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Systemic cost-effectiveness analysis of food hazard reduction – Campylobacter in Danish broiler supply

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ABSTRACT

An integrated microbiological–economic framework for policy support is developed to determine the cost-effectiveness of alternative intervention methods and strategies to reduce the risk of Campylobacter in broilers. Four interventions at the farm level and four interventions at the processing stage are considered. Cost analyses are conducted for different risk reduction targets and for three alternative scenarios concerning the acceptable range of interventions. Results demonstrate that using a system-wide policy approach to risk reduction can be more cost-effective than a policy focusing purely on farm-level interventions. Allowing for chemical decontamination methods may enhance cost-effectiveness of intervention strategies further.

1. Introduction

In the past, a large number of different policies have been implemented to control Campylobacter in the broiler supply chain, but Campylobacter is still among the most common bacterial causes of human gastrointestinal disease infections in many countries (EFSA, 2011; Havelaar et al., 2005). The consequences of human Campylobacter infections are numerous, including human suffering and deaths, medical costs, productivity losses, reduced consumer confidence and restricted market access. It is therefore essential to identify and implement new policy strategies to further reduce the burden of human Campylobacter infections in an effective and economically efficient manner.

During recent years, governments in especially western countries have tended to adopt a farm-to-table systems approach, because food safety failures often arise from problems that are systemic in nature. This is due to problems related to the provision of rights and alignment of incentives (Jensen, 2003; Unnevehr & Jensen, 2005, Chapter 6) and because contemporary food supply chains are characterized by interconnecting stages, implying that safety problems at one stage may easily spread to other parts of the supply chain and hence incur extra costs there. Thus, the analysis of food safety issues should cover all relevant actors in the broiler supply chain from stable to table (Hennessy, Roosen, & Jensen, 2002; Rosenquist, Nielsen, Sommer, Nørrung, & Christensen, 2003).

Several "novel" technologies have been suggested in the literature in order to reduce the incidence of human campylobacteriosis from Campylobacter in broilers (reviewed by Keener, Bashor, Curtis, Sheldon, & Kathariou, 2004). These are based on either a reduction of the number of Campylobacter in the gut of living birds (by changed feeding or by protecting the broiler flocks against contamination from e.g. insects or wild birds), or a reduction of the number of Campylobacter on the chicken carcasses during slaughter using chemical decontamination or physical decontamination methods, such as heat (steam or dry heat) or freezing (including "crust" freezing). The process of Campylobacter spread, as well as the microbiological efficiency of many of these techniques, should be considered as stochastic by nature when it comes to e.g. the prevalence of contaminated birds and in reducing the number of colony forming units (cfu) on the broiler meat (e.g. Nauta, Jacobs-Reitsma, Evers, van Pelt, & Havelaar, 2005; Nauta, van der Ine, & Havelaar, 2005).

From a systemic perspective, it is crucial not only to consider the reduction of Campylobacter risk, but also to investigate the effects of implementing new interventions on the distribution of costs among agents in the broiler supply chain. If firms cannot capture the economic benefits from new costly control measures, they lack the incentives to implement the methods in their production (Jensen, 2003). For example, Mangen, Havelaar, and Poppe (2005), Mangen, Havelaar, Nauta, de Koeijer, and de Wit (2005), Mangen, Havelaar, Bernsen, van Koningsvel, and de Wit (2005)

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found that the total cost for provision of extra hygiene measures, phage therapy and PCR-tests would cost Dutch broiler farms € 0.05 per bird, with considerable variation across farms. Although these costs may seem low, they are still significant in comparison with the economic margin per broiler. And despite the great importance, the stochastic features have – with few exceptions – either been neglected or poorly addressed in the economic evaluation of new intervention methods.

This study develops and demonstrates a new system-based microbiological–economic modelling approach to evaluate the costs of different intervention portfolios in the broiler supply chain, and to identify cost-effective strategies to reduce the risk of Campylobacter infections when the safety risks and economic incentives for risk reductions are unequally distributed in the chain. The selection of intervention measures is based on farm level results of a Danish epidemiological risk-factor analysis (Sommer & Heuer, 2007; Sommer & Rosenquist, 2011), research concerning the prevention of Campylobacter carrying flies entering the broiler houses (Hald, 2007), literature on Campylobacter risk factors (Bouwknegt et al., 2004; Refregier-Petton, Rose, Denis, & Salvat, 2001), as well as interventions selected in dialogue with industry representatives. Consequently, four intervention methods pertaining to the broiler grow-out houses and their environment are analysed: rodent control, house quality, fly screen and feeding strategy. At the slaughter processing stage four intervention measures are considered, including two mechanical methods (steam-ultrasound treatment, crust freezing), and two chemical decontamination methods (trisodium acids, marinade). The Danish broiler supply chain is used as a case.

