, J.L. & Griffin, P.M. 2011. Foodborne illness acquired in the United States – major pathogens. *Emerging infectious Diseases*, 17(1): 7–15. https://wwwnc.cdc.gov/eid/article/17/1/P1-1101_article

Sotir, M.J., Ewald, G., Kimura, A.C., Higa, J.I., Sheth, A., Troppy, S., Meyer, S., Hoekstra, R.M., Austin, J., Archer, J., Spayne, M., Daly, E.R. & Griffin, P.M. 2009. Outbreak of *Salmonella* Wandsworth and Typhimurium infections in infants and toddlers traced to a commercial vegetable-coated snack food. *The Pediatric Infectious Disease Journal*, 28(12): 1041–1046.

Teunis, P.F., Kasuga, F., Fazil, A., Ogden, I.D., Rotariu, O. & Strachan, N.J. 2010. Dose-response modeling of *Salmonella* using outbreak data. *International Journal of Food Microbiology*, 144(2): 243–249. https://doi.org/10.1016/j.ijfoodmicro.2010.09.026

Van Doren, J.M., Blodgett, R.J., Pouillot, R., Westerman, A., Kleinmeier, D., Ziobro, G.C., Ma, Y., Hammack, T.S., Gill, V., Muckenfuss, M.F. & Fabbri, L. 2013. Prevalence, level and distribution of *Salmonella* in shipments of imported capsicum and sesame seed spice offered for entry to the United States: Observations and modeling results. *Food Microbiology,* 36(2): 149–160.

Annexes

Annex 1

Characterization of spice production and processing factors influencing risk based on pathogenicity, severity, conditions and practices in the spice industry worldwide

Factor influencing risk	Categories within each factor characterizing the range production/ processing across all spices and dried aromatic herbs*	Considerations applied	Numerical score value		
			C. perfringens	*B. cereus*	*Salmonella* spp.
1. **Agricultural** contamination factor: level of contamination of the selected organism at harvest considering agriculture inputs and environmental factors but no inputs from human handling	Very highly contaminated	Spice source plant material is in direct contact with soil/ground; soil/ground may have been treated with soil amendments (e.g. turmeric)		3	
	Highly contaminated	Irrigated with water not fit-for-purpose, spice source plant material open to insects, domestic/wild animals (e.g. chilli/red pepper)		1	
	Moderately contaminated	Spice source plant material is not in close contact with the ground so that no contamination is expected from domestic or wild animals; plant provides natural protection from contamination from birds (e.g. black pepper)		-1	
	Lightly contaminated	Potential contamination arising from dust or contact with the ground when spice source plant material falls to the ground (e.g. cinnamon, nutmeg and mace [when pod splits])		-3	
	Effectively sterile	No contamination expected (e.g. saffron)		-6	

*Note: Not all categories are applicable to all spices or dried aromatic herbs.

(cont.)

Factor influencing risk	Categories within each factor characterizing the range production/ processing across all spices and dried aromatic herbs*	Considerations applied	Numerical score value		
			C. perfringens	*B. cereus*	*Salmonella* spp.
2. Handling: added contamination during collection and human handling before drying, e.g. from workers, storage and equipment use	Poorly controlled	Direct human contact with spice source plant (e.g. harvester collects by hand, not using gloves or other protection); product packed in used uncleaned bags/bins, reuse of animal feed bags, poor harvest management practices (e.g. chilli/red pepper, black pepper)	2	2	2
	Moderately controlled	Some GHP followed (e.g. clean, unused bags used for packing product), other controls not implemented	-1	-2	-1
	Well controlled	Human contact with product minimized, good storage conditions (clean warehouse), product packed in new bags	-4	-4	-4
	Fully controlled	GHP and additional preventive controls employed so stringently that potential for contamination is negligible (e.g. saffron)	-6	-7	-6
3a. Drying: addition of recontamination	On ground and no cover	Potential for contamination from soil, rain, domestic & wild animals, birds, insects, humans (e.g. many spices and dried aromatic herbs)	2	2	2
	Slightly raised and no cover (may have net)	Potential for contamination from rain, birds, insects; humans; some animal access possible (e.g. many spices)	-1	-2	-1
	Fully raised higher and no cover	Potential for contamination from rain, birds, insects (e.g. chilli/red pepper)	-3	-3	-2
	Fully raised and covered	Potential contamination from insects, e.g. drying in a greenhouse (i.e. chilli/red pepper)	-4	-4	-4
	Mechanically dried (low temperature >80 °C, multiple hrs)	No added contamination likely	-6	-6	-10
	Mechanically dried (high temperature >100 °C, not less than 1 h)	No added contamination likely	-7	-7	-10

