



A quantitative exposure model simulating human norovirus transmission during preparation of deli sandwiches



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ABSTRACT

Human noroviruses (HuNoVs) are a major cause of food borne gastroenteritis worldwide. They are often transmitted via infected and shedding food handlers manipulating foods such as deli sandwiches. The presented study aimed to simulate HuNoV transmission during the preparation of deli sandwiches in a sandwich bar.

A quantitative exposure model was developed by combining the GoldSim® and @Risk® software packages. Input data were collected from scientific literature and from a two week observational study performed at two sandwich bars. The model included three food handlers working during a three hour shift on a shared working surface where deli sandwiches are prepared. The model consisted of three components. The first component simulated the preparation of the deli sandwiches and contained the HuNoV reservoirs, locations within the model allowing the accumulation of NoV and the working of intervention measures. The second component covered the contamination sources being (1) the initial HuNoV contaminated lettuce used on the sandwiches and (2) HuNoV originating from a shedding food handler. The third component included four possible intervention measures to reduce HuNoV transmission: hand and surface disinfection during preparation of the sandwiches, hand gloving and hand washing after a restroom visit.

A single HuNoV shedding food handler could cause mean levels of 43 ± 18 , 81 ± 37 and 18 ± 7 HuNoV particles present on the deli sandwiches, hands and working surfaces, respectively. Introduction of contaminated lettuce as the only source of HuNoV resulted in the presence of 6.4 ± 0.8 and 4.3 ± 0.4 HuNoV on the *food* and *hand* reservoirs. The inclusion of hand and surface disinfection and hand gloving as a single intervention measure was not effective in the model as only marginal reductions of HuNoV levels were noticeable in the different reservoirs. High compliance of hand washing after a restroom visit did reduce HuNoV presence substantially on all reservoirs.

The model showed that good handling practices such as washing hands after a restroom visit, hand gloving, hand disinfection and surface disinfection in deli sandwich bars were an effective way to prevent HuNoV contamination of the prepared foods, but it also demonstrated that further research is needed to ensure a better assessment of the risk of HuNoV transmission during preparation of foods.

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1. Introduction

Human noroviruses (HuNoVs) are a worldwide important cause of food borne gastroenteritis and can easily contaminate food products via pre- or post-harvest contamination (Holvoet et al., 2014; Kotwal, 2013; Hall, 2012; Berger et al., 2010; Moe, 2008). Transmission of HuNoV is facilitated by several factors. A first factor is the low presumed 50% infectious dose (ID_{50}) of 18 segregated infectious NoV particles (Teunis et al., 2008). Other factors include the shedding of high amounts of virus particles (up to 10^{10} virus particles per gram feces) (Jeong et al., 2013; Lai et al., 2012; La Rosa et al., 2009; Atmar et al., 2008; Ozawa

et al., 2007; Lee et al., 2007; Chan et al., 2006), a high environmental stability (Hirneisen and Kniel, 2013; Wang et al., 2013; Baert et al., 2009a) and the frequent occurrence of asymptomatic infections (Jeong et al., 2013; Nicolay et al., 2011; Phillips et al., 2010). Regarding HuNoV post-harvest contamination of foods, a recent study found that in 42.5% of described HuNoV food borne outbreaks between 2000 and 2008 an infected food handler was responsible (Baert et al., 2009b). While catered foods and ready-to-eat foods are generally known as HuNoV vectors, deli sandwiches are in particular considered as ideal for post-harvest food borne HuNoV transmission as their preparation involves a lot of manipulations by food handlers. Additionally, the ingredients such as lettuce (that can be contaminated with HuNoV before manipulation by a food handler) used in deli sandwiches are often stored at low temperatures, allowing the conservation of HuNoV and

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Table 1
Overview of the input parameters used in the presented HuNoV exposure model.