Effectiveness and costs of alternative interventions in primary broiler production and in broiler processing are assessed, and systemic intervention strategies combining different types of interventions are developed and analysed. Cost-effectiveness analysis is adopted to compare the intervention strategies, resting on the evaluation of monetized costs relative to outcomes that are expressed in units other than money (Drummond, O'Brien, Stoddart, & Torrance, 1999). In the case of food safety, the physical benefits comprise the number of averted adverse outcomes, e.g. mortality and morbidity hazards. These outcomes are assumed to be correlated with the Campylobacter exposure in terms of the share of meat containing sufficient bacteria concentration to be infectious. Cost-effective strategies are determined using a mathematical programming model, where three scenarios are analysed: (a) only new interventions in primary broiler production are allowed, (b) new interventions are allowed in the primary as well as the processing stage of the chain, and (c) new interventions in both primary and processing stages are allowed, however excluding chemical decontamination of broiler meat in the processing stage.

The rest of the paper is organised as follows: The next section presents the Danish broiler supply chain. Intervention methods and their economic evaluations at the farm and slaughterhouse stages are outlined in the subsequent section, followed by a description of the modelling approach for evaluating cost-effectiveness of strategies to reduce the incidence of Campylobacter. Model results illustrating optimal policy strategies for reduction of Campylobacter risk are presented and discussed in the following section, and some conclusions and perspectives obtained from the study are provided in the final section.

2. Broiler farms and slaughter-process stages

For the study, we had access to primary data from 280 Danish broiler farms for 2004, the base year. The farms had a total of 4383 flock rotations, representing 135.8 million birds. According to DPC (2005), broilers were reared at the stocking density of 42 kilograms live-weight per square meter in 2004. The average growing days were 37 days, with a weight gain of 53 grams per day. The mortality rate was 3.7% (DPC, 2005).

Based on data from a subsample of farms representing 48% of the Danish broiler flocks and 51% of total broiler production, information on production level, as well as revenue (farm gate price), variable costs and gross margin per broiler is used to describe the economic status of farms (Table 1, left section). Due to heterogeneity of farm sizes and investment in Campylobacter intervention measures, the economic information for the primary broiler sector is divided into small (<2000 square meter broiler house capacity), medium-sized (2–4000 square meter) and large farms (>4000 square meter), respectively.

Table 1 (right section), shows the gross margin in the processing stage. During 2004, three slaughter companies with six production units had broiler supplies from the 280 primary producer farms. Apart from the basic price, payment to farmers is to a high degree governed by a number of requirements put forward by the slaughter companies (Lawson, Jensen, & Lund, 2009), including requirements for e.g. delivery weight of birds, product quality, and the welfare of birds measured by the footpad index. Food safety also plays an important role in the determination of the price paid by the slaughter companies to broiler farmers. Salmonella and food-borne livestock disease surveillance and control plans started in 1996/1997 with the associated regulation passed in 1999 (DPC, 2000). Since 2003, all Danish broiler farms should comply with a 10-point bio-security arrangement aimed at production free of food-borne diseases. Farmers are penalized in terms of lower prices, if they fail to fulfill these requirements.

An essential element in evaluating the burden of Campylobacter intervention costs is the gross margin generated at the farm stage and at the slaughterhouse production unit. At the farm level, gross margin amounts to about 15% of the price (with no dramatic differences among farm sizes), and in processing, the average calculated gross margin is 25% of average sales price.

3. Campylobacter intervention methods

In the literature, various risk analyses have been conducted to estimate or identify possible control intervention measures along the broiler supply chain (Evans & Sayers, 2000; Herman et al., 2003; Nauta, van der Ine, et al., 2005; Rosenquist et al., 2003; van de Giessen, Tilburg, Ritmeester, & van der Plas, 1998). In the following, we briefly describe the control measures analysed in the present study, in terms of their effects on Campylobacter and their cost implications (including which types of costs that are influenced by the respective measures).

3.1. Farm intervention measures and costs

In general, the total cost of an intervention measure j is calculated as the sum of annualized capital costs representing long term investments and variable costs, which are directly related to the current production, and which cover feed, labour, materials (e.g. disinfectants) and miscellaneous inputs (e.g. water, energy and maintenance). For all capital investments the annuity cost per year is calculated using an annual inflation-corrected interest rate of 3%. All costs at the farm level were calculated using production information from individual broiler units expressed per broiler. This allows us to estimate the farm-level intervention costs in three farm size groups using statistical methods.

Table 2 summarizes the partial costs and effectiveness of the four selected intervention types at the farm level. Some of these intervention types (house quality, feeding) have more than one level of intervention. For simplicity, Table 2 only shows the