A Model documentation

Variable name	Type	Units	Initial value	Equation	Source	Important assumptions	Submodel
chickens arriving from hatcheries	Flow	Chicken/Week	na	population*(consumption rate per person/meat per chicken)	Model conceptualization	Supply = Demand	Chicken
chicken on farms	Stock	Chicken	Initial Chickens on Farms	chickens arriving from hatcheries-chicken infections with CPY-"chicken non-infections with CPY"	Model conceptualization		Chicken
initial chickens on farms	Constant	Chicken	na	100000	Model conceptualization	Arbitrary number	Chicken
CPY-positive chickens	Stock	Chicken	0	chicken infections with CPY-"CPY-positive chickens slaughtered"	Model conceptualization		Chicken
chicken infections with CPY	Flow	Chicken/Week	na	chickens on farms*rate of chicken infection from environment	Model conceptualization		Chicken
chicken non-infections with CPY	Flow	Chicken/Week	na	chickens on farms*(1-rate of chicken infection from environment)	Model conceptualization		Chicken
CPY-negative chickens	Stock	Chicken	0	chicken non-infections with CPY-"slaughtering with cross-contamination"-"slaughtering without cross-contamination"	Model conceptualization	This is the final contamination before slaughtering	Chicken
slaughtering without cross-contamination	Flow	Chicken/Week	na	CPY-negative chickens * (1-"rate of cross-contamination")	Model conceptualization		Chicken
slaughtering with cross-contamination	Flow	Chicken/Week	na	CPY-negative chickens * "rate of cross-contamination"	Model conceptualization		Chicken
contaminated meat	Stock	kg	0	("CPY-positive chickens slaughtered"+"slaughtering with cross-contamination")*meat per chicken-contaminated meat consumption	Model conceptualization	This stock includes a modifier to change from chickens to chicken meat (changes units from chicken to kg). This is outside of convention, but was a necessary modifier to make the stock-flow structure work.	Chicken
CPY-positive chickens slaughtered	Flow	Chicken/Week	na	CPY-positive chickens*slaughter rate	Model conceptualization	All infected chicken become contaminated meat	Chicken
rate of cross-contamination	Variable	1/Week	na	IF THEN ELSE(safe slaughtering policy = 1, ((ZIDZ("CPY-positive chickens",("CPY-negative chickens"+"CPYpositive chickens")))*CPY reproduction in chickens)*0.8 , (ZIDZ("CPY-positive chickens",("CPY-negative chickens"+"CPY-positive chickens")))*CPY reproductive number in chickens)	Model conceptualization	Depends on the proportion of infected chicken	Chicken
meat per chicken	Constant	Kg/Chicken	na	1,5	Denton & Miller, 1988; National Chicken Council 2021		Chicken
contaminated meat consumption	Flow	Kg/Week	na	MIN(proportion of contaminated meat * consumption rate per person * population, (contaminated meat/week))	Model conceptualization	Cannot consume more than there is available	Chicken
total chickens slaughtered	Variable	Chicken/Week	na	CPY-positive chickens slaughtered+"slaughtering with cross-contamination"+"slaughtering without cross-contamination"	Model conceptualization		Chicken
contaminated slaughtered chickens	Variable	Chicken/Week	na	CPY-positive chickens slaughtered+"slaughtering with cross-contamination"	Model conceptualization		Chicken
Proportion of contaminated meat	Variable	Dmnl	na	ZIDZ(contaminated slaughtered chickens,total chickens slaughtered)	Model conceptualization		Chicken
slaughter rate	Constant	1/Week	na	0,3	Calibration	30% of all chickens present on the farms are slaughtered each week	Chicken
proportion of CPY-positive chickens	Variable	Dmnl	na	ZIDZ("CPY-positive chickens", "CPY-positive chickens"+"CPY-negative chickens")	Model conceptualization		Chicken
