Risk Assessment of Campylobacteriosis Due to Consumption of Roast Beef Served in Beer Bars in Arusha, Tanzania

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Summary
The objective of the study was to assess the risk of campylobacteriosis due to consumption of cross-contaminated nyama-choma (roast beef) sold in beer bars in Arusha Municipality, Tanzania.

In 2010, thirty butchers and thirty beer bars serving roast beef, selected using stratified random sampling, were visited to estimate the prevalence and the most probable number (MPN) of thermophilic Campylobacter in raw and roast beef. Ten purposively selected bars serving roast chicken were also surveyed, to assess cross-contamination after cooking, as Campylobacter spp. are generally more prevalent in poultry. One meat sample was collected in each butcher and each bar, and sales and hygiene were assessed through questionnaires and direct observation. A risk model was developed in statistical software R, and Monte Carlo simulation was performed to estimate disease incidence among customers and the adult male population in Arusha.

In the field survey, Campylobacter coli was recovered only from one chicken sample, of which bacterial concentration was 0.37 MPN/g (95% CI : 0.12–1.08). The daily incidence of campylobacteriosis among customers in Arusha was estimated to be 0.15 (95% CI : 0.02–0.95). Annual incidence rates among customers and in the adult male population in Arusha were 12.4 (95% CI : 1.2–83.6) per 1,000 and 0.6 (95% CI : 0.06–4.0) per 1,000, respectively. The most influential factor was the prevalence of thermophilic Campylobacter in roast beef, followed by MPN. Most (26/40, 65%) bar owners sold meat from different species of animals, and cross-contamination could easily occur between poultry and beef. Nearly half (18/39, 46%) the bar owners used the same knife for raw and roast meat. Although half (20/40, 50%) had received hygiene training there was no statistical association between training and separate use of knives for raw and roast meats, considered to be the major source of contamination (χ² = 0.22, df = 1, p = 0.64).

The study concluded campylobacteriosis from roast beef was a low public health issue in Arusha. However, considering the risks from other types of bacteria, improvement of cooking hygiene training was recommended to further reduce the risk of food-borne diseases from food consumed in beer bars.

Keywords: Campylobacter, Cross contamination, Risk assessment, Roast beef, Tanzania

1. Introduction
Campylobacteriosis is a zoonosis, that is, a disease transmitted to humans from animals or animal products, caused by Campylobacter spp. Globally, C. jejuni is one of the most commonly identified bacterial causes of acute gastroenteritis and a typical case is characterized by diarrhea, fever and abdominal...
cramps\textsuperscript{14, 20, 38}. *Campylobacter* infections are generally mild, but can be fatal among very young children, as well as among elderly and immunosuppressed individuals\textsuperscript{39}. Infections are often more frequent than those caused by *Salmonella* spp., *Shigella* spp. or *Escherichia coli* O157 : H\textsuperscript{7}\textsuperscript{25, 31}. In addition to diarrheal symptoms, *Campylobacter* infections have been identified as the most common antecedent to Guillain-Barré syndrome, an acute neurological disease\textsuperscript{24, 26}.

Some *Campylobacter* spp. grow best at 42°C. These are called thermophilic *Campylobacter* and *C. jejuni* and *C. coli* are clinically the most important. *C. jejuni* and *C. coli* are common components of the gut flora of warm-blooded animals including livestock (cattle, sheep and pigs), domestic pets and wild animals, and are especially prevalent in avian species\textsuperscript{7, 22}. Therefore, feces are the most frequent source of contamination of carcasses or meat during slaughtering\textsuperscript{39}. *Campylobacter* spp. are particularly sensitive to drying and reduced pH\textsuperscript{23}. *C. jejuni* is relatively sensitive to the lethal effects of heat, and dies after heating at 55°C for 0.6 to 2.3 minutes\textsuperscript{23}.

In developing countries, *Campylobacter* infections are hyperendemic among young children, especially those aged less than two years, and asymptomatic infections occur commonly in both children and adults. The illness lacks the marked seasonal patterns observed in developed nations\textsuperscript{29}.

In Morogoro Municipality, Tanzania, several studies have reported that *Campylobacter* spp. are prevalent in cattle, pigs, chickens, ducks, crows and humans\textsuperscript{21, 12, 26, 27}. Among these, a study showed that prevalences of thermophilic *Campylobacter* in cattle feces, dressed carcasses in slaughter house, and beef in meat shops were 5.6%, 9.3% and 1.9%, respectively, and that 88.9% of the isolates were *C. jejuni* and the rest (11.1%) were *C. coli*\textsuperscript{27}.