*Note: Not all categories are applicable to all spices or dried aromatic herbs.

(cont.)

Factor influencing risk	Categories within each factor characterizing the range production/ processing across all spices and dried aromatic herbs*	Considerations applied	Numerical score value		
			C. perfringens	*B. cereus*	*Salmonella* spp.
3b. Drying: potential for microbial growth or inactivation	i) On ground and no cover	Less air moving past so humidity is higher; thus takes longer to dry, resulting in more potential for growth; also, potential for condensation at night	2	4	4
	ii) Slightly raised with no cover (may have net)	Growth during initial drying while sample still has high enough water activity	1	2	2
	iii) Fully raised higher off ground and no cover	Growth during initial drying while sample still has high enough water activity	1	2	2
	iv) Fully raised and covered	Growth during initial drying while sample still has high enough water activity	1	2	2
	Mechanically dried (low temperature >80 °C, multiple hrs)	Expect complete kill of *Salmonella*; no decrease in level of spores (e.g. dried aromatic herbs)	0	0	-20
	Mechanically dried (high temperature >100 °C, not less than 1 h)	Low humidity during drying, expect complete kill of *Salmonella* in this step; minor reductions of *B. cereus* or *C. perfringens*	-1	-1	-20
3c. Drying: evaporation, Included to account for concentration of the hazard as water evaporates and product loses weight. Evaporation ratios from European Spice Association (ESA)	1–15	Spice-specific dehydration factors describing increase in concentration of pathogen due to volume reduction (i.e. capsicum large factor, black pepper essentially no change in volume [factor = 1])	Spice-specific		

*Note: Not all categories are applicable to all spices or dried aromatic herbs.

(*cont.*)

Factor influencing risk	Categories within each factor characterizing the range production/ processing across all spices and dried aromatic herbs*	Considerations applied	Numerical score value		
			C. perfringens	*B. cereus*	*Salmonella* spp.
4a. Post-drying processes before treatment: growth during handling, storage and treatment	Uncontrolled growth	Extended periods of storage under poor storage practices where wetting of spice is likely (e.g. open piles of spice stored in areas where water or rain may wet the spice from leaky roof or poor drainage); high humidity (e.g. black pepper)	4	4	4
	Probable lapses in handling, storage and transport	Handling storage and transport conditions likely to lead to a situation in which pathogen growth is supported, such as cold storage where very humid (e.g. capsicum); inappropriate storage locations or conditions; raised humidity during transport or in storage	2	2	2
	Potential lapses in handling, storage and transport	Lapses in handling, storage and transport leading to growth are unexpected but possible	1	1	1
	Dry product stored <1 month	No significant lapses in handling storage and transport take place; spice stored for relatively short period; thus, only slight inactivation of pathogens expected	0	0	-1
	Dry product storage >1 month stored	No significant lapses in handling storage and transport take place; spice stored for long period; some inactivation of *Salmonella* may take place (e.g. 3–4 months max for capsicum, months to years for black pepper; a year for nutmeg in shell)	0	0	-2

*Note: Not all categories are applicable to all spices or dried aromatic herbs.