consumption rate per person	Constant	kg/(Week*Person)	na	0.203+meat consumption behaviour	https://files.wakkerdier.nl/app/uploads/2020/10/20151422/2020-078-Vleesconsumptie-2019-WUR-Dagevos_def.pdf?_ga=2.115483654.1629359199.1615461809-1770319697.1615461809		Chicken
population	Variable	Person	na	population by 2020 + RAMP((projected population by 2050-population by 2020)/(weeks per year*30),0,weeks per year*30)	Model conceptualization		Chicken
week	Constant	Week	na	1			Chicken
CPY reproduction in chickens	Constant	1/Week	na	0,5	(Campylobactor) in a Dairy herd. In 19th International		Chicken
Infections per kg of meat consumed	Variable	Cases/kg	na	IF THEN ELSE(food safety policy=1, 0.8*5e-05, 5e-05)	Calibration		Cost of Illness
CPY Cases	Stock	Cases	0	human CPY infections-asymptomatic infections-symptomatic infections	Model conceptualization		Cost of Illness
human CPY infections	Flow	Cases/Week	na	(contaminated meat consumption*infections per kg of meat consumed)+rate of human infection from environment	Model conceptualization		Cost of Illness
Acute GE Cases	Stock	Cases	0	symptomatic infections-Death by CPY-GBS development-GE Recovery-IBD development-ReA development	Model conceptualization		Cost of Illness

A Model documentation

symptomatic infections	Flow	Cases/Week	na	(CPY Cases*rate of symptomatic cases)*(PULSE TRAIN(weeks per year, TIME STEP, weeks per year , FINAL TIME)) / TIME STEP	Model conceptualization		Cost of Illness
base rate of symptomatic cases	Constant	Dmnl	na	0,88	Medema et al.		Cost of Illness
rate of symptomatic cases	Variable	Dmnl	na	base rate of symptomatic cases*rate of symptomatic cases modifier	Model conceptualization		Cost of Illness
asymptomatic infections	Flow	Cases/Week	na	(CPY Cases*(1-rate of symptomatic cases))*(PULSE TRAIN(weeks per year, TIME STEP, weeks per year , FINAL TIME)) / TIME STEP	Model conceptualization		Cost of Illness
GE Recovery	Flow	Cases/Week	na	recovery rate*Acute GE Cases	Model conceptualization		Cost of Illness
recovery rate	Constant	1/Week	na	0,98125	Mangen et al.		Cost of Illness
ReA Cases	Stock	Cases	0	ReA development	Model conceptualization	Chronic disease, does not empty	Cost of Illness
GBS Cases	Stock	Cases	0	GBS development	Model conceptualization	Chronic disease, does not empty	Cost of Illness
IBD Cases	Stock	Cases	0	IBD development	Model conceptualization	Chronic disease, does not empty	Cost of Illness
Death by CPY	Flow	Cases/Week	na	Acute GE Cases*death rate	Model conceptualization	Disease burden/cost of illness associated with deaths accounted for within DALY metric. This flow is only used to empty the cases stock	Cost of Illness
ReA development	Flow	Cases/Week	na	Acute GE Cases*ReA rate	Model conceptualization	Development of chronic disease assumed to all occur subsequent to acute cases. In reality, some campylobacter infections do connect directly to incidence of chronic disease.	Cost of Illness
GBS development	Flow	Cases/Week	na	Acute GE Cases*GBS rate	Model conceptualization		Cost of Illness
IBD development	Flow	Cases/Week	na	Acute GE Cases*IBD rate	Mangen et al.		Cost of Illness
ReA rate	Constant	1/Week	na	0,0175	Mangen et al.		Cost of Illness
GBS rate	Constant	1/Week	na	0,00075	Mangen et al.		Cost of Illness
IBD rate	Constant	1/Week	na	0,000125	Mangen et al.	Rate doubled to account for increase in diagnosis of IBD over past 2 decades: https://www.cdc.gov/ibd/data-statistics.htm#:~:text=Inflammatory%20Bowel%20Disease%20Prevalence%20(IBD,%25%20or%202%20million%20adults).	Cost of Illness
death rate	Constant	1/Week	na	0,000375	Mangen et al.	Assumed that death only caused by acute symptoms, death from chronic cases largely contained within DALYs.	Cost of Illness
