

THE ECONOMICS OF REDUCING *Campylobacter* IN THE BELGIAN POULTRY MEAT CHAIN**

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**Plenary invited paper

Abstract: *Campylobacter* infections are a serious public health problem in Belgium. Poultry meat is most likely responsible for 40% of human campylobacteriosis cases in Belgium. On a yearly basis, consumption of poultry meat causes at least 22,000 campylobacteriosis cases with a costs-of-illness of €11 million. This study aims to evaluate the efficiency, i.e. the ratio of reduced costs-of-illness on intervention costs, of various intervention measures. These measures were selected by representatives from the poultry meat sector and experts in the field. The selection comprised measures at farm level (administration of bacteriocins to feed of broilers shortly before slaughter), at the processing plant (spraying of carcasses with lactic acid or electrolyzed oxidizing (EO) water, crust-freezing or irradiation of carcasses and chicken filets at the end of the slaughterline) and at consumer level (improving kitchen hygiene and application of home-freezing). Among these measures, the decontamination of carcasses with EO water is the most efficient. Administration of bacteriocins to feed of broilers is also efficient. Irradiation is the most effective intervention, however, one of the least efficient. There seems to be less gain by trying to improve food handling in the kitchen. The cost to reach consumers is large while only a very limited fraction of the consumers is willing to change their behavior.

Key words: *Campylobacter*, chicken meat, interventions, electrolyzed oxidizing water, cost-benefit analysis

Introduction

Campylobacter is the leading cause of zoonotic enteric human infections

in most developed countries (Viane *et al.* 2006). In Belgium, *Campylobacter* enteritis is mainly caused by *Campylobacter jejuni* (80% of the isolates) and *Campylobacter coli* (12%) (Ducoffre, 2005). The most common clinical symptoms of campylobacteriosis are fever, abdominal pain and diarrhea occurring within 2 to 5 days after ingestion of food or water contaminated with *C. jejuni* (Black *et al.*, 1988, Robinson 1981). Symptoms are usually self-limiting and are resolved within a period of 3 to 10 days. The infection may lead to serious ongoing sequelae and may even be fatal. The most common complications are reactive arthritis (ReA), Guillain-Barré syndrome (GBS) and inflammatory bowel disease (IBD) (Rautelin and Hanninen 2000).

Handling and consumption of poultry meat have been identified as 40% of human campylobacteriosis. Several case-control studies have shown that consumption of poultry meat is one of the principal sources of infection (Deming *et al.*, 1987, Eberhart-Phillips *et al.*, 1997, Effler *et al.*, 2001, Studahl and Andersson, 2000, Viane *et al.* 2006). Reducing the contamination of *Campylobacter* in the poultry production chain may be obtained by interventions i. at the farm and during transport, ii. at the processing plant and iii. during storage and meat preparation (Havelaar *et al.*, 2005). Several Quantitative Microbial Risk Assessment (QMRA) studies have been undertaken to assess the risk of human infection with *Campylobacter* upon the consumption of poultry meat and used to investigate the effect of interventions (Hartnett 2001, Nauta *et al.*, 2005, Rosenquist *et al.*, 2003).

The aim of this study is to estimate the efficiency of various intervention measures in Belgium to control *Campylobacter* in the poultry meat chain. The efficiency is defined as the ratio of reduced costs-of-illness on intervention costs. Available models for risk assessment and cost-of-illness of *Campylobacter* infections and sequelae served as input for the current calculations.

Materials and Methods

Figure 1 describes the framework for calculating the efficiency of various selected intervention measures. The year 2004 is used as reference in this economic evaluation.

Reduced cost-of-illness. The QMRA model is based on the model developed by Hartnett (2001) and describes the chain from farm-to-fork in a modular fashion. The modules considered are 1) rearing and transport, 2)

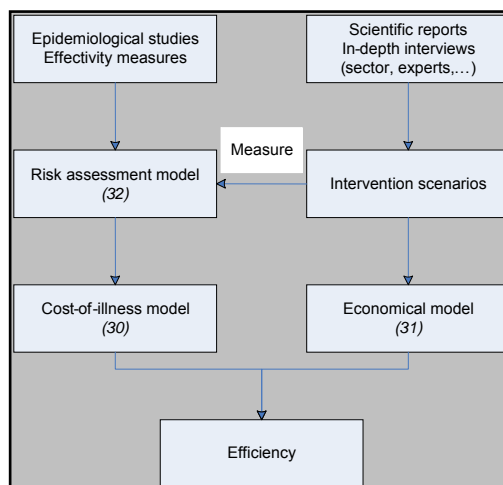


Figure 1. The framework for calculating the efficiency of various selected intervention measures