(*cont.*)

Factor influencing risk	Categories within each factor characterizing the range production/ processing across all spices and dried aromatic herbs*	Considerations applied	Numerical score value		
			C. perfringens	*B. cereus*	*Salmonella* spp.
4b. Post-drying processes before treatment: recontamination during handling/storage/ transport	Gross recontamination	New contamination added to spice through access of domestic and wild animals, rodents, humans, birds, or insects to spice, e.g. when spice is stored in pile on ground, in location that does not limit access (no doors on building) or in building with leaky roof	2		
	Possible recontamination	Recontamination during storage and transport possible but less likely because of application of GMP that limits access by domestic or wild animals or birds (e.g. raised storage in closed building, but human handling still takes place) (e.g. cinnamon)	-1		
	No recontamination	No recontamination is possible because spice is stored and transported in dry containers or bags that cannot be penetrated by water, animals, insects, or birds and which are not handled by humans.	-6		
5. Treatment	None	No microbial reduction treatment is applied.	0	0	0
	Moderate process, not validated	Steam wash – some reduction in pathogen levels is expected but insufficient time-temperature combination to eliminate pathogens; non-validated or controlled process	0	0	-2
	Validated process, delicate product – process designed to reduce Salmonella by 6 logs	Process designed to reduce *Salmonella* by 6 logs.	-1	0	-5
	Validated process, sporicidal – process designed to reduce spores by 5 logs	Process designed to reduce spores by 5 logs.	-5	-5	-15

*Note: Not all categories are applicable to all spices or dried aromatic herbs.

(cont.)

Factor influencing risk	Categories within each factor characterizing the range production/ processing across all spices and dried aromatic herbs*	Considerations applied	Numerical score value		
			C. perfringens	*B. cereus*	*Salmonella* spp.
6. Post-treatment	Gross recontamination	Recontamination through poor GMPs (e.g. access of domestic and wild animals, rodents, humans, birds, or insects to spice) (e.g. when spice is stored, transported or handled inappropriately)		1	
	Possible recontamination	Good GMP and HACCP, but some possible conditions/occasions when recontamination may take place (e.g. from dust)		-2	
	No recontamination	Processor applies GMP and HACCP, including primary *Salmonella* control area, to eliminate the potential for recontamination.		-7	
7. Food preparation and storage prior to eating: growth/inactivation during preparation/ storage	Potential for significant growth in food	Gross time-temperature abuse of spice-containing food leading to growth of pathogen in food supportive of growth	6	6	6
	Possible growth in food	Minor time-temperature abuse of spice-containing food leading to some pathogen growth	2	2	2
	No growth	No time-temperature abuse of spice containing food; uncooked spice added to food immediately before consumption so no time for growth	0	0	0
	Moderately cooking, no potential for growth	Cooking produces some heat inactivation of *Salmonella*; limited inactivation of spore-formers but not hot long enough for complete inactivation	-1	-1	-3
	Thorough cooking, no potential for growth	Cooking time and temperature leads to substantial reduction in *Salmonella* (complete kill or nearly so); some reduction in level of spore-formers achieved.	-2	-2	-6

*Note: Not all categories are applicable to all spices or dried aromatic herbs.

Annex 2

Risk ranking of the 129 scenarios

Factor influencing risk	Categories	CHILLI (whole and ground)				CINNAMON (stick and ground)				TURMERIC (whole)			
		Chilli PCNT	Chilli PCVST	Chilli WCVST	Chilli WCNT	Cinnamon PCNT	Cinnamon PCVDT	Cinnamon WCVDT	Cinnamon WCNT	TurmericW PCNT	TurmericW PCVST	TurmericW WCVST	TurmericW WCNT
1. Agricultural contamination factor	Very highly contaminated									X	X	X	X
	Highly contaminated	X	X	X	X								
	Moderately contaminated												
	Lightly contaminated					X	X	X	X				
	Effectively sterile												
2. Handling	Poorly controlled	X	X			X	X			X	X	X	X
	Moderately controlled												
	Well controlled			X	X			X	X				
	Fully controlled												
3a. Drying: addition of recontamination	On ground and no cover	X	X							X	X		
	Slightly raised and no cover (may have net)											X	X
	Fully raised higher and no cover					X	X						
	Fully raised and covered			X	X			X	X				
	Mechanically dried (low temperature >80 °C, multiple hrs)												
	Mechanically dried (high temperature >100 °C, not less than 1 h)												

(cont.)