The Safe Food Fair Food (SFFF) project of the International Livestock Research Institute (ILRI) aimed to build capacity to conduct participatory risk analysis in resource-poor sub Saharan African countries to improve the safety of animal source foods in informal markets while enhancing market access for poor farmers\textsuperscript{29}. One of the project activities in Tanzania focused on a popular ready-to-eat food served in beer bars called ‘nyama-choma’ (roast beef); this is seasoned with salt and black pepper and served with relish (often consisting of uncooked tomatoes, onions and chilli peppers). These beer bars are not necessarily well regulated by the government, and are regarded as informal outlets. They are very popular among adult males, and play an important role in socialization. Ready-to-eat foods pose a risk for campylobacteriosis if they come into contact with raw foods or material contaminated with *Campylobacter*, and cross-contamination is a cause of approximately 30% of outbreaks\textsuperscript{39}. In a meta-analysis\textsuperscript{39}, prevalence of campylobacters among beef cattle was 62.1% (range : 42%–83%), and although *Campylobacter* is sensitive to heat as stated above, cross-contamination from raw meat can occur after beef is roasted especially if the same knife and cutting board is used for raw and cooked meat. The present study was conducted to understand the risk of campylobacteriosis from consumption of roast beef served in beer bars in Arusha, focusing on the most important thermophilic *Campylobacter*, *C. jejuni* and *C. coli*, as part of capacity development for risk assessment in Tanzania. This study involved sampling roast chicken, assuming post-cooking cross-contamination with thermophilic *Campylobacter* via a cutting board is similar for chicken and beef.

2. Materials and Methods

2.1. Study sites

This study was conducted in urban and peri-urban areas of Arusha Municipality in the northern part of Tanzania. Arusha Municipality is situated at latitude between 3°22' and 3°36’7”S and longitude between 36°41’ and 36°68’E, with an elevation of 1265 meters above sea level. The population of Arusha Municipality was 416,442 in 2012\textsuperscript{39}. The annual average rainfall is 800–1200 mm and the mean temperature ranges from 15 to 30°C.

2.2. Study design

The present study followed the format of Codex Alimentarius Commission microbiological food safety risk assessment\textsuperscript{21}, which involves hazard identification, hazard characterization, exposure assessment, and risk characterization, incorporating participatory methods, an approach known as “participatory risk assessment”\textsuperscript{13}.

2.3. Butcher and beer bar survey

Key informant interviews were conducted with veterinary officers in Arusha Municipality Abattoir to understand the geographical distributions of butchers and beer bars serving roast beef. In Arusha, butchers and beer bars serving roast beef are registered with the Arusha Municipality Business Office and a list of them was generated for this study.

In order to calculate sample size for prevalence study of *Campylobacter*, the following equation was used\textsuperscript{39}.

\[
N = 1.96^2 \times P_{\exp} \times (1 - P_{\exp})/d^2
\]  

(Equation 1)

As there was no report on the prevalence of *Campylobacter* on cooked beef in Tanzania, the prevalence on raw beef in meat shops in Morogoro, 1.9\%\textsuperscript{26} was used as the expected frequency (*P*\textsubscript{exp}). Required precision (1–d) was set to 95%. The sample size was calculated to be 28.6≈29, and 30 raw beef and 30 roast beef samples were targeted for collection.

We assumed that, if *Campylobacter* is isolated from roast beef, the bacteria was most likely the result of cross-contamination as bacteria would be eliminated from meat surface by heat during roasting, and that therefore bacteria levels would be determined by the level of hygiene of the bars, not by the animal species contaminated before roasting. In order to estimate the bacteria concentration of *Campylobacter* on roast beef likely to result from cross-contamination, ten roast chicken samples were additionally collected. Chicken was used as *Campylobacter* is most
common in chicken and hence more likely to be in the cooking environment where raw chicken meat is handled, making it a good indicator of cross-contamination levels. In September 2010, a field survey was conducted to determine the prevalence and the Most Probable Number (MPN) of thermophilic Campylobacter on raw beef, roast beef and roast chicken. In this survey, 30 butchers and 30 beer bars serving roast beef in urban and peri-urban areas were selected using stratified random sampling where strata were wards within Arusha Municipality. The number of butchers and beer bars within wards in Arusha were proportionally allocated, and butchers and bars were selected on the basis of first encountered. In addition, 10 purposively selected bars serving roast chicken (kuku-choma) in urban areas were visited. One sample of raw beef was collected from each butcher, and likewise one sample of roast beef or roast chicken from each bar. Written consent was obtained before administering a short questionnaire about sales and hygiene practice, and consumption patterns of customers, and meats sampled. Samples, which were slices of roast beef or chicken, the same form as served to customers, were collected in a sterile plastic bag with sterile equipment, cooled in a cool box packed with ice, and sent to the Veterinary Investigation Center, Arusha within 2 hours.

