Food Control 44 (2014) 92–109

Contents lists available at ScienceDirect

Food Control

journal homepage: www.elsevier.com/locate/foodcont

Review

Persistence of foodborne pathogens and their control in primary and secondary food production chains

Marianne Halberg Larsen [a], Marion Dalmasso [b], Hanne Ingmer [a], Solveig Langsrud [c], Mindaugas Malakauskas [d], Anneluise Mader [e], Trond Møretrø [c], Sonja Smole Možina [f], Kathrin Rychli [g], Martin Wagner [g], R. John Wallace [h], Jurgen Zentek [e], Kieran Jordan [b,*]

[a] Department of Veterinary Disease Biology, University of Copenhagen, Denmark
[b] Teagasc Food Research Centre, Moorepark, Fermoy, Co. Cork, Ireland
[c] Nofima, The Norwegian Institute of Food, Fisheries and Aquaculture Research, Aas, Norway
[d] Veterinary Academy, Lithuanian University of Health Sciences, Kaunas, Lithuania
[e] Institute of Animal Nutrition, Freie Universität Berlin, Germany
[f] Department of Food Science and Technology, Biotechnical Faculty, University of Ljubljana, Slovenia
[g] Institute for Milk Hygiene, Milk Technology and Food Science, University of Veterinary Medicine Vienna, Austria
[h] Rowett Institute of Nutrition and Health, University of Aberdeen, Bucksburn, UK

ARTICLE INFO

Article history:
Received 14 June 2013
Received in revised form
19 March 2014
Accepted 25 March 2014
Available online 3 April 2014

Keywords:
Foodborne pathogen
Persistence
Control
Escherichia coli
Listeria monocytogenes
Salmonella

ABSTRACT

This review highlights factors involved in the persistence of foodborne pathogens in selected food chains and covers aspects of the basis for persistence, the consequences of persistence in terms of food safety implications, and the strategies that can be employed to combat persistence. The examples selected are *Escherichia coli* O157 and *Salmonella* at primary production of cattle and pigs, respectively, *Listeria monocytogenes* and *Cronobacter* spp. at secondary production, while persistence of *Campylobacter* spp. represents both primary and secondary production.

Contents

* Corresponding author. Tel.: +353 2542451; fax: +353 2542340.
E-mail address: kieran.jordan@teagasc.ie (K. Jordan).

http://dx.doi.org/10.1016/j.foodcont.2014.03.039
0956-7135/

1. Introduction to persistence in the food chain

In recent years, the awareness of the persistence of foodborne pathogens in primary and secondary food processing environments has attracted much scientific interest in microbiology. Persistence means that particular types of microorganisms survive for prolonged periods of time in certain habitats. Persistence of a pathogen relies on many factors, such as the physical and microbial natural habitat, transmission routes and genetic determinants (Fig. 1). Persistence can cause repeated food contamination, and an increasing risk of food safety violation, thus impacting on public health (Pricope, Nicolau, Wagner, & Rychli, 2013). Persistence always refers to a particular matrix or environment, either soil, feed, animals, farm production environments, food processing environments or food itself. If looking to transmission of food-borne pathogens, one may easily understand that pathogens travel through a sequence of ecological niches before they pose a threat to humans. A very simple example is *Listeria monocytogenes* that is believed to be ubiquitously spread in nature, and can colonize food processing environments through inappropriate or inadequate hygiene, from where it can contaminate food and finally infect humans who have been exposed to contaminated food (Khelef et al., 2006). Thus, scientific disciplines such as microbial ecologists and food microbiologists should work together in a multidisciplinary approach to address the issue.

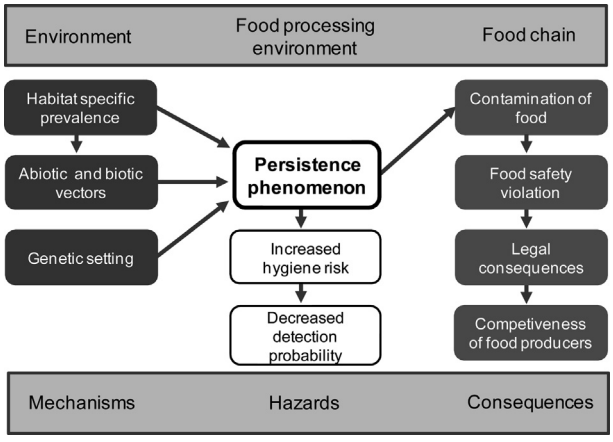

Fig. 1. Elements of persistence and the food safety consequences.

Most microbial communities are highly complex and subject to reorganisation. That some microbial communities are more stable than others implies that exposure to stress and reorganisation can lead to a more resistant population. Even under very harsh conditions, such as in the animal stomach or during high heat treatments, a surviving microbiota exists that may proliferate and pose new hazards. In contrast, some environments such as the animal intestine may be carriers of human pathogens, although they are not pathogenic to the carriers (Naylor et al., 2003). Such zoonotic strains include verocytotoxigenic *Escherichia coli* or shigatoxin producing *Escherichia coli* (VTEC or STEC, in this review we used VTEC) in cattle and *Campylobacter* in chickens. Understanding factors that foster creation of stable microbial communities will allow manipulation of these factors. With respect to environmental contaminants, the goal should be to understand persistence and therefore enable the development of a stable commensal microbiota not inducing persistence of pathogens, rather than placing an over-emphasis on sanitisation.

For the purposes of this review, persistence will be defined broadly and differently at primary and secondary production. At primary production, colonization of the animal is in this review perceived as persistence as it may result in shedding of the same strain of for example *E. coli* O157:H7 from cattle for weeks or months, or repeated isolation of the same *Salmonella* strain from pigs. In addition, bacterial isolates may persist in the farm environment such as in the stable or the feed. At secondary production in the processing environment, persistence of bacterial strains refers to repeated isolation of the same strain for months or even years at the same sites (Unnerstad et al., 1996).

For the purposes of understanding the basis of persistence, it is usual to compare the behaviour and properties of persistent (also called permanent or resident) and non-persistent strains. In order to do this, the term non-persistent needs to be defined. This is more difficult as failure to isolate a strain may be due to a sampling issue