Factor influencing risk	Categories	CHILLI (whole and ground)				CINNAMON (stick and ground)				TURMERIC (whole)			
		Chilli PCNT	Chilli PCVST	Chilli WCVST	Chilli WCNT	Cinnamon PCNT	Cinnamon PCVDT	Cinnamon WCVDT	Cinnamon WCNT	TurmericW PCNT	TurmericW PCVST	TurmericW WCVST	TurmericW WCNT
3b. Drying: potential for microbial growth or inactivation	i) On ground and no cover	X	X							X	X		
	ii) Slightly raised with no cover (may have net)											X	X
	iii) Fully raised higher off ground and no cover					X	X						
	iv) Fully raised and covered			X	X			X	X				
	Mechanically dried (low temperature >80 °C, multiple hrs)												
	Mechanically dried (high temperature >100 °C, not less than 1 h)												
3c. Drying: evaporation		10	10	10	10	1	1	1	1	3	3	3	3
4a. Post-drying: growth	Uncontrolled growth									X	X		
	Probable lapses in handling, storage and transport	X	X	X	X	X	X						
	Potential lapses in handling, storage and transport												
	Dry product stored <1 month												
	Dry product storage >1 month stored							X	X			X	X

(cont.)

Factor influencing risk	Categories	CHILLI (whole and ground)				CINNAMON (stick and ground)				TURMERIC (whole)			
		Chilli PCNT	Chilli PCVST	Chilli WCVST	Chilli WCNT	Cinnamon PCNT	Cinnamon PCVDT	Cinnamon WCVDT	Cinnamon WCNT	TurmericW PCNT	TurmericW PCVST	TurmericW WCVST	TurmericW WCNT
4b. Post-drying: recontamination	Gross recontamination												
	Possible recontamination	X	X			X	X			X	X		
	No recontamination			X	X			X	X			X	X
5. Treatment	None	X			X	X			X	X			X
	Moderate process, not validated												
	Validated process, delicate product - process designed to reduce Salmonella by 6 logs						X	X					
	Validated process, sporicidal – process designed to reduce spores by 5 logs		X	X							X	X	
6. Post-treatment	Gross recontamination	X	X										
	Possible recontamination					X			X	X	X	X	X
	No recontamination			X	X		X	X					
7. Food	Potential for significant growth in food												
	Possible growth in food	X	X	X	X	X	X	X	X				
	No growth												
	Moderately cooking, no potential for growth									X	X	X	X
	Thorough cooking, no potential for growth												

(cont.)

Factor influencing risk	Categories	TURMERIC (ground)				CUMIN (whole and ground)				BLACK PEPPER (whole and ground)					
		TurmericG PCNT	TurmericG PCVDT	TurmericG WCVDT	TurmericG WCNT	Cumin PCNT	Cumin PCVST	Cumin WCVST	Cumin WCNT	Black pepper PCNVT	Black pepper PCNT	Black pepper PCVST	Black pepper WCNVT	Black pepper WCVST	Black pepper WCNT
1. Agricultural contamination factor	Very highly contaminated	X	X	X	X										
	Highly contaminated					X	X	X	X						
	Moderately contaminated									X	X	X	X	X	X
	Lightly contaminated														
	Effectively sterile														
2. Handling	Poorly controlled	X	X	X	X	X	X			X	X	X			
	Moderately controlled														
	Well controlled							X	X				X	X	X
	Fully controlled														
3a. Drying: addition of recontamination	On ground and no cover	X	X			X	X			X	X	X			
	Slightly raised and no cover (may have net)			X	X										
	Fully raised higher and no cover							X	X				X	X	X
	Fully raised and covered														
	Mechanically dried (low temperature >80 °C, multiple hrs)														
	Mechanically dried (high temperature >100 °C, not less than 1 h)														

(cont.)