2.4. Isolation of Campylobacter and the estimation of MPN

The isolation and estimation of MPN of Campylobacter was conducted at the Veterinary Investigation Centre, Arusha. Fifty grams of samples, including raw beef, roast beef, and roast chicken, were rinsed with 25 ml of Phosphate Buffered Saline (PBS) and 1 ml of each three replicates of this solution and their 10 and 100 times diluted solutions were inoculated to Bolton selective enrichment broth (Oxoid Ltd, Basingstoke, UK) in airtight test tubes and incubated at 42°C for 24 hours. The enrichment cultures were then inoculated to CCDA agar and incubated at 42°C for 48–72 hours again in a micro-aerobic jar with Anero Pack Micro Aero (Mitsubishi Gas Chemical co., Inc.). One colony cultured on each CCDA agar was selected and sub-cultured on blood agar at 42°C for 48–72 hours. Conventional microbiological tests (Gram stain, oxidase and catalase tests) were performed for the isolates sub-cultured and the DNA of all the isolates was extracted using Insta Gene Matrix (Bio Rad). PCR was performed on the extracted DNA as the definitive identification for C. jejuni and C. coli in Rakuno Gakuen University, Japan. First, PCR based on 16S rRNA (rrs) gene was performed to co-identify C. jejuni and C. coli for all the DNA samples. The rrs gene-positive samples were tested for hip gene (specific to C. jejuni) and CCCH (specific to C. coli). As the rrs gene was positive only for one sample (see Results), randomly selected five negative samples were tested using 16S rRNA to ensure that enough volume of DNA were extracted, and all samples produced bands. All PCR amplifications were performed in a 25 μl solution containing 1 × Go Taq Green Master Mix (Promega), 1 μM primer and 2 μl DNA sample.

The mean (μ) of MPN was estimated based on the MPN table. The standard error (se) of MPN was estimated using below equation 3:

\[ se = 0.55 \sqrt{\frac{\log_{10} \alpha}{n}} \] (Equation 2)

Where \( n \) is the number of samples per dilution, three and \( \alpha \) is dilution ratio, ten. In the statistical software R version 3.0.2, the MPN was modeled using Log-Normal distribution with the mean (μ) and standard deviation (sd) which is a multiplication of se and \( \sqrt{n} \), thus is modeled as below.

\[ sd = 0.55\sqrt{\frac{\log_{10} \alpha}{n}} \] (Equation 3)

2.5. Risk assessment

Hazard identification (identification of an agent which can cause the adverse health effects to humans) was done through literature review as described in the introduction.

As part of hazard characterization, the dose-response relationship of thermophilic Campylobacter infection was modeled using a beta-Poisson model with the parameters alpha = 0.145 and beta = 7.59 of C. jejuni based on the human feeding studies using volunteers in USA. The dose was modeled by multiplying the MPN with consumption of roast beef per person (Qcon). Qcon was modeled by bootstrapping from 36 discrete distributions (response of consumption patterns from 36 bars) which showed the quantities of roast beef a customer consumed from selections of 250 g, 500 g, 750 g, and 1 kg in 36 bars. Each of 36 discrete distributions sampled one of the selections of the quantity based on the probability densities, of which one of 36 distributions was selected under the equal chance at a time. For the selection of a bar, a value was randomly sampled from the uniform distribution (0.5, 36.4) and rounded ; this value showed the identity of the bar to be sampled. This procedure was repeated for below mentioned iterations, and mean quantity was calculated using stored iteration results.