slaughter and processing, 3) preparation and consumption and finally 4) health consequences. At each stage, the model estimates the probability that a bird/carcass/product is colonized/contaminated with campylobacters and the associated microbial levels. Both fresh and frozen whole carcasses and filets, consumed at home, were included. The original model was adapted to the Belgian situation and updated to incorporate results of recent studies (*Messens et al., in press*). In Belgium, only air cooling of the carcasses is used, which is assumed to have no effect on the contamination levels on the carcass. For portioning, the model described in the *Campylobacter Risk Management and Assessment (CARMA)* project (*Nauta et al., 2005*) was used. For duration of refrigerated and frozen storage at home, own Belgian data involving 471 respondents was used (*Halet et al., 2006*). At the preparation and consumption stage, only poor hygiene during cooking was considered, as inadequate cooking poses a much lower risk as shown by *Hartnett (Hartnett 2001)*. Cross contamination to raw vegetables was modeled as described in the *CARMA* project (*Nauta et al., 2005*). This can either be from the raw meat through hand-salad contact or from raw meat via the cutting board to the salad. Consumer data was used to make the model applicable to the Belgian situation (*Anonymous 2006*).

Estimating the intervention costs (according to *Mangen et al., 2005a*). The annual total cost (TC) for an intervention m comprises the estimated annuity (A) of the non-recurrent costs (NRC) for intervention m and the

recurrent costs (RC) of intervention m :

$$TC_m = A_m + RC_m (I)$$

The NRC includes purchase costs and installation and reorganization costs and are mostly long-lasting investments (lifetime of ≥ 8 years). These investment costs will be depreciated over the lifetime (n) of the equipment at an interest rate (i) of 4%.

Results and Discussion

Reduced cost-of-illness. Based on epidemiological studies, the annual incidence of *Campylobacter* associated gastro-enteritis (GE) and sequelae in Belgium are calculated. It is estimated that 30 to 40% of GBS is attributable to *Campylobacter* infections and that about one out of a thousand patients with campylobacteriosis develops GBS (*Nachamkin et al.*, 1998). The annual incidence of GBS in Belgium is 1.5 cases per 100,000 inhabitants (*Anonymous* 2006). Consequently, the annual incidence of *Campylobacter* associated GE cases in Belgium with a population of 10.5 million, is about 55,000 cases. Among these cases about 19,300 patients visit a general physician (GP), 345 are hospitalized and 20 cases are fatal. The latter distribution is obtained from *Mangen et al.* (2004). Only the parameter “proportion people visiting the GP” is multiplied by 1.5, since Belgian people visit the GP more frequent than Dutch people (*Anonymous* 2005). The annual incidence of *Campylobacter* associated GBS is estimated to be 56 cases.

Based on a Belgian 3-years prospective study, the annual incidence of Crohn’s disease and ulcerative colitis is estimated at 4.5 respectively 3.6 cases per 100,000 inhabitants, giving a total of 8.1 cases of IBD per 100,000 inhabitants (*Nauta et al.*, 2005). *Campylobacter* is involved in up to 6.2% of Crohn’s disease and up to 3.7% of ulcerative colitis (*Boyanova et al.*, 2004). Accordingly, the estimated annual incidence of *Campylobacter* associated IBD in Belgium is 43 cases. The rate of ReA associated with *Campylobacter* is fairly low, ranging from 0 to 2.6% (*Hannu et al.*, 2004, *Skirrov and Blaser*, 2002), resulting in an average of about 700 cases of *Campylobacter* associated ReA in Belgium.

When assessing the intervention measures, many factors should be taken into account such as effectivity, levels of microbial contamination, potential for introducing other food safety hazards, impact on the environment, effect

on sensory properties and quality of the product, feasibility, and consumer perception (*Anonymous* 1998). Information and data for the selection of the various intervention measures and estimates of effectivity are obtained from scientific reports, in depth interviews with representatives from the Belgian poultry sector and from experts in the field. A summary of the intervention measures studied together with their effectivity (pessimistic, most likely and optimistic scenario) is presented in Table 1.