Factor influencing risk	Categories	TURMERIC (ground)				CUMIN (whole and ground)				BLACK PEPPER (whole and ground)					
		TurmericG PCNT	TurmericG PCVDT	TurmericG WCVDT	TurmericG WCNT	Cumin PCNT	Cumin PCVST	Cumin WCVST	Cumin WCNT	Black pepper PCNVT	Black pepper PCNT	Black pepper PCVST	Black pepper WCNVT	Black pepper WCVST	Black pepper WCNT
3b. Drying: potential for microbial growth or inactivation	i) On ground and no cover	X	X			X	X			X	X	X			
	ii) Slightly raised with no cover (may have net)			X	X										
	iii) Fully raised higher off ground and no cover							X	X				X	X	X
	iv) Fully raised and covered														
	Mechanically dried (low temperature >80 °C, multiple hrs)														
	Mechanically dried (high temperature >100 °C, not less than 1 h)														
3c. Drying: evaporation		3	3	3	3	1	1	1	1	1	1	1	1	1	1
4a. Post-drying: growth	Uncontrolled growth	X	X							X	X	X			
	Probable lapses in handling, storage and transport					X	X								
	Potential lapses in handling, storage and transport														
	Dry product stored <1 month														
	Dry product storage >1 month stored			X	X			X	X				X	X	X
4b. Post-drying: recontamination	Gross recontamination					X	X			X	X	X			
	Possible recontamination	X	X												
	No recontamination			X	X			X	X				X	X	X

(cont.)

Factor influencing risk	Categories	TURMERIC (ground)				CUMIN (whole and ground)				BLACK PEPPER (whole and ground)					
		TurmericG PCNT	TurmericG PCVDT	TurmericG WCVDT	TurmericG WCNT	Cumin PCNT	Cumin PCVST	Cumin WCVST	Cumin WCNT	Black pepper PCNVT	Black pepper PCNT	Black pepper PCVST	Black pepper WCNVT	Black pepper WCVST	Black pepper WCNT
5. Treatment	None	X			X	X			X		X				X
	Moderate process, not validated									X			X		
	Validated process, delicate product – process designed to reduce Salmonella by 6 logs		X	X											
	Validated process, sporicidal – process designed to reduce spores by 5 logs						X	X				X		X	
6. Post-treatment	Gross recontamination					X				X	X				
	Possible recontamination	X	X	X	X		X					X			
	No recontamination							X	X				X	X	X
7. Food	Potential for significant growth in food														
	Possible growth in food									X	X	X	X	X	X
	No growth														
	Moderately cooking, no potential for growth	X	X	X	X	X	X	X	X						
	Thorough cooking, no potential for growth														

(cont.)

Factor influencing risk	Categories	BASIL, Oregano				NUTMEG (whole and ground)				ROSEMARY (MOROCCO)				SAFFRON	BASIL			
		Oregano PCNT	Oregano PCVDT	Oregano WCVDT	Oregano WCNT	Nutmeg PCNT	Nutmeg PCVST	Nutmeg WCVST	Nutmeg WCNT	Rosemary PCNT	Rosemary PCVDT	Rosemary WCVDT	Rosemary WCNT	Saffron WCNVT	Basil PCNT	Basil PCVDT	Basil WCVDT	Basil WCNT
1. Agricultural contamination factor	Very highly	X	X	X	X													
	Highly																	
	Moderately									X	X	X	X		X	X	X	X
	Lightly					X	X	X	X									
	Effectively sterile													X				
2. Handling	Poorly controlled	X	X			X	X			X	X	X	X					
	Moderately controlled														X	X		
	Well controlled			X	X			X	X					X			X	X
	Fully controlled																	
3a. Drying: addition of recontamination	On ground and no cover	X	X			X	X			X	X	X	X		X	X		
	Slightly raised and no cover (may have net)																	
	Fully raised higher and no cover							X	X									
	Fully raised and covered																	
	Mechanically dried (low temperature >80 °C, multiple hrs)			X	X									X			X	X
	Mechanically dried (high temperature >100 °C, not less than 1 h)																	

(cont.)