For exposure assessment, a beta distribution based on prevalence of thermophilic Campylobacter on roast beef (Pcon, Table 1) was applied. Thus probability of infection (Pinf) was modeled as below equation.

\[ P_{\text{infection}} = P_{\text{con}} \times \left(1 - \left(1 + \frac{MPN \times Q_{\text{con}}}{\beta} \right)^{-\alpha} \right) \] (Equation 4)

In the study by Black et al., onset of disease (fever and/or diarrhea) did not follow a beta-Poisson model. Therefore we modeled the probability of illness (Pill) by multiplying Pinf with a beta distribution expressing a probability of illness given infected, using the data reported in the study (Pill|infected, Table 1).

\[ P_{\text{ill}} = P_{\text{infection}} \times P_{\text{ill|infected}} \] (Equation 5)

For risk characterization, total daily incidence (Inc) in Arusha was simulated as below.
Inc_{day} = P_{ill} \times N_{Customers} \quad \text{(Equation 6)}

Where \( N_{Customers} \) is the number of customers visit beer bars serving roast beef. By observation, almost all customers were consuming roast beef during the survey, even if they ordered roast chicken as well, and in this model, we assumed all customers consumed roast beef. \( N_{Customers} \) was modeled by summing of 184 (the number of bars serving roast beef in Arusha) simultaneous random sampling from a pool of 29 records of the numbers of customers visiting a bar a day (Table 1). The numbers of customers were calculated dividing the total sales per day by the simulated means of quantities of beef consumed in the bars.

For the estimation of annual incidence, \( Inc_{day} \) was simply multiplied by 365 days as below.

\[ Inc_{ann} = Inc_{day} \times 365 \quad \text{(Equation 7)} \]

Annual incidence rate among customers \((IR_{Customers})\) was modeled as below equation, assuming patients are generated at the same rate for 365 days.

\[ IR_{Customers} = P_{ill} \times 365 \quad \text{(Equation 8)} \]

The annual incidence rate was modeled for adult males (point estimate), as follows. The adult male population was used as men make up almost all the consumers of meat in beer bars.

\[ IR_{adult} = \frac{Inc_{ann}}{Pop_{adult}} \quad \text{(Equation 9)} \]

Where \( Pop_{adult} \) is the adult male population in Arusha Municipality, 90,368, which was calculated by multiplying the total population in Arusha \((Pop_{Arusha})\) 416,442\(^{33}\) with the proportion of male over 20 years old among the Tanzanian population, that is 21.7\%, based on the United Nations database\(^{30}\).

The model was developed in RStudio in statistic software R version 3.0.2 and Monte Carlo simulation was run for 5,000 iterations. Sensitivity analysis was run for 5,000 iterations for each setting.

3. Results

3.1. Consumption of roast beef in beer bars

In Arusha, there were 184 beer bars serving roast beef registered at Arusha Municipal Business Office \((N_{bars}, Table 1)\). The median number of customers per day was 21 (range : 4–107) in these bars. The mean quantities of beef consumption per person were

| Parameters | Statistics | Distributions |
|------------|------------|---------------|
| Average consumption of roast beef per person (g \((Q_{Cons})\)) | 611 (95% CI : 340–778) | Bootstrap of Discrete distributions (selections : 250 g, 500 g, 750 g, 1 Kg). |
| Prevalence of thermophilic \textit{Campylobacter} in roast beef \((P_{Cont})\) | 4.1% (95% CI : 0.6%–12.8%) | Beta \((1 + 1, 40 - 1 + 1)\) |
| Most probable number/g \((MPN)\) | 0.37/g (95% CI : 0.12–1.08) | Lognormal distribution with mean 0.37, SD 0.55 |
| Dose-response parameters | Alpha = 0.145 \<br> Beta = 7.590 | Beta-Poisson model (Parameters solved using Black et al. 1988)) |
| Probability of illness given infected \((P_{ill|Infected})\) | 0.22 (95% CI : 0.13–0.35) | Beta \((11 + 1, 50 - 11 + 1)\) 11 of 50 infected people showed fever or diarrhea. Black et al. (1988) |
| Number of roast beef serving bars \((N_{bars})\) | Point estimates | Arusha Municipal Business Office |
| Number of customers ordering roast beef per day per bar | Median 21 (range : 4–107) | Daily sales/ consumption per person at 29 bars |
| Number of customers at all roast beef serving bars in Arusha per day \((N_{Customers})\) | 4,320 (95%CI : 3,803–4,916) | Sum of 184 bootstrap of the numbers of customers from 29 records |
| Population in Arusha Municipality \((Pop_{Arusha})\) | 416,442 | Tanzania National Bureau of Statistics (2013) |
| Adult male population in Arusha \((Pop_{adult})\) | 90,368 | \(Pop_{Arusha}\) and UNData., (2013) |
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3.2. Prevalence and MPN of thermophilic Campylobacter in raw and roast beef

