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The risk of *Campylobacter jejuni* and *Campylobacter coli* associated with the consumption of fresh camel milk in Qatar

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ABSTRACT

Campylobacter spp. are among the ten top leading causes of foodborne diseases around the world and are capable of triggering severe gastroenteritis with potential for severe sequelae. Fresh camel milk is one of the most common hospitality gestures among certain cultures. We investigated the potential risk of illness from the consumption of camel milk contaminated with *Campylobacter* spp. in Qatar and identified critical intervention points that would contribute to mitigating its consequences. Quantitative risk assessment (QRA) methodology with a combination of deterministic and stochastic approaches was employed to address this objective. Data on the likelihood of either *C. jejuni* or *C. coli* in camel milk or in humans was obtained through repeat cross-sectional studies in these populations in Qatar. Estimates of the adverse health effects were computed using risk characterization which integrated data on the hazard, the probability of exposure, and dose-response models. Our analyses showed that the probability of illness for a healthy female from the consumption of camel milk contaminated with *C. jejuni* ranged from 5×10^{-3} to 24×10^{-2} depending on the amount of milk consumed. The risk of illness for males was higher (13×10^{-3} to 30×10^{-2}). The estimates of illness were three times higher for immunocompromised females in comparison to healthy females. Immunocompromised males had a five-times higher risk of illness in comparison to healthy men. The computed risk of illness from consumption of camel milk contaminated with either *C. jejuni* or *C. coli* could be significantly mitigated by increasing the efficacy of sterilizing or pasteurization before serving.

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1. Introduction

Illnesses due to foodborne diseases represent a major hinderance to advances in health systems worldwide. It is estimated that 48 million people become ill due to foodborne diseases per year in the US of which 128,000 cases being hospitalized and 3,000 resulting in death (1).

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Reports by the the World Health Organization (WHO) estimates the fatality at 2.2 million people worldwide per year associated with food and waterborne diseases alone (2). Although, one would expect that data on the amount of disease due to foodborne pathogens from individual country are available, information at the global level is missing. There is a prevailing perception that the estimated cost of disease per individual nation is high (3, 4). The Foodborne Diseases Burden Epidemiology Reference Group (FERG), which established by the WHO's Department of Food Safety and Zoonosis (FOS), is currently undertaking studies to estimate the worldwide burden of foodborne diseases. The group have listed *Campylobacter* spp. among the top challenges (2).

The ease of travel around the world and globalization of trade have exacerbated risk of foodborne pathogen transmission (5). This is especially true in countries where the demand for foreign labor is high, i.e. Qatar, where the ratio of natives to expatriates is 1:9. Areas of such cultural diversity are key to studying foodborne illnesses. *Campylobacter* is one of the major foodborne pathogens that contributes to the burden of disease in areas where the demand for foreign labor is high and the hygiene and sanatory measures among these labors is low (6). The risk of consumers contracting foodborne illnesses is increased by food consumption in public places due to potential post retail contamination. Current detailed data on the pathogenicity of foodborne pathogens is required to implement intervention strategies to mitigate the risks of transmission.

The practice of drinking fresh camel milk as a hospitality gesture or perceived medical benefit, is increasing around the world. Among certain cultures there is a prevailing perception that the consumption of fresh camel milk has a medical value against certain conditions such as diabetes, autism, and allergies (7). In addition to the fact that camel milk is the closest to human milk, it contains high levels of antioxidants and iron (8-10). However, in spite of its nutritional value, camel milk is reported to be contaminated with foodborne pathogens that have potential to cause disease in humans (11, 12). Knowledge of the occurrence and distribution of these pathogens in fresh animal products is needed in order to develop cost-effective strategies to mitigate their adverse health consequences.

Not only exposure to these foodborne pathogens leads to gastrointestinal symptoms, there is risk of chronic sequelae. The mechanisms by which these pathogens predispose hosts to these sequelae are poorly understood. Several studies hypothesize the role of cytolethal distending toxin (CDT) in the pathogenesis (13-15). However, the data remains scarce.

One of the important foodborne pathogens is *Campylobacter* spp. The pathogen is known to are among the leading causes of foodborne illness and are capable of triggering severe gastroenteritis with grave long-term sequelae and serious economic impact such as Inflammatory Bowel Disease (IBD) (16-18). The practice of drinking fresh camel milk, is increasing around the world because of the perceived medicinal value for health in general (8).