Factor influencing risk	Categories	BASIL, Oregano				NUTMEG (whole and ground)				ROSEMARY (MOROCCO)				SAFFRON	BASIL			
		Oregano PCNT	Oregano PCVDT	Oregano WCVDT	Oregano WCNT	Nutmeg PCNT	Nutmeg PCVST	Nutmeg WCVST	Nutmeg WCNT	Rosemary PCNT	Rosemary PCVDT	Rosemary WCVDT	Rosemary WCNT	Saffron WCNVT	Basil PCNT	Basil PCVDT	Basil WCVDT	Basil WCNT
3b. Drying: potential for microbial growth or inactivation	i) On ground and no cover	X	X			X	X			X	X	X	X		X	X		
	ii) Slightly raised with no cover (may have net)																	
	iii) Fully raised higher off ground and no cover							X	X									
	iv) Fully raised and covered																	
	Mechanically dried (low temperature >80 °C, multiple hrs)			X	X									X			X	X
	Mechanically dried (high temperature >100 °C, not less than 1 h)																	
3c. Drying: evaporation		7	7	7	7	1	1	1	1	7	7	7	7	1	6	6	6	6

(cont.)

Factor influencing risk	Categories	BASIL, Oregano				NUTMEG (whole and ground)				ROSEMARY (MOROCCO)				SAFFRON	BASIL			
		Oregano PCNT	Oregano PCVDT	Oregano WCVDT	Oregano WCNT	Nutmeg PCNT	Nutmeg PCVST	Nutmeg WCVST	Nutmeg WCNT	Rosemary PCNT	Rosemary PCVDT	Rosemary WCVDT	Rosemary WCNT	Saffron WCNVT	Basil PCNT	Basil PCVDT	Basil WCVDT	Basil WCNT
4a. Post-drying: growth	Uncontrolled growth									X	X							
	Probable lapses in handling, storage and transport					X	X											
	Potential lapses in handling, storage and transport	X	X												X	X		
	Dry product stored <1 month																	
	Dry product storage >1 month stored			X	X			X	X			X	X	X			X	X
4b. Post-drying: recontamination	Gross					X	X											
	Possible	X	X							X	X			X	X	X		
	No			X	X			X	X			X	X				X	X

(cont.)

Factor influencing risk	Categories	BASIL, Oregano				NUTMEG (whole and ground)				ROSEMARY (MOROCCO)				SAFFRON	BASIL			
		Oregano PCNT	Oregano PCVDT	Oregano WCVDT	Oregano WCNT	Nutmeg PCNT	Nutmeg PCVST	Nutmeg WCVST	Nutmeg WCNT	Rosemary PCNT	Rosemary PCVDT	Rosemary WCVDT	Rosemary WCNT	Saffron WCNVT	Basil PCNT	Basil PCVDT	Basil WCVDT	Basil WCNT
5. Treatment	None	X			X	X			X	X			X		X			X
	Moderate process, not validated													X				
	Validated process, delicate product – process designed to reduce Salmonella by 6 logs		X	X							X	X				X	X	
	Validated process, sporicidal – process designed to reduce spores by 5 logs						X	X										
6. Post-treatment	Gross									X			X					
	Possible	X	X			X	X							X	X	X		
	No			X	X			X	X		X	X					X	X
7. Food	Potential for significant growth in food																	
	Possible growth in food	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X
	No growth																	
	Moderately cooking, no potential for growth																	
	Thorough cooking, no potential for growth													X				

Annex 3

Full list of a total of 129 scenarios and the ranking result

Table 5 shows the code of the symbols.