Out of 70 samples (30 raw beef, 30 roast beef and 10 roast chicken), thermophilic Campylobacter was isolated from only one chicken sample; this was C. coli. By observation, beef and chicken were well roasted and if Campylobacter was present on beef, it was assumed to be due to post-roast contamination through handling of the meat. The prevalence of roast beef and chicken combined was 4.1% (95%CI: 0.6%–12.8%, note that this is the mean of beta distribution, not the mode (2.5%, 1/40)). In the sample from which C. coli was recovered, the numbers of the tubes contained the bacteria were one, one, and none for the tubes inoculating 1 ml, 0.1 ml, and 0.01 ml of meat rinse, respectively. The MPN of the contaminated sample was estimated to be 74 per 100 ml from the MPN table. As 1 ml rinse included bacteria washed from 2 g of meat, bacteria concentration was determined to be 0.37 MPN/g (95% CI: 0.12–1.08) (Table 1).

3.3. Hygiene practice among beer bar owners in the south zone

Hygiene was assessed in the 30 butchers and 40 bars studied. Seven of 30 butchers (23.3%) and eight of 40 beer bars (20%) had a refrigerator and all had tap water supply (Table 2). About half of butchers (53.3%) and beer bar owners (beef sampled bars: 46.7%, chicken sampled bars: 60%) had received hygiene training. However, there was no correlation between training and separate use of knives for raw and roast meat among beer bars (18/39, 46% used the same knife) ($\chi^2 = 0.22$, df = 1, $p = 0.64$). Sales of meats of more than one species of animals were common, and all the bars serving roast chicken sold roast beef as well. In these bars, use of the same utensils for meats from different animals was common (81.3% and 50% for beef and chicken sampled bars, respectively). In most of the bars, we observed the cutting board was shared for raw and roast meats.

In the beer bar where C. coli was isolated, chicken, beef and mutton were sold, and the same knife was used for different types of meats, but separate knives were used for raw and roast meats.

3.4. Risk characterization

The probability of campylobacteriosis due to consumption of roast beef was estimated to be 3.4 (95% CI: 0.4–22.5) per 10³ trials (Table 3). The daily incidence of campylobacteriosis was estimated to be 0.15 (95% CI: 0.02–0.95) cases in Arusha. The annual incidence rates among customers and adult males were 12.4 (95% CI: 1.2–83.6) per 1,000 (Figure 1), and 0.6 (95% CI: 0.06–4.0) per 1,000, respectively.

3.5. Sensitivity analysis

Table 4 shows the sensitivity analysis results. The most influential factor was the prevalence of Campylobacter in meat, followed by its MPN. The third most influential parameter was probability of illness in susceptible population given infection with thermophilic Campylobacter. The quantity of beef consumed and the numbers of customer were less influential.

4. Discussion

In this study, the risk of campylobacteriosis due to consumption of popular ready-to-eat "nyama-choma" beef in beer bars was assessed. This is the first comprehensive study on meat consumption in Arusha bars and the first risk assessment for roast beef in Tanzania. The risk estimated was low, and given the relatively

| Items                        | Butchers (n = 30) | Beef sampled (n = 30) | Chicken sampled (n = 10) |
|------------------------------|-------------------|-----------------------|--------------------------|
| Possession of a refrigerator | 7 (23.3%)         | 7 (23.3%)             | 1 (10%)                  |
| Use of tap water             | 30 (100%)         | 30 (100%)             | 10 (100%)                |
| Experience of a hygiene training | 16 (53.3%) | 14 (46.7%)              | 6 (60%)                  |
| Selling meats of more than one animal species | 2 (6.7%) | 16 (53.3%)              | 10 (100%)                |
| Use same utensils for meat of different animals | 2/2 (100%) | 13/16 (81.3%) | 5/10 (50%) |
| Use same utensils for raw and roast meat | NA | 17/29 (58.6%)* | 1 (10%) |