DALY	Variable	DALY	na	(recovered GE*DALYs per GE Case) + (GBS Cases*DALYs per GBS Case) + (IBD Cases*DALYs per IBD Case) + (ReA Cases*DALYs per ReA Case)	Model conceptualization		Cost of Illness
Cost of Illness	Variable	Euro	na	((recovered GE*COI per GE Case) + (GBS Cases*COI per GBS Case) + (IBD Cases*COI per IBD Case) + (ReA Cases*COI per ReA Case))*COI modifier	Model conceptualization		Cost of Illness
COI modifier	Constant	Dmnl	na	1	Model conceptualization	Used only to test sensitivity	Cost of Illness
DALYs per GE Case	Constant	DALY/Cases	na	0,008	Mangen et al.	All undiscounted DALYs	Cost of Illness
DALYs per ReA Case	Constant	DALY/Cases	na	0,09	Mangen et al.	All undiscounted DALYs	Cost of Illness
DALYs per GBS Case	Constant	DALY/Cases	na	5	Mangen et al.	All undiscounted DALYs	Cost of Illness
DALYs per IBD Case	Constant	DALY/Cases	na	11,6	Mangen et al.	All undiscounted DALYs	Cost of Illness
COI per GE Case	Constant	Euro/Cases	na	190	Mangen et al.		Cost of Illness
COI per ReA Case	Constant	Euro/Cases	na	20	Mangen et al.		Cost of Illness
COI per GBS Case	Constant	Euro/Cases	na	85000	Mangen et al.		Cost of Illness
COI per IBD Case	Constant	Euro/Cases	na	173000	Mangen et al.		Cost of Illness
Recovered GE	Stock	Cases	0	GE Recovery	Model conceptualization		Cost of Illness
weeks per year	Constant	Week	na	52	This is how time works.		Cost of Illness
consumer food consumption behaviour lever	Variable	Dmnl	na	IF THEN ELSE((known CPY cases/population) > consumer food consumption behaviour threshold , 1 , 0)	Model conceptualization	0 - Normal consumption 1 - Reduced consumption due to too many cases	Cost of Illness
consumer food consumption behaviour threshold	Constant	Cases/Person	na	0,0038	Own interpretation		Cost of Illness
time to know about CPY cases	Constant	Week	na	1	Own interpretation		Cost of Illness
known CPY cases	Variable	Cases	na	SMOOTH N(CPY Cases,time to know about CPY cases, CPY Cases, 3)	Model conceptualization		Cost of Illness
meat consumption behaviour	Variable	kg/(Week*Person)	na	IF THEN ELSE(((consumer food consumption behaviour lever + consumption behaviour policy) = 0), 0 , -0.05)	Model conceptualization	Natural consumer behavior and government intervention to modify behavior do not compound	Cost of Illness

A Model documentation

rate of symptomatic cases modifier	Variable	Dmnl	na	WITH LOOKUP (scenario switch): ([(0,0)-(12,2)],(0,1),(9,1),(10,0.9),(11,1.1),(12,1.1))	Mangen et al.	Ranges from 0.9 to 1.1 across scenarios	Cost of Illness
fly population	Stock	MFly	initial fly population	fly development-fly deaths	Model conceptualization		Environmental
fly deaths	Flow	MFly/Week	na	DELAY1I(fly development, fly lifetime, fly population/fly lifetime)	Model conceptualization		Environmental
fly development	Flow	MFly/Week	na	fly development rate	Model conceptualization		Environmental
Initial fly population	Constant	MFly	na	0,1	Model conceptualization		Environmental
fly lifetime	Constant	Week	na	4	https://www.orkin.com/flies/how-long-do-flies-live		Environmental
fly population growth per degree	Constant	MFly/(degree*Week)	na	0,0024	Blanckenhorn, W. U. (1997). Effects of temperature on growth, development and diapause in the yellow dung fly - against all the rules? Oecologia, 111(3), 318–324. doi:10.1007/s004420050241		Environmental
base fly population development rate	Constant	MFly/Week	na	-0,0091	Blanckenhorn, W. U. (1997). Effects of temperature on growth, development and diapause in the yellow dung fly - against all the rules? Oecologia, 111(3), 318–324. doi:10.1007/s004420050241		Environmental