	CP	BC	SA
Chilli PCNT	-1.45	-0.64	7.09
Chilli PCVST	-6.41	-4.6	0.09
Chilli WCVST	-8.49	-7.64	-7.91
Chilli WCNT	-3.49	-2.64	5.09
Cinnamon PCNT	-3.49	-2.64	5.09
Cinnamon PCVDT	-4.49	-2.64	0.09
Cinnamon WCVDT	-11.45	-9.6	-7.86
Cinnamon WCNT	-10.17	-9.56	-2.86
TurmericW PCNT	-2.02	-2.16	3.57
TurmericW PCVST	-7.02	-7.16	-7.91
TurmericW WCVST	-11.96	-11.12	-7.91
TurmericW WCNT	-6.98	-6.12	-2.39
TurmericG PCNT	-2.02	-2.16	3.57
TurmericG PCVDT	-3.02	-2.16	-1.43
TurmericG WCVDT	-7.98	-6.12	-7.28
TurmericG WCNT	-6.98	-6.12	-2.39
Cumin PCNT	-5.45	-3.6	2.13
Cumin PCVST	-10.45	-8.6	-7.91
Cumin WCVST	-14.49	-13.64	-12.91
Cumin WCNT	-9.49	-8.64	-4.91
Black pepper PCNVT	-1.49	-1.64	6.09
Black pepper PCNT	-1.49	-1.64	6.09

(cont.)

	CP	BC	SA
Black pepper PCVST	-5.49	-4.64	-2.91
Black pepper WCNVT	-8.49	-7.64	-3.91
Black pepper WCVST	-13.49	-12.64	-7.91
Black pepper WCNT	-8.49	-7.64	-1.91
Oregano PCNT	-1.61	-0.79	6.94
Oregano PCVDT	-2.61	-0.79	2.98
Oregano WCVDT	-5.65	-4.79	-7.91
Oregano WCNT	-4.65	-4.79	-6.87
Nutmeg PCNT	-2.49	-1.64	6.09
Nutmeg PCVST	-7.49	-5.64	-2.91
Nutmeg WCVST	-15.15	-14.56	-7.91
Nutmeg WCNT	-10.42	-9.59	-3.83
Rosemary PCNT	-0.65	-0.79	6.94
Rosemary PCVDT	-0.65	-0.79	3.94
Rosemary WCVDT	-4.65	-1.79	-1.06
Rosemary WCNT	-3.64	-1.79	3.94
Saffron WCNVT	-13.45	-13.6	-10.87
Basil PCNT	-4.64	-3.78	4.19
Basil PCVDT	-5.64	-3.78	-0.81
Basil WCVDT	-9.72	-8.86	-7.91
Basil WCNT	-8.72	-8.86	-6.87

FAO/WHO Microbiological Risk Assessment Series

1 Risk assessments of *Salmonella* in eggs and broiler chickens: Interpretative Summary, 2002

2 Risk assessments of *Salmonella* in eggs and broiler chickens, 2002

3 Hazard characterization for pathogens in food and water: Guidelines, 2003

4 Risk assessment of *Listeria monocytogenes* in ready-to-eat foods: Interpretative Summary, 2004

5 Risk assessment of *Listeria monocytogenes* in ready-to-eat foods: Technical Report, 2004

6 *Enterobacter sakazakii* and microorganisms in powdered infant formula: Meeting Report, 2004

7 Exposure assessment of microbiological hazards in food: Guidelines, 2008

8 Risk assessment of *Vibrio vulnificus* in raw oysters: Interpretative Summary and Technical Report, 2005

9 Risk assessment of choleragenic *Vibrio cholerae* 01 and 0139 in warm-water shrimp in international trade: Interpretative Summary and Technical Report, 2005

10 *Enterobacter sakazakii* and *Salmonella* in powdered infant formula: Meeting Report, 2006

11 Risk assessment of *Campylobacter* spp. in broiler chickens: Interpretative Summary, 2008

12 Risk assessment of *Campylobacter* spp. in broiler chickens: Technical Report, 2008

13 Viruses in food: Scientific Advice to Support Risk Management Activities: Meeting Report, 2008

14 Microbiological hazards in fresh leafy vegetables and herbs: Meeting Report, 2008

15 *Enterobacter sakazakii* (*Cronobacter* spp.) in powdered follow-up formula: Meeting Report, 2008