* One beer bar owner did not respond to the question
low consumption of beef in Tanzania (11 kg per capita per year), our finding supports other reports that campylobacteriosis resulting from roast beef consumption is not a major contributor to the burden of gastro-intestinal disease among adults in Tanzania, amounting to 1% and 7% of diarrhea cases. Large amounts of roast beef per person were consumed in bars (611 g), in contrast with the low beef consumption per capita, suggesting that beer bar customers may form a sub-population of frequent beef eaters. We conducted separate participatory appraisals in Tanzania (data not shown in the paper) to verify that this large consumption was correct, and we found it was plausible. Therefore the risk of campylobacteriosis due to consumption of roast beef may be limited to a sub-population.

This risk assessment has three limitations. First, in the exposure assessment, roast beef and roast chicken samples were combined to calculate the prevalence. Second, in order to investigate cross-contamination from chicken meat, prevalence in low chicken meat should have been studied. Third, again in order to prove cross-contamination via the cutting board, a question about sharing cutting boards for raw and roast meat should have been asked, and a swab from the cutting boards should have been sampled. These limitations were due to limited budget for this

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Table 3  Risk characterization results

| Items                                                                 | Estimated results                                      |
|-----------------------------------------------------------------------|--------------------------------------------------------|
| Probability of campylobacteriosis due to consumption of roast beef per 100,000 ($P_{illadj, 10^5}$) | 3.4 (95% CI : 0.4–22.5) per 100,000                   |
| Daily incidence ($Inc_{Day}$)                                         | 0.15 (95% CI : 0.02–0.95)                             |
| Annual incidence rate among consumers in beer bars per thousand ($IR_{Customers, 10^3}$) | 12.4 (95% CI : 1.2–83.6) per 1000                      |
| Annual incidence rate among adult males in Arusha per thousand ($IR_{AdultM, 10^3}$) | 0.6 (95% CI : 0.06–4.0) per 1000                      |

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Fig. 1  Probability density of annual incidence of campylobacteriosis among customers having nyama-choma in beer bars in Arusha
study. Also, in the informal markets, it was very difficult to conduct sampling from the cutting board while customers were observing.

The most influential factors for our risk model were prevalence of thermophilic Campylobacter in roast beef, and MPN. A risk assessment of Campylobacter spp. in broiler chicken suggested that reduction in prevalence had proportional effect in reduction of the risk, while that in level of contamination mild effect for highly contaminated chicken\(^9\). The order of influential factors was comparable to our study. Campylobacter is known to be sensitive to dryness, reduced pH and heat\(^{19}\), and it is unlikely to remain alive after being heated on roasted beef. On the other hand, campylobacters are known to become heat tolerant as a consequence of attachment to biological or other materials\(^{19}\). Moreover, campylobacters can exist in the viable but non-culturable (VBNC) state in a coccoid shape (they have spiral shape in the exponential phase)\(^{19}\), and thus we might have underestimated the prevalence. In our study, prevalence of Campylobacter in raw beef was low, however, considering possibility of Campylobacter becoming heat tolerant or VBNC, risk of campylobacteriosis due to survived Campylobacter may not be eliminated. Moreover, 53.3% of the beer bars where beef was sampled sold meats of more than one species of animals, and all bars where chicken was sampled sold roast beef as well. Therefore, considering the chance of cross-contamination of Campylobacter from chicken, in theory the risk of campylobacteriosis through consumption of roast beef exists, as shown in this study, although it was low.

The concentration of Campylobacter on meat has been studied in many countries\(^{1,40}\) but no results for Tanzania have been published. Moreover, the concentration of Campylobacter on roast meat has not been studied and the present study in Tanzania is the first report. The MPN in this study was comparable to that found in raw beef in New Zealand and USA\(^1,40\) but much higher levels have been found in raw un-weaned veal in New Zealand\(^{40}\) and similarly high concentrations are typical of chicken, especially from colonized poultry\(^{19}\). However, the MPN in this study was calculated using only one sample of roast chicken, not beef, which could result in biased estimates of risk. However, the MPN would not be much higher than this study considering the effect of heat so our study should not over-estimate risk.