Table 1. Effectivity (pessimistic (P), most likely (ML) and optimistic (O) scenario) of the various selected intervention measures

Stage	Intervention	Effectivity			References	Reduction in campylobacteriosis cases (%)		
		P	ML	O		P	ML	O
Farm	Bacteriocins	5.3 ^a	6 ^a	6.9 ^a	(38, 39)	100	100	100
Processing plant	Lactic acid	0.3 ^a	1.3 ^a	2 ^a	(37, 41)	0	38	72
	EO water	1.1 ^a	2.3 ^a	3 ^a	(23, 30)	28	80	91
	Crust-freezing	0.4 ^a	1.1 ^a	1.7 ^a	(9)	32	61	82
	Irradiation	4.7 ^a	10.5 ^a	20.8 ^a	(9, 15, 16, 22)	99.8	100	100
Consumer	Kitchen hygiene	0% ^b	3% ^b	7% ^b	(11)	0	3	9
	Home-freezing	0% ^b (0.13 ^a)	3% ^b (0.24 ^a)	7% ^b (0.46 ^a)	(11, 37)	0	6	9

^a log reduction

^b change in behavior after one communication campaign

Table 2. Estimated cost-of-illness associated with gastro-enteritis (GE), Guillain-Barré syndrome (GBS), inflammatory bowel disease (IBD) and reactive arthritis (ReA)

Description	Cases/year	Cost/case (€)	Total costs (€ thousand)	% of the costs-of-illness
GE case not visiting GP	35,445	126	4,466	16,3
GE case visiting GP only	19,314	485	9,367	34,3
Hospitalized GE case	345	2,661	918	3,4
Fatal GE case	21	1,774	37	0,135
GBS	56	67,852	3,799	13,9
IBD	43	202,385	8,712	31,9
ReA	714	23	16	0,059
Total costs			27,317	100

At consumer level two interventions are analyzed, i.e. mass-media campaigns to improve kitchen hygiene and home-freezing of poultry meat. As only a very limited fraction of the consumers is willing to change their behavior, these have a limited reduction in number of campylobacteriosis cases.

The cost-of-illness associated with *Campylobacter* infections and sequelae in Belgium is shown in Table 2.

As mentioned before 40% of these costs is attributable to the consumption of poultry meat, resulting in a yearly cost-of-illness of €10.9 million. The reduced cost-of-illness of the different intervention measures is obtained by multiplying this value with the percentage risk reduction of the intervention measure. The results are presented in Table 3.

Table 3. Estimated reduced cost-of-illness and efficiency for the different interventions

Stage	Intervention	Reduced cost-of-illness: X (million €/year)		Treatment costs: Y (million €/year)			Efficiency ¹	
		Belgian cons: X ₁	All cons: X ₂	Farmer	Industry	Government	X ₁ /Y	X ₂ /Y
Farm	Bacteriocins	10.9	15.8	5.2	-	-	2.1	3.1
Processing plant	Lactic acid	4.2	6.0	-	1.0	-	4.1	5.9
	EO water	8.7	12.7	-	0.5	-	17.7	25.6
	Crust-freezing	6.7	9.7	-	18.0	-	0.4	0.5
	Irradiation	10.9	15.8	-	35.1	-	0.3	0.5
Consumer	Kitchen hygiene	0.3	-	-	-	1.9	0.2	-
	Home-freezing	0.7	-	-	-	1.9	0.4	-

¹ The intervention measure is efficient if the ratio > 1 (in bold)

Intervention costs. One potential approach to control *Campylobacter* colonization at the farm level is the administration of bacteriocins to the feed at a dose of 250 mg/kg, 1 to 3 days before slaughter (Cole *et al.*, 2006, Stern *et al.*, 2005, 2006). With a daily feed utilization of 100 g per broiler (Veilinga and Van Loock, 2002), the cost ranges between €2.6 million (1 day administration) and €7.8 million (3 day administration).

At the processing plant, several interventions were studied: acid decontamination of carcasses, decontamination of carcasses with EO water,

crust-freezing and irradiation. For acid decontamination of carcasses a spraying device is installed immediately at the end of the slaughter line, before entering the chilling tunnel. According to the suppliers prescription, each carcass needs to be sprayed with 50 ml lactic acid solution (*Pipek et al.*, 2004), but practices in the slaughterhouse show a surplus of 20%, i.e. 60 ml/carcass. With a total of 38 slaughterlines, the sector cost is about € 1.02 million (range € 0.98 - 1.06 million).

The EO-water generator and spraying device would also be installed before entry to the chilling tunnel. The sector cost is about € 0.49 million (range € 0.45 - 0.54 million).

In the slaughterhouse, crust-freezing would be applied after cooling the carcasses and possible portioning. The purchase and installation costs are estimated between € 1.5 and € 3.0 million per piece of equipment (Airproducts, UK). The sector cost is about € 18 million (range € 13.7 – 22.3 million).

Since the purchase cost per piece of equipment used for irradiation is rather high (several millions), it is assumed that gamma irradiation would not be applied in the processing plant itself built instead by a specialized company. Isotron is Europe's leading provider of contract sterilization services. The closest site is in Etten-Leur (Breda, The Netherlands). The sector cost is about € 35.1 million (range € 20.6 - 49.6 million).