non-diapause development rate	Variable	MFly/Week	na	base fly population development rate + fly population growth per degree* temperature	Blanckenhorn, W. U. (1997). Effects of temperature on growth, development and diapause in the yellow dung fly - against all the rules? Oecologia, 111(3), 318–324. doi:10.1007/s004420050241		Environmental
diapause development rate	Constant	MFly/Week	na	0,0005	Blanckenhorn, W. U. (1997). Effects of temperature on growth, development and diapause in the yellow dung fly - against all the rules? Oecologia, 111(3), 318–324. doi:10.1007/s004420050241		Environmental
fly development rate	Variable	MFly/Week	na	IF THEN ELSE(temperature > 4, "non-diapause development rate" ,diapause development rate)	Blanckenhorn, W. U. (1997). Effects of temperature on growth, development and diapause in the yellow dung fly - against all the rules? Oecologia, 111(3), 318–324. doi:10.1007/s004420050241	Below 4 degrees fly development enters diapause	Environmental
temperature	Variable	degree	na	((-1)*(SIN(2*pi*(Time+start of year offset)/weeks per year))*((maximum average weekly temperature-minimum average weekly temperature)/2)+((maximum average weekly temperature+minimum average weekly temperature)/2))+temperature increase	Model conceptualization	More than four inputs to the variable - this presents issues for readability, but all variables were necessary for formulation.	Environmental
minimum average weekly temperature	Variable	degree	na	-4	KNMI		Environmental
maximum average weekly temperature	Variable	degree	na	23	KNMI		Environmental
pi	Constant	Dmnl	na	ARCCOS(-1)	Archimedes of Syracuse		Environmental
proportion of infectious flies	Variable	Dmnl	na	base infectious flies + "chance of chicken-to-fly transmission"* "proportion of CPY-positive chickens"	Model conceptualization		Environmental
chance of chicken-to-fly transmission	Constant	Dmnl	na	0,5	Calibration		Environmental
base infectious flies	Constant	Dmnl	na	0,35	Calibration		Environmental
infectious flies	Variable	MFly	na	fly population*proportion of infectious flies * IF THEN ELSE(fly population control policy = 1 ,0.8 ,1)	Model conceptualization		Environmental
rate of chicken infection from environment	Variable	1/Week	na	base chicken exposure rate+(infectious flies*rate of chicken exposure to infectious flies)	Model conceptualization		Environmental
human infection from environment	Variable	Cases/Week	na	infectious flies*rate of human exposure to infectious flies*population + (infection risk from birds * population)	Model conceptualization		Environmental
base chicken exposure rate	Constant	1/Week	na	0,1	Calibration		Environmental
chicken exposure to infectious flies	Variable	1/(MFly*Week)	na	2	Calibration		Environmental
rate of human exposure to infectious flies	Variable	Cases/(MFly*Person*Week)	na	base human exposure rate * SMOOTH(IF THEN ELSE(exposure control policy = 1 , 0.8 , 1) , number of weeks needed to adopt policy)	Model conceptualization		Environmental

A Model documentation

base human exposure rate	Constant	Cases/(MFly*Week*Person)	na	0.001	Calibration		Environmental
average temperature increase	Variable	degree	na	RAMP(temperature increase by 2050/(weeks per year*30),0,weeks per year*30)	Model conceptualization		Environmental
temperature switch	Variable	Dmnl	na	WITH LOOKUP (scenario switch):([(0,0)-(12,2)],(0,0),(7,0),(8,2),(9,1),(10,0),(11,0),(12,2))	Model conceptualization	0 - No change 1 - Linear change 2 - Faster summer warming than winter warming	Environmental
