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Smoked salmon industry practices and their association with *Listeria monocytogenes*

Ovidiu Rotariu [a,*], D. John I. Thomas [b], Kaarin E. Goodburn [c], Michael L. Hutchison [b], Norval J.C. Strachan [a]

[a] School of Natural and Computing Sciences, University of Aberdeen IBES, St. Machar Drive, Cruickshank Bd., Aberdeen AB24 3UU, UK
[b] Hutchison Scientific Ltd, Wolverhampton Science Park, Glaisher Drive, Wolverhampton WV10 9RU, UK
[c] Chilled Food Associates, Poplars Farm Road, Barton Seagrave, Kettering NN15 5AF, UK

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ABSTRACT

This study was conducted to analyse the current practices used by the Scottish smoked salmon industry that will affect the likelihood of *Listeria monocytogenes* contamination in products. Sixteen visits to smoked salmon premises were conducted between June and November 2011, interviews were carried out based on a questionnaire. The results indicate that most processors carry out appropriate food safety practices, but some improvements are needed in order to minimize the risk of *Listeria* contamination. It was found that the larger processors achieved better temperature control than the smaller processors. Approximately half of the visited premises needed to improve their refrigerated storage. The risk of ceiling condensation dripping onto product was a common problem, but the smaller premises were the most affected. Small food business operators require additional information on how cleaning and sanitation throughout the process can reduce contamination of the final product. Furthermore, guidance describing the best way of determining shelf life was requested by small processors. Fifty six percent of the smoked salmon processors (mostly large and medium size) tested the product for *L. monocytogenes* and prevalence ranged widely (0–12%) between processors. Those processors having the highest *Listeria* prevalence were also those most concerned about what microbiological testing should be carried out and how to evaluate the quality of their products. Most processors rarely exceeded (i.e. once every several years) the statutory limit set by the European Union (>100 cfu/g or presence in 25 g). The small producers did not undertake product testing for *Listeria* because of high test costs and lack of technical expertise. Hence, it was concluded that sharing expertise between producers, especially to smaller processors would be beneficial in terms of consumer protection.

1. Introduction

The farmed salmon industry is important economically for a number of countries worldwide. It has been estimated that approximately 60% (2 mil. tonnes/year) of salmon production is farm-cultured with Norway as the main producer (53%). However Chile (23%) and Scotland (10%) also farm significant quantities of salmon (Anon, 2010a, pp. 1–72). In the EU, over 60% of salmon is sold fresh and smoked salmon (cold or hot) comprises > 30% of the processed product market (Anon, 2010a, pp. 1–72). The Scottish farmed salmon industry is worth >£500 million/year, supports >8500 jobs (http://www.scottishsalmon.co.uk/), and exports to more than 60 countries with key markets in the EU, the USA and the near and far east. Cold smoked salmon is a raw ready to eat food, in contrast with most meat products which are cooked prior to consumption. Cold smoked salmon can therefore pose a risk to human health if it is contaminated with pathogens along the food chain (Garrido, Torroba, Garcia-Jalon & Vitas, 2008).

Listeria monocytogenes (*L. monocytogenes*) can be an invasive gastrointestinal human pathogen (Lorber, 1997) capable of causing serious illness, with a high mortality rate (20–30% of total cases) in vulnerable groups such as pregnant women and the elderly (Bennion, Sorvillo, Wise, Krishna & Mascola, 2008). In the period between 2005 and 2008 sixteen outbreaks involving *L. monocytogenes* in ready to eat foods (deli meats, ham, dairy products, fish etc.), were reported in several EU countries and the USA (Todd & Notermans, 2011). Also, several listeriosis outbreaks have been associated with smoked fish, including cold smoked

* Corresponding author. Tel.: +44 (0)1224272700.
E-mail address: ovidiu.rotariu@abdn.ac.uk (O. Rotariu).

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rainbow trout (Ericsson et al., 1997; Miettinen et al., 1999) and cold smoked salmon (Garrido et al., 2008).

In common with a number of ready to eat food sectors, the smoked salmon industry has historically had issues with *Listeria* contamination of products. Previous studies (Farber, 1991; Jemmi & Keusch, 1992; Meloni et al., 2009; Miya, Takahashi, Ishikawa, Fujii & Kimura, 2010; Rorvik, Yndestad & Skjerve, 1991; Wagner, Auer, Trittremmel, Hein & Schoder, 2007) indicate that *Listeria* can be present in the cold smoked product with prevalence up to 39.4% (Hudson, Mott, Delacy & Edridge, 1992). Several research groups (Embarek, Jeppesen & Huss, 1994; Garrido, Vitas & Garcia-Jalon, 2009; Medrala et al., 2003; Vitas & Garcia-Jalon, 2004) report that the manufacture of smoked salmon is complex and that the contamination can originate from several sources along the production chain (e.g. from the fish farm, primary processing plants and smoke houses). Therefore, understanding both the process of contamination and identification of potential *Listeria* niches within the factory are a prerequisite for designing successful plans to reduce the pathogen burden.