At the consumer level, communication campaigns can be applied. According to *Allos* (2001) and *Peterson* (1994), poultry meat should be adequately cooked, and cutting boards and utensils used in handling uncooked poultry or other meats should be washed with hot soapy water before being used for the preparation of salads or other raw foods. Another possible intervention measure is the freezing of fresh meat at home by the consumer. Freezing has a damaging effect on *Campylobacter*, resulting in fewer organisms in broiler carcasses (*Georgsson et al.*, 2006). Both intervention measures presume a change in consumer behavior. Such a change might be realized through communication campaigns. The annual cost of such a national communication campaign is €1.85 million (Interministerieel Commissariaat Influenza, Belgium, 2006).

Efficiency and sensitivity analysis. Dividing reduced cost-of-illness by intervention costs indicates the efficiency. With a self-sufficiency degree of 145%, about one third of the Belgian poultry meat is exported. This implies that measures taken to reduce the contamination with *Campylobacter* of poultry flocks or meat will not only have a positive effect on the health risk of consumers in Belgium, but also in countries importing Belgian products.

In the analysis, the benefits realized on the Belgian market and export markets are integrated. Results of the various interventions are presented in Table 3, assuming most likely values for effectivity and intervention costs. Three interventions are considered efficient, i.e. having a ratio > 1 . The most efficient intervention measure is the decontamination of carcasses with EO-water with an efficiency near 18. The decontamination of carcasses with lactic acid and the addition of bacteriocins to the feed have an efficiency of 4.06 and 2.10 respectively. Considering all consumers, the efficiency is even higher.

The social perspective is traditionally the perspective chosen in economic evaluation. It is assumed that investments are worth doing, when society as a whole is better off than under a status quo situation. However, in our study the “benefactors” and the “losers” are not identical. Costs are made in the food supply chain, while the benefits are realized at consumer level. The distribution of the intervention costs over the different stakeholders, namely farmers, industry and government are summarized in Table 3.

Conclusions

Campylobacter infections pose a serious public health problem in Belgium with poultry meat being most likely responsible for 40% of human cases of campylobacteriosis. On a yearly basis, this results in at least 22,000 campylobacteriosis cases with a costs-of-illness of € 11 million/year.

Of all analyzed intervention measures, the decontamination of carcasses with EO water is the most efficient, assuming that all other levels in the poultry meat chain continue with good practice behavior. The administration of bacteriocins to the feed of broilers 1 to 3 days before slaughter might be another efficient intervention measure. However, care should be taken considering these results. Up-to-day, the application of bacteriocins has only been investigated in 10-day-old chickens. Further research is necessary to investigate whether these effects remain valid when the bacteriocins are administrated shortly before slaughter. Irradiation is the most effective intervention, however, one of the least efficient.

EKONOMSKI ASPEKT SMANJENJA POJAVE *Campylobacter* U LANCU ŽIVINSKOG MESA U BELGIJI

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Rezime

Campylobacter infekcije predstavljaju ozbiljan zdravstveni problem u Belgiji. Živinsko meso je najverovatnije odgovorno za 40% kampilobakterioza kod stanovnika Belgije. Godišnje, potrošnja živinskog mesa izaziva najmanje 22.000 slučajeva kampilobakterioza, čiji je trošak oko 11 miliona evra. Ovo ispitivanje ima za cilj ocenu efikasnosti odnosno odnosa smanjenja troškova bolesti kod intervencija, različitih oblika interventnih mera. Ove mere su odabrane od strane predstavnika sektora proizvođača živinskog mesa i stručnjaka iz ove oblasti. Odabrane mere su se sastojale od mera na nivou farme (davanje bacteriocina u hrani za brojlere neposredno pred klanje), u preradi (prskanje trupova mlečnom kiselinom ili elektrolitskom oksidirajućom vodom (EO), zamrzavanje ili iradijacija trupova i pilećih fileta na liniji klanja) in a nivou potrošača (poboljšanje higijenskih uslova u kuhinji i primena zamrzavanja u domaćinstvu). Od navedenih mera, dekontaminacija trupova primenom EO vode je najefikasnija. Davanje bacteriocina u hrani za brojlere je takođe efikasno. Iradijacija je najdelotvornija intervencija, međutim, najmanje efikasna. Čini se da je najmanja dobit od pokušaja da se poprave postupci u rukovanju piletinom u kuhinji. Trošak neophodan da bi se doprlo do svih potrošača je veliki a samo ograničen deo potrošača je spreman da promeni svoje ponašanje.

Ključne reči: *Campylobacter*, pileće meso, intervencije, electrolizovana oksidirajuća voda, analiza troška i koristi

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