Input association	Name of input parameter	Definition	[Unit]	Distribution type	Mean	Stdev ^a	Distribution parameters	Source
All HuNoV contamination sources	<i>HuNoV_genomic_copies_per_pfu</i>	HuNoV genomic copies per infectious HuNoV particle	Log	Normal (truncated)	3.65	0.98	Min: 2.00 Max: 5.40	Strong (2012), Verhaelen et al. (2012), Li et al. (2011), Kitajima et al. (2010), De Gussemme et al. (2010), Baert et al. (2008a) US Environmental Protection Agency (2011)
Contamination of food handlers' hands during restroom visit	<i>Surface_hands</i>	Surface area of both hands of a food handler	cm ²	Uniform	98.0	5.2	Min: 89.0 Max: 107.0	Mokhtari and Jaykus (2009), Lin et al. (2003), Gibson et al. (2002)
	<i>m_feces_hands</i>	Mass of feces on both hands of a HuNoV shedding food handler	Log(g/hands)	Beta (generalized)	−3.50	1.17	Min: −8.00 Max: −1.00 α : 4.57 β : 2.55	
	<i>HuNoV_in_feces</i>	HuNoV concentration per gram feces of a HuNoV shedding food handler	Log (HuNoV GC/g)	Log-normal	6.65	2.06	Min: 0.00 Max: 10.98 (truncated)	Jeong et al. (2013), Lai et al. (2012), La Rosa et al. (2009), Atmar et al. (2008), Ozawa et al. (2007), Chan et al. (2006) Mokhtari and Jaykus (2009)
	<i>HuNoV_restroom</i>	HuNoV level in restroom environment	Log (HuNoV/cm ²)	Uniform	1.0	0.6	Min: 0.0 Max: 2.0	Stals et al. (2013), Bidawid et al. (2004), Mbithi et al. (1992)
	<i>TE_RH</i>	Transfer efficiency of HuNoV from restroom to food handlers' hands	/	Triangular	10.9%	4.0%	Min: 3.6% Most likely: 7.0% Max: 22.0%	
	<i>Restroom_visits_FH1</i>	Number of restroom visits from a HuNoV shedding food handler during 180 min shift	/	Discrete normal	2	0.7	Min: 1 Max: 3	
		<i>Restroom_visits_FH2/3</i>	Number of restroom visits from a non HuNoV shedding food handler 2 during 180 min shift	/	Discrete uniform	0	0.5	Min: 0 Max: 1
Initial contamination of lettuce used on the deli sandwich	<i>Initial_contam_level_lettuce</i>	Initial contamination level of 5 g lettuce	Log(HuNoV genomic copies/g)	Log-normal	2.38	3.52	Min: 0.00 Max: 6.97	Kokkinos et al. (2012), Felix-Valenzuela et al. (2012), Mattison et al. (2010)
	<i>Initial_contam_chance_lettuce</i>	Chance of the lettuce used on the deli sandwich being contaminated with HuNoV (before manipulation by any food handler)	/	Beta (generalized)	8.64%	5.90%	Min: 0% Max: 20% α : 0.79 β : 1.03	Kokkinos et al. (2012), Felix-Valenzuela et al. (2012), Baert et al. (2011), Mattison et al. (2010), Cheong et al. (2009), Allwood et al. (2004) Observational study
Deli sandwich preparation	<i>Food_prep_per_15min</i>	Number of food servings prepared per 15 min by a single food handler	/	Normal	26.7	11.4		Observational study
	<i>Food_surface_contacts</i>	Number of food-surface (both directions) contacts per food preparation	/	Extreme value	2.5	0.2		Observational study
	<i>Food_hand_contacts</i>	Number of food-hand contacts (both directions) per food preparation	/	Triangular	7.8	0.6		Observational study
	<i>Hand_surface_contacts</i>	Number of hand-surface contacts (both directions) per food preparation	/	Extreme value	2.3	0.2		Observational study
	<i>TE_HF</i>	Transfer efficiency of HuNoV from <i>hands</i> reservoir to <i>foods</i> reservoir	/	Beta (generalized)	20.9%	12.8%	Min: 2.6% Max: 46.0% α : 0.76	Stals et al. (2013), Verhaelen et al. (2013), Zhao (2012), Bidawid et al. (2000, 2004)

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