



A risk based sampling design including exposure assessment linked to disease burden, uncertainty and costs



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ABSTRACT

A methodology is presented to optimize a sampling plan for retail products to monitor the prevalence of foodborne pathogens in relation to disease burden. The optimization procedure links an exposure assessment, a quantitative measure for disease burden (i.e. Disability Adjusted Life Years), number of samples to be analyzed (based on uncertainty of the prevalence estimate) and costs for sample analysis. The methodology attributes DALY's on 'pathogen-matrix level' to 'pathogen-food products' using the exposure assessment. The subsequent procedure includes the number of samples that need to be analyzed per retail product such that the prevalences can be monitored within a preset uncertainty bound, and the costs per sample. The final optimization step sorts pathogen-product combinations using the costs per DALY criterion which results in a monitoring program with a maximum number of DALY's given a certain amount of money. An optimized sampling plan was established for four foodborne pathogens on meat products: *Campylobacter* in pork and poultry meat, *Salmonella* in pork, *Toxoplasma* in pork and Shiga-toxin producing *Escherichia coli* (STEC) O157 in beef, veal, and mutton/lamb. Results show that *Campylobacter* on poultry products and one *Toxoplasma* – pork combination constitute the top 10 in the proposed Dutch public health risk meat monitoring program. This optimized sampling plan monitors 98% of the total amount of DALY's attributed to the considered pathogen-animal species combinations. At the same time, the procedure gives insight in how the preset optimization criteria leads to the proposed set of pathogen-product combinations. An iterative implementation of updated model input (prevalences, DALY estimates) will lead to an up-to-date optimized risk based monitoring program.

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1. Introduction

Supply chain management is the basis to govern food safety and to prevent foodborne outbreaks in the ever increasing complexity of the (inter)national food chain. An appropriate test system is required to support stakeholders in their decision-making regarding safety measures in the food supply chain. A "risk based sampling plan" is a crucial component of this test system with the ultimate goal to take the right measures at the right time and the right place in the food supply chain in order to prevent food borne disease. Yet, the term "risk based" can be, and has been, interpreted in many different ways depending on, for example, the manager and scientists involved, data and time availability and public health status of the population concerned. This has resulted in different

"risk based sampling plan" approaches in several EU and non-EU member states. These approaches have been published, e.g. by Lee, Herrman, and Dai (2016) who derive a sampling plan to monitor chemical and microbial violation rates of feed products, by Lahou, Jacxsens, Van Landeghem, and Uyttendaele (2014) who implemented a microbial sampling plan to improve the food safety management system in an institutional food service operation, and, by Farkas et al. (2014) who designed an early warning self-control plan for the detection of aflatoxin contamination at the farm level. Furthermore, knowledge has been shared during workshops, e.g. a Risk Based Sampling workshop at a conference of the International Association on Food Protection in Athens in 2016, and, the European Food Safety Authority published a technical specification on harmonized monitoring (EFSA, 2012).

The objective of this paper is to present a methodology for risk based sampling that includes an optimization procedure to monitor the prevalence of foodborne pathogens at retail level in relation to their burden of disease. The methodology distinguishes pathogen-

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product combinations based on an exposure assessment (starting from pre-retail processing up until food preparation inclusive), uncertainty in the prevalence estimate at retail and available monitoring budget. The procedure is explained using pathogen/product combinations that are relevant for The Netherlands, that is: *Campylobacter*, *Salmonella*, *Toxoplasma* and *Escherichia coli* (STEC) O157 on different meat products. Yet, the procedure is applicable for any country by changing the input parameters.

The monitoring program includes those pathogen/product combinations that will capture as many Disability Adjusted Life Years (DALY's) as possible given a certain amount of money. The DALY (Havelaar et al., 2012) is a consistent, quantitative measure to compare the disease burden of different foodborne pathogens and, as such, good to inform risk based sampling. The DALY measures disease burden as the number of life years lost due to ill-health, disability or early death. Other health metrics as QALY (Quality Adjusted Life Years) and Cost-of-illness are also valid metrics but the DALY is often used in (European) foodborne disease burden studies (Havelaar et al., 2015) and therefore our preferred metric.

A risk based sampling plan will help stakeholders to monitor the prevalence of the most important pathogen/product combinations from a public health risk perspective in a consistent manner (e.g. by trend analysis) and, with that, give input for targeted intervention programs.