Listeria has an optimum growth temperature of 30–37 °C, but can survive between 1 and 45 °C, and is capable of psychrotrophic growth at refrigeration temperatures (Farber, 2000). During the production of smoked fish, temperature is one of many key influences that affect the growth and inactivation of *Listeria*. For example challenge tests have demonstrated that smoking at temperatures from 17.1 to 21.1 °C using smoke containing some phenolic components can eliminate *L. monocytogenes*, whilst smoking at 22.2–30 °C using a different smoke composition makes no significant impact to populations of *Listeria* (Rorvik, 2000). The temperatures and conditions required to denature fish protein during hot smoking are generally sufficient to cause the complete kill of *L. monocytogenes* present on the surface of the fish (Jemmi & Keusch, 1992; Poysky et al., 1997) but this is not applicable to cold smoked salmon.

The hygiene regime and the cleaning and sanitation practices applied during smoked salmon production represent key factors in reducing the *Listeria* burden in smoked products (Jorgensen & Huss, 1998). It was shown (Johansson, Rantala, Palmu & Honkanen-Buzalski, 1999) that the same serotypes of *L. monocytogenes* found in the smoked fish products were also isolated from the plant drains, the skinning and salting equipment, conveyor belts and the packing machinery. The authors concluded that difficulties in cleaning and sanitising effectively without disassembling the salting and slicing equipment was the main reason for the contamination. Another study (Autio et al., 1999) concluded that plant-environment strains of *L. monocytogenes* represented important sources of contamination for the smoked products and demonstrated that effective decontamination of the plant environment could be achieved using hot (80 °C) water, steam and hot (80 °C) air ovens.

Although there is evidence that smoking plant employees can act as fomites for *L. monocytogenes* (Tompkin, Scott, Bernard, Sveum & Gombas, 1999) the plant environment is widely considered as an ideal niche for the multiplication of *L. monocytogenes* particularly if biofilms can be formed in areas such as drains and poorly-designed equipment which are difficult to clean and sanitise (Gram, 2001).

The main objective of this study was to gather, analyse and critically present information on the current practices used by the Smoked Salmon Operators (SSOs) in Scotland with particular emphasis on previously identified risk factors reported for *L. monocytogenes* and smoked fish. This objective was achieved by conducting factory visits.

Table 1
Visits and interviews with smoked salmon plants ($n = 16$) stratified by the smoking process and number of employees.

Type of smoking	Number of plants	Plant type		
		Small*	Medium**	Large***
Cold only	6	1	2	3
Hot only	1	1	–	–
Cold and hot	9	2	4	3

*<5 employees; **5 to 25 employees; ***>25 employees.

2. Material and methods

A survey, comprising completion of a questionnaire during factory visits, was conducted in sixteen Scottish SSOs between June and November 2011. The recruitment of plants ($n = 71$) to the study was by letter or e-mail and contact details were obtained from the Food Scotland database (http://www.seafoodscotland.org). Initially agreement was obtained from 28 (39%) plants which processed various fish species, and the 16 (22.5%) producing salmon were selected for this study. The SSOs were located in Mainland Scotland ($n = 13$) and the Shetland Isles ($n = 3$). Table 1 presents the classification of the visits by the type of smoking and size of factory. All of the salmon processed in these plants were of Scottish origin at the time of visit. However, it could be possible for a smoke house to import salmon if there was a shortage of local supply.

Factory visits (lasting 0.5–1.5 h) comprised face-to-face discussions with plant managers and were conducted under normal processing conditions in order to observe routine practices and to identify potential *Listeria* contamination routes and reservoirs across the production and processing chains. A questionnaire comprising 105 questions (Annex A-supplementary material) was developed through two initial factory visits and using previous experience. The questionnaire structure was designed based on the flow of the processing line in the smoking premises (Fig.1). This was how the managers described and showed the factory. The questions focused on: the details of the company (i.e. infrastructure, processing practices and hygiene), the application of food safety standards related to microbiological contamination (with emphasis on *Listeria*), the shelf life of the product and the availability of guidance information to tackle the *Listeria* problem. Questions referring to microbiological testing were formulated to comply with EC Microbiological Criteria for Food stuffs Regulation (Regulation EC 2073/2005 and Regulation EC 1441/2007). Although regulations relating to the hygiene of foodstuffs exist (e.g. Regulations EC 852/2004 and EC 853/2004) they were not considered in this study, as they are not specifically tailored to the production of smoked fish. Instead, hygienic practices for the effective control of *Listeria* in the production of cold smoked salmon, developed by Scottish Salmon Producers Organisation (SSPO) and Salmon Processors and Smokers Group (SPSG), were used (Goodburn, 2008; personal communication). The majority of questions were answered from a list of prepared response options and best practices answers to the questions were included (see Annex A-supplementary material and Tables 2–5). Where available ($n = 6$) the prevalence of *Listeria* in raw or final product was obtained. Three processors' products were tested only by Environmental Health Officers (EHO) and their results were not available. Before starting the discussion the plant managers were familiarised with the purpose of the study and were assured that the data they supplied would be anonymised.

The most pertinent questionnaire data (answers to 62 questions) were collated into Excel 2007 (Microsoft Plc, Redmond WA) covering four main themes: (1) plant infrastructure, (2) temperature control, (3) hygiene, cleaning and sanitation, (4) microbiological/*Listeria* testing, product characteristics (quality), shelf life and product traceability and awareness of regulations (Fig.1). If a