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In addition to the fact that camel milk is the closest to human milk, it contains high levels of antioxidants and iron (9, 19). Being a fresh product, it is exposed to foodborne pathogens, including *Campylobacter* spp. Understanding the pathway by which these hazards enter the food chain and pose risk to humans will help in developing risk mitigation strategies. We carried out a study to assess the potential risk of illness from the consumption of fresh camel milk contaminated with *C. jejuni* and *C. coli* in Qatar and to identify critical intervention points that would contribute to mitigating their associated risk.

2. Materials and Methods

To address the stated objectives, we employed the quantitative microbial risk assessment (QMRA) methodology using a combination of deterministic and stochastic approaches (20). The QMRA approach helps in identifying stages in the production system from farm-to-table that are likely to play a role in mitigating or exacerbating the risk of illness associated with the consumption of contaminated camel milk with this pathogen. The risk assessment consists of four complementary steps: hazard identification, hazard characterization, exposure assessment, and risk characterization.

2.1. Hazard Identification

The hazard of interest in this study is *Campylobacter* spp. There are two common species of this bacteria that are associated with disease in animal and humans: *C. jejuni* and *C. coli*. Data on the probability of these species in camel milk and humans were obtained through repeat cross-sectional studies in these populations in Qatar (12, 21). The presence of the pathogens in samples collected during the repeated cross-sectional studies in these populations in Qatar was determined using a combination of bacteriological enrichment and real time PCR detection (21, 22).

2.2. Hazard Characterization

These two species are known to cause diseases in animal and humans which is mainly characterized by gastroenteritis symptoms. The symptoms are generally mild but in immunocompromised, children, and elderly the clinical manifestation could be severe and some incidents could be fatal (23). One of the main routes of transmission is ingestion of contaminated food of animals' origin, including milk.

2.3. Exposure Assessment

Consumers getting exposed to the pathogens either at the farm or at home. Data on the probability of either *C. jejuni* or *C. coli* in fresh camel milk or in humans were obtained through repeat cross-sectional studies in these populations (22, 23). The presence of the pathogens in samples collected during the repeated cross-sectional studies in these populations in Qatar was determined using a combination of bacteriological enrichment and real time PCR detection (12).

2.4. Risk characterization

For the dose-response model we used the proposed model by Teunis et. al (24). All probabilities used in the model are listed in Table 1. Estimates of the adverse health effects for healthy individuals and immunocompromised individuals were obtained using risk characterization which integrated data on hazard characterization and exposure assessment, including dose-response models. The scenario pathway for the analysis is shown in Fig. 1. A Monte Carlo Simulation of inputs in the model was performed using the @Risk software (Palisade Software, Newfield, NY, USA) and parameters were obtained in the analysis using Latin Hypercube sampling. Sensitivity analyses were performed to capture the effect of uncertainty and variability of the different parameters used in the model on the predicted risk of illness.

3.Results

Figure. 1 shows the scenario-pathway model that was employed in the analysis. The food of interest was the camel milk which was either consumed directly on the farm or transported to homes to be served. In our observational study, a total of 50 fecal samples were collected from camels and the prevalence of *C. jejuni* and *C. coli* are shown in Figure. 2 (12). The occurrence of *C. jejuni* and *C. coli* in milk samples appears to be the same. We collected 50 camel milk samples from retail and none of them were positive. For the purpose of the risk analysis we used the upper limit for the zero-confidence interval which was computed as 7%. This value represented the probability of exposure.

The analyses showed that the probability of illness for a healthy female from the consumption of camel milk contaminated with *C. jejuni* or *C. coli* ranged from 5 x 10^{-3} to 24 x 10^{-2} (0.005 to 0.24) depending on the amount of camel milk consumed (Figure. 3). The analysis was performed for the average consumption of one pound at the time. However, the risk for males is higher, 13 x 10^{-3} to 30 x 10^{-2} (0.13 to 0.30). The estimates of illness are three times higher for immunocompromised females who consumed fresh camel milk. We also evaluated the risk of illness for immunocompromised males that consumed fresh camel milk and it was five times higher in comparison to healthy men. The risk of illness due to the consumption of camel milk contaminated with either *C. jejuni* or *C. coli* could be significantly reduced for either gender by increasing the efficacy of sterilizing the milk by boiling or pasteurization. Figure. 4 shows the frequency distribution of the probability of illness for healthy individuals. The 90% confidence interval among the population ranges from 2% to 54% depending on the on the health status of the consumer and the amount of contamination of the milk.