There is much debate on the dose-response relationship for campylobacteriosis. The difficulty lies in the difference between dose-response of infection and illness. As mentioned in the materials and methods section, experimental data showed dose-response relationship for infection but not for illness\(^3\). Teunis et al.\(^{30}\) attempted to model the dose-response relationship of illness conditional to infection, using data from two outbreaks of campylobacteriosis due to milk contaminated among school children in the Netherlands\(^7\) and in the UK\(^9\). Many studies in developing countries have shown that children below 5 years old acquire immunity and incidence decreases with age; however, the protection is not perfect because cross immunity is less likely to occur\(^{19}\). The proportion of campylobacteriosis among diarrhea cases is reported to be higher in young individuals than adults in Tanzania ; 18% versus 1%\(^9\) and 16% versus 7%\(^21\), respectively, and our estimation may over-estimate the risk.

In considering control of campylobacteriosis due to roast beef consumption, prevention of cross contamination after roasting is critical. As stated above, we did not ask about sharing a cutting board, but this was assessed by observation during the survey. Sales of meats from different species of animals were common (65%), and cross-contamination of Campylobacter from chicken carcasses to roasted beef can easily occur on a shared cutting board. Future training for beer bar owners should emphasize the importance of disinfection of cutting boards, or ideally separate boards for raw and roasted meat, as well as for raw vegetables.

Because of lack of data, the estimates relied on several assumptions around exposure and susceptibility. In developing countries, detailed information is often lacking and cost of collection can be prohibitive. The “participatory risk analysis” entails the use of qualitative and secondary data in developing quantitative risk assessments (QRA)\(^{30}\). The assessments produced are less accurate than more costly QRAs but are more appropriate for resource poor contexts and can be followed by more rigorous assessments if required and funded.

In conclusion, the risk for campylobacteriosis due to consumption of roast beef in beer bars in Arusha was low, but we cannot state that beef was safe as we did not study about the other pathogens. Further improvement of food hygiene can be achieved by better training program emphasizing on the separate use of utensils between raw and roast meat.
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原著

タンザニア国アルーシャのビール・バーで提供される
牛焼き肉喫食によるカンピロバクター症のリスク評価

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要旨

本研究は、タンザニア国アルーシャ市のビール・バーで
販売されている「ニャマチョマ」と呼ばれる焼き牛肉の、
カンピロバクター交差汚染によるリスクを評価することを
目的として実施された。

2010年に、生牛肉と焼き牛肉における好熱性カンピロバクターの汚染率と最確数推定のため、層化無作為抽出した精肉店30件と焼き肉を提供するビール・バー30件を訪問した。さらに、カンピロバクターは一般的に家禽類より多く保菌されているので、交差汚染の状態を観察するため焼き鶏肉を提供するバー10件を有意抽出して調査した。

各精肉店とバーで一点の肉を収集し、質問票と直接観察により、販売ならびに衛生状況を評価した。リスクモデルを統計ソフトRで作成し、モンテカルロシミュレーションにより、アルーシャにおけるバーの客と成人男性集団における疾病発生率を推定した。

フィールド調査では、唯一焼き鶏肉サンプル1点からCampylobacter coliが検出され、その最確数は0.37/g（95%CI：0.12-1.08）であった。アルーシャ市全体で、利用客における一当日当たりカンピロバクター症発生数は0.15人（95%CI：0.02-0.95）と推定された。利用客およびアルーシャ市成人男性における年間発生率は、千人当たりそれぞれ12.4人（95%CI：1.2-83.6）と0.6人（95%CI：0.06-4.0）と推定された。最も結果に影響を与える因子は焼き牛肉における好熱性カンピロバクター汚染率であり、次に最確数であった。多くのバー経営者（26/40, 65％）は異なる動物種由来の肉を提供しており、鶏肉と牛肉間での交差汚染は起こりやすい状況であった。ほぼ半数（18/39, 46％）の経営者は生肉と焼き肉に同じ包丁を使用していた。経営者の半数（20/40, 50％）が調理衛生研修を受講していたにも関わらず、研修の受講歴と交差汚染の主な原因と考えられる生と焼き肉の包丁の使い分けの実践とは統計学的関連性がなかった（χ²=0.22, df=1, p=0.6）。

結論として、焼き牛肉喫食によるカンピロバクター症は公衆衛生学的重要性が低いことが分かった。しかしながら、他の菌種のリスクを考えると、ビール・バーの食品による食中毒リスクをさらに低減するには、調理衛生研修内容の改善が望まれる。