2. Materials and methods

2.1. Methodology

Estimating food related microbiological public health risks involves knowledge about different variables. First, prevalence and concentration data of specific pathogens in specific food products and consumption patterns are of importance. These types of data are available from food safety authority monitoring programs and food consumption surveys. Next, pre-retail treatment and food handling by consumers are important aspects for the ultimate risk. Another aspect is accounting for the uncertainty about the final prevalence estimate, as this is the variable that is monitored to get insight in the microbial status of food products. Finally, there is limited budget available and fixed costs per sample analysis.

This results in the following procedure to obtain an optimizing criterion for risk based sampling (Fig. 1):

- Exposure assessment for a certain pathogen/product combination depending on the pathogen prevalence and concentrations in that product at time of purchase, the consumed amount and food preparation style,
- Linking exposure of pathogen/product combinations (from A.) to pathogen/animal species (via food) DALYs, i.e. exposure is assumed to be proportional to disease burden,
- The number of samples needed for each product based on baseline prevalence knowledge at retail,
- Costs per sample (personnel, analysis and administration).

The optimizing criterion is

$$\frac{\text{Number of samples (C)} \times \text{Costs per sample (D)}}{\text{Number of DALY (f(B,A))}},$$

and has unit costs per DALY. The pathogen/product combinations are ordered on basis of this criterion, where the combination with the lowest costs per DALY will have the highest sampling priority. The method will be explained using the following case studies: *Campylobacter* in pork and poultry, *Salmonella* in pork, *Toxoplasma* in pork and Shiga-toxin producing *Escherichia coli* (STEC) O157 in beef, veal and mutton/lamb.

2.2. Exposure assessment

Based on the approach as described in Evers et al. (2017) and Chardon and Evers (2017), 27 products containing chicken; 143 products containing pork and 92 products containing beef, veal, or mutton/lamb were extracted from the Dutch National Food Consumption Survey (DNFCS, 2017), resulting in a total of 548 pathogen/product combinations. The exposure assessment model is deterministic and does not include variability and uncertainty. The model and part of the parameter values used for the exposure calculations associated with these pathogen/product combinations can, for a large part, be found in Evers et al. (2017) and Chardon and Evers (2017) which describes analogous calculations for EBL *E. coli*.

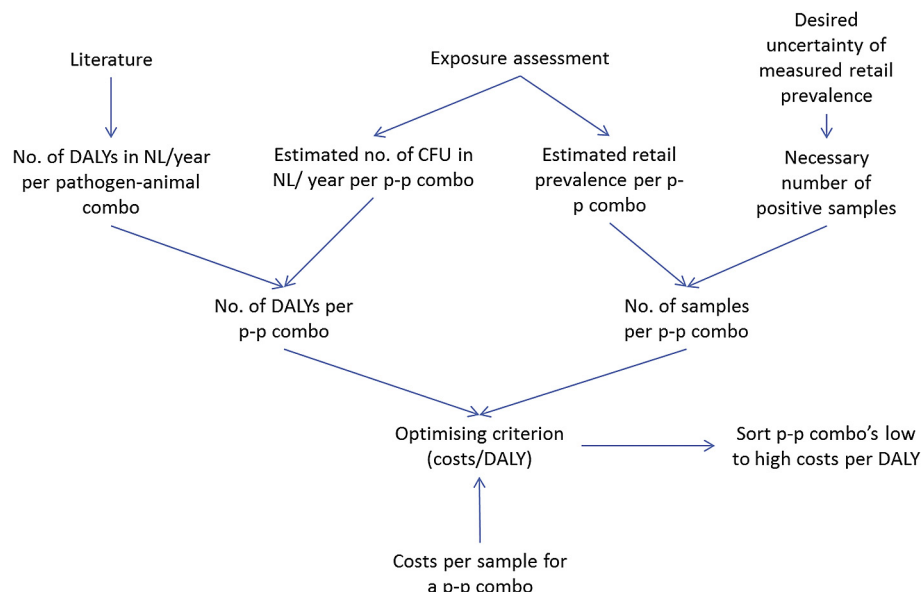


Fig. 1. Procedure to obtain an optimizing criterion for risk based sampling. 'p-p combo' stands for pathogen-food product combination.

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