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Table 1. Parameters used in the model, their associated distribution, and the source of the estimate

Variable	Value used	Distribution	Source
Fecal samples	0.16	Beta (16+1, 100 + 7 -1)	Mohammed et al., 2015
Concentration in feces	5.0 cfu/g	Lognormal (5, 5)	
Probability in milk	0.05	Beta (5+1, 53 – 24 +1)	Mohammed et al., 2015
Probability at retail	0.07	Beta (7+1, 100 – 7 +1)	
Probability at home	0.25	Beta (38+1, 150 – 38 +1)	
Concentration at retail	500 cfu/ml	Pert (114, 571, 4286)	
Concentration at home	500 cfu/ml	Pert (71, 429, 2571)	
Dose-response model	0.005		Tunis et al., 2018
Probability of illness	0.25	Beta (25+1, 114 – 25 + 1)	Weam et al., 2016

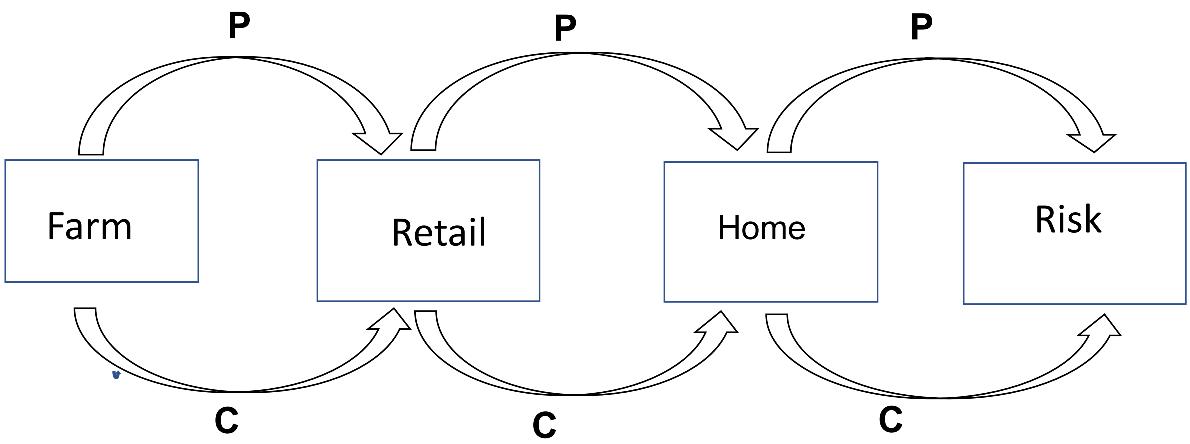

Figure 1. The hypothesized scenario pathway by which the target population would be put at risk of *Campylobacter* spp.

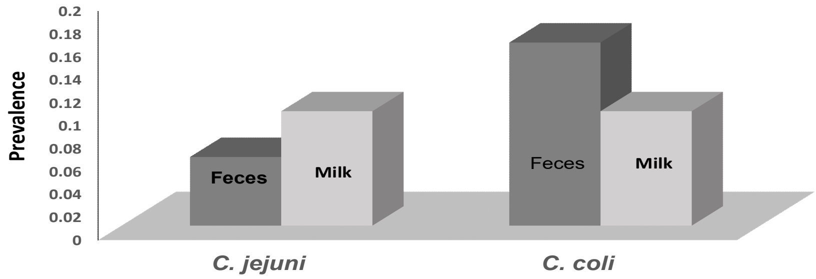

Figure 2. Prevalence of *Campylobacter* spp. in feces from camel and in milk samples collected at the farm

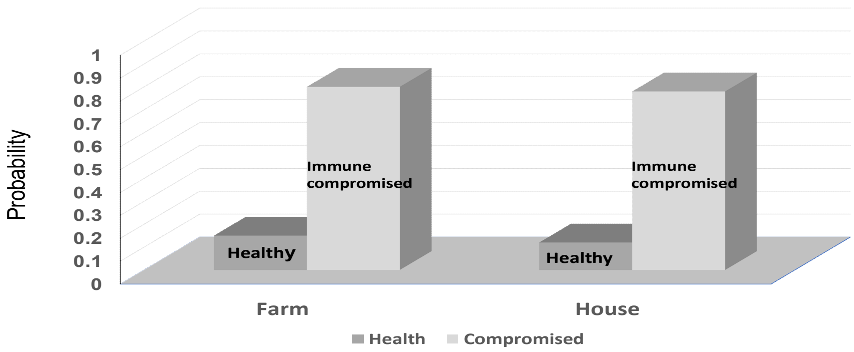

Figure 3. The probability of illness from drinking fresh camel milk contaminated with *C. jejuni and C. coli* in the two different scenarios: for healthy and immunocompromised individuals