16 Risk assessment of *Vibrio parahaemolyticus* in seafood: Interpretative Summary and Technical Report, 2011

17 Risk characterization of microbiological hazards in food: Guidelines, 2009.

18 Enterohaemorrhagic *Escherichia coli* in raw beef and beef products: approaches for the provision of scientific advice: Meeting Report, 2010

19 *Salmonella* and *Campylobacter* in chicken meat: Meeting Report, 2009

20 Risk assessment tools for *Vibrio parahaemolyticus* and *Vibrio vulnificus* associated with seafood: Meeting Report, 2020

21 *Salmonella* spp. in bivalve molluscs: Risk Assessment and Meeting Report, In press

22 Selection and application of methods for the detection and enumeration of human pathogenic halophilic *Vibrio* spp. in seafood: Guidance, 2016

23 Multicriteria-based ranking for risk management of food-borne parasites, 2014

24 Statistical aspects of microbiological criteria related to foods: A risk managers guide, 2016

25 Risk-based examples and approach for control of *Trichinella* spp. and *Taenia saginata* in meat: Meeting Report, 2020

26 Ranking of low moisture foods in support of microbiological risk management: Meeting Report and Systematic Review, 2022

27 Microbiological hazards in spices and dried aromatic herbs: Meeting Report, 2022

28 Microbial safety of lipid based ready-to-use foods for management of moderate acute malnutrition and severe acute malnutrition: First meeting report, 2016

29 Microbial safety of lipid based ready-to-use foods for management of moderate acute malnutrition and severe acute malnutrition: Second meeting report, 2021

30 Interventions for the control of non-typhoidal *Salmonella* spp. in Beef and Pork: Meeting Report and Systematic Review, 2016

31 Shiga toxin-producing *Escherichia coli* (STEC) and food: attribution, characterization, and monitoring, 2018

32 Attributing illness caused by Shiga toxin-producing *Escherichia coli* (STEC) to specific foods, 2019

33 Safety and quality of water used in food production and processing, 2019

34 Foodborne antimicrobial resistance: Role of the environment, crops and biocides, 2019.

35 Advance in science and risk assessment tools for *Vibrio parahaemolyticus* and *V. vulnificus* associated with seafood: Meeting report, 2021.

36 Microbiological risk assessment guidance for food: Guidance, 2021

37 Safety and quality of water used with fresh fruits and vegetables, 2021

Microbiological Risk Assessment Series

Spices and dried aromatic herbs impart flavour when added to food, and they may include many parts of the plant, including berries, flowers, leaves, roots and seeds. A number of different pathogens have been found in spices on the market, especially *Salmonella* spp., *B. cereus* and *C. perfringens*. There have also been several disease outbreaks associated with spices and dried aromatic herbs. An increased concern and attention to the safety of spices and dried aromatic herbs prompted, the Codex Committee on Food Hygiene (CCFH) to request FAO and WHO to undertake a risk assessment on microbiological hazards in these food commodities.

An expert meeting of the FAO/WHO Joint Expert Meeting on Microbiological Risk Assessment (JEMRA) considered the global evidence on the burden of illness, prevalence and concentration of selected microbial hazards with respect to various spices and dried aromatic herbs, and interventions aimed at controlling them in these commodities. The experts developed the approach to rank the health risks related to the commodity-pathogen combinations, and assessed the performance of the existing Codex sampling plan for *Salmonella* against several contamination scenarios.

Food Systems and Food Safety - Economic and Social Development
jemra@fao.org
http://www.fao.org/food-safety
Food and Agriculture Organization of the United Nations
Viale delle Terme di Caracalla
00153 Rome, Italy

Department of Nutrition and Food Safety
jemra@who.int
https://www.who.int/health-topics/food-safety/
World Health Organization
20 Avenue Appia 1211 Geneva 27,
Switzerland

ISBN 978-92-5-135792-7 ISSN 1726-5274
9 789251 357927
CB8686EN/1/02.22