temperature increase	Variable	degree	na	IF THEN ELSE(temperature switch = 0,0,(IF THEN ELSE(temperature switch = 2,(-1)*(SIN(2*pi*(Time+start of year offset)/weeks per year)*0.8*average temperature increase)+average temperature increase,average temperature increase)))	Bresser et al, 2006		Environmental
temperature increase by 2050	Constant	degree	na	WITH LOOKUP (scenario switch): ([(0,0)-(12,2)],(0,1.5),(3,1.5),(4,1),(5,1.5),(6,1.5),(7,1.5),(8,2),(9,1.5),(11,1.5),(12,2))	KNMI 14' klimaatscenario's voor Nederland	Ranges from 1 to 2 across the different scenarios	Environmental
Infection risk from birds	Constant	Cases/(Week*Person)	na	2,5E-0,5	Calibration		Environmental
start of year offset	Variable	Week	na	8	KNMI	Needed to make the sinusoidal curve for the temperature to match the appropriate time of year.	Environmental
population by 2020	Constant	Person	na	1,73E+07	CBS		Environmental
projected population by 2050	Variable	Person	na	WITH LOOKUP (scenario switch): ([(0,0)-(12,3e+07)],(0,1.94e+07),(1,1.94e+07),(2,2.16e+07),(3,1.71e+07),(4,1.94e+07),(11,1.94e+07),(12,2.16e+07))	CBS (https://www.cbs.nl/en-gb/news/2020/51/forecast-population-growth-unabated-in-the-next-50-years)	Ranges from 1.71e+07 to 2.16e+07 across scenarios	Environmental
exposure control policy	Variable	Dmnl	na	IF THEN ELSE(exposure control policy switch = 1, IF THEN ELSE(temperature > temperature trigger for exposure control policy, 1 , 0), 0)	Policy conceptualization		Policies
temperature trigger for exposure control policy	Constant	degree	na	20	Policy conceptualization		Policies
exposure control policy switch	Constant	Dmnl	na	0	Policy conceptualization	0 - No policy 1 - Policy implemented	Policies
number of weeks needed to adopt policy	Constant	Week	na	2	Policy conceptualization		Policies
fly population control policy	Variable	Dmnl	na	IF THEN ELSE(fly population control policy switch = 1, IF THEN ELSE(temperature > temperature trigger for fly population control policy , 1 , 0), 0)	Policy conceptualization		Policies
temperature trigger for fly population control policy	Constant	degree	na	20	Policy conceptualization		Policies
fly population control policy switch	Constant	Dmnl	na	0	Policy conceptualization	0 - No policy 1 - Policy implemented	Policies
safe slaughtering policy	Variable	Dmnl	na	IF THEN ELSE(safe slaughtering policy switch = 1, IF THEN ELSE(Cost of Illness-COI accumulated a year ago > COI trigger for slaughtering policy , 1 , 0), 0)	Policy conceptualization		Policies
COI trigger for slaughtering policy	Constant	Euro	na	1,50E+07	Policy conceptualization		Policies
safe slaughtering policy switch	Constant	Dmnl	na	0	Policy conceptualization	0 - No policy 1 - Policy implemented	Policies
consumption behaviour policy	Variable	Dmnl	na	IF THEN ELSE(consumption behaviour policy switch = 0, 0 , IF THEN ELSE ((Cost of Illness-COI accumulated a year ago)<COI trigger for consumption behaviour policy,0, (PULSE(weeks per year,1500)*1)))	Policy conceptualization		Policies
COI accumulated a year ago	Level	Euro	na	DELAY FIXED (Cost of Illness, weeks per year,0)	Policy conceptualization		Policies
COI trigger for consumption behaviour policy	Constant	Euro	na	2,20E+07	Policy conceptualization		Policies
consumption behaviour policy switch	Constant	Dmnl	na	0	Policy conceptualization	0 - No policy 1 - Policy implemented	Policies
food safety policy	Variable	Dmnl	na	IF THEN ELSE(food safety policy switch = 1, IF THEN ELSE(Cost of Illness-COI accumulated a year ago > COI trigger for food safety policy , 1 , 0), 0)	Policy conceptualization		Policies
COI trigger for food safety policy	Constant	Euro	na	1,50E+07	Policy conceptualization		Policies
food safety policy switch	Constant	Dmnl	na	0	Policy conceptualization	0 - No policy 1 - Policy implemented	Policies