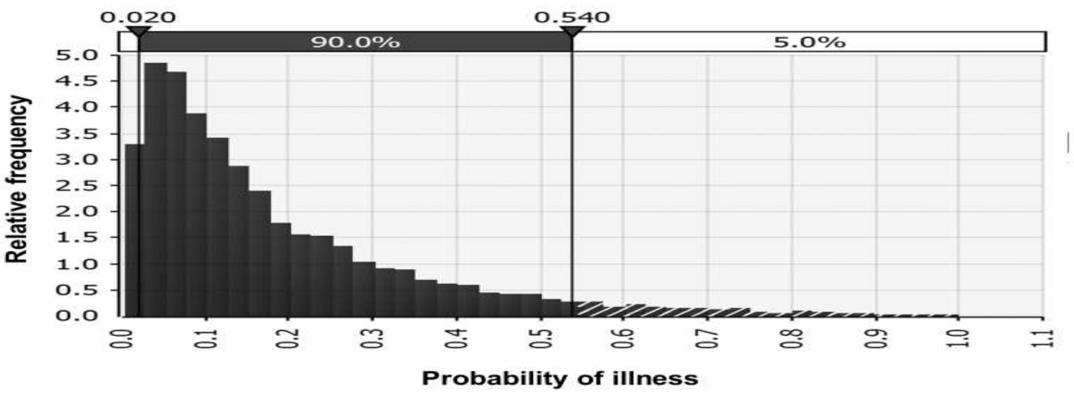

Figure 4. The relative frequency of the probability of illness at home from consuming camel milk contaminated with *C. jejuni*. as estimated with the proposed model

4.Discussion

The practice of drinking camel milk is common in the middle east and is gaining popularity because of the perceived nutritional value. Among nomads the practice of serving fresh camel milk is viewed as special hospitality for guests (10, 19). However, in spite of its many nutritional values, the milk poses a major health risk to the consumer because of its likely contamination with foodborne pathogens (12, 17).

One of the foodborne pathogens that has potential to pose risk to human health is *Campylobacter* spp. This pathogen is ranked among the top health risk in the worlds that impact the human health and has severe economic consequences (18, 25, 26). It has been reported in several food items from camels worldwide and in Qatar (12, 26-28). The clinical disease has been associated with acute intestinal disease and severe sequalae (29).

One of the advantages of quantitative risk assessment analysis (QRA) approach is that it provides guidance to health professionals about the probability of potential adverse health effects to populations from exposure to harmful foodborne pathogens such as *Campylobacter* spp. This knowledge could be used to implement intervention strategies to mitigate the cost associated with the adverse health impacts in a specific population. QRA models are used in different scenarios including the assessment of the risks associated with the consumption of food contaminated with pathogenic organisms (30, 31). The primary intent of this study was to inform public health professionals about the risk associated with a certain commodity so that cost-effective strategies could be implemented to ensure the wellbeing of the targeted population.

In addition, the public, producer, and the industry could use the knowledge gained from QRA to safeguard the health quality of the products and the health of consumers.

In this study we chose to use the beta-distribution to capture the uncertainty of the estimate of the presence of *Campylobacter* spp. in feces as a proxy for environmental contamination. The estimate of the prevalence of the pathogen was obtained in a cross-sectional study (12). However, we are not sure about the uniformity in application of sanitary measures among camel farms in the target population, hence we surmised that the variability in environmental contamination could be captured using the beta-distribution because of the versatility of the distribution. Some of the camel attendees clean the camel pens frequently and others do not keep the camels in pens. A similar approach was adopted in capturing the uncertainties associated with the presence *Campylobacter* spp. in milk and at retail (12, 21). However, we have not taken direct milk samples from retail but we understood that some of the milk is transported to households on instructions from the herd owner. Because of the weather temperature in Qatar, we assumed that the organism would multiply in milk during transportation.

There are several dose-response models for *C. jejuni* reported in the literature, but we have opted to use the one reported by Tunis et al., (24). The proposed model was developed with consideration of the variability among the pathogens and the susceptibility of the host.

The model argues that if the susceptibility of the host is high, then the exposure requires low doses, but if the susceptibility of the host is normal, which we assumed that the average in a population, then it requires high doses of exposure. Published data on the population in Qatar showed that the isolation rate of *Campylobacter* spp. among the individuals admitted to hospitals in Qatar with the diagnosis of gastroenteritis was 25% (32).

5.Conclusions

The use of the risk assessment approach provides a science-based justification for the awareness about the importance of the probability of adverse health effects associated with the consumption of raw camel milk and provides the foundation for risk managers and public health professionals to suggest intervention strategies to the public. We recognize that it is a challenge to the health professionals to intervene in the tradition, however it is imperative to educate the public about the risk associated with this foodborne pathogen.

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