Quantitative risk assessment of *E. coli* in street-vended cassava-based delicacies in the Philippines

I C P Mesias

Department of Food Science and Technology
Visayas State University, Baybay City, Leyte, Philippines

Email: inishchris.mesias@vsu.edu.ph

Abstract. In the Philippines, rootcrop-based food products are gaining popularity in street food trade. However, a number of street-vended food products in the country are reported to be contaminated with *E. coli* posing possible risk among consumers. In this study, information on quantitative risk assessment of *E. coli* in street-vended cassava-based delicacies was generated. The assessment started with the prevalence and concentration of *E. coli* at post production in packages of the cassava-based delicacies. Combase growth predictor was used to trace the microbial population of *E. coli* in each step of the food chain. The @Risk software package, version 6 (Palisade USA) was used to run the simulations. Scenarios in the post-production to consumption pathway were simulated. The effect was then assessed in relation to exposure to the defined infective dose. In the worst case scenario, a minimum and most likely concentration of 6.3 and 7.8 log CFU of *E. coli* per serving respectively were observed. The simulation revealed that lowering the temperature in the chain considerably decreased the *E. coli* concentration prior to consumption and subsequently decreased the percentage of exposure to the infective dose. Exposure to infective dose however was increased with longer lag time from postproduction to consumption.

Keywords: quantitative risk assessment, street-vended cassava-based delicacies, *E. coli*

1. Introduction
The Food and Agricultural Organization defines street food as a ready-to eat food and beverage prepared and/or sold by vendors on the street from pushcarts, buckets, balance pole, stalls or shops having fewer than four permanent walls. It encompasses a wide range of ready-to-eat foods and beverages prepared and/or sold by mobile or stationary vendors and hawkers especially on streets and around public places [1-5]. Such foods feed millions of people daily with a wide variety of foods that are relatively cheap and easily accessible. In selling snacks, complete meals, and refreshments at relatively low prices, vendors provide an essential service to students, workers, shoppers, travellers, and people on low income [6]. People who depend on such food are often more interested in its convenience than in questions of its safety, quality and hygiene. However, to date, it is well known that majority of the reported contamination of food that contributes to food-borne disease in countries is associated with street-vended foods [7-8]. In developing countries, since infrastructure development was relatively limited, with restricted access to potable water, toilets, refrigeration and washing and waste disposal facilities [9], food-borne illnesses are occurring and recurring.

In the Philippines, increasing pace of urbanization has resulted in proliferation of street food vendors and hawkers as the movement of people from rural to urban areas has led to the need to feed
large numbers of working people away from their place of residence. Street food vending became a popular type and distinctive part of a large informal sector providing the vendors with a means to sustain their livelihood. While the importance of street-vended food is not to be negated as an important source of nourishment as well as income and work opportunity offered for the informal sector, the safety of the food is a particular problem, especially from a microbiological point of view. However, in the country, studies investigating the epidemiological link between street foods and food borne diseases, profile of street food vendors, hygiene practices as well as the microbial quality of street-vended foods were considerably limited. In the Philippines, as much as 70% of diarrhea diseases are believed to be of foodborne origin. Although the government authority is making initiatives to ensure public health and consumers safety in street-vended foods, nevertheless, strategies for efficiently improving food safety can only be developed after obtaining science-based studies on local foods, conditions and practices along each area from the production to consumption. Quantitative microbial risk assessment (QMRA) for instance is considered as a very indispensable tool in estimating the risk of a certain pathogen along the food chain. With QMRA, scientifically-supported information can be provided to help risk managers set priorities, decisions and strategies for the most effective intervention. In this paper therefore, risk assessment of \textit{E. coli} in the street-vended cassava-based delicacies in the Philippines is presented. These delicacies are contributing a large portion in the wide range of the most commonly marketed street foods in the country.

2. \textbf{Quantitative risk assessment methodology}

2.1 \textit{Statement of purpose}

A number of street-vended food products in the Philippines are reported to be contaminated with \textit{E. coli} \cite{8}. This has caused concern among regulatory agencies, particularly because a lot have been patronizing such products across population. This assessment aimed to estimate the risk to a general consumer of the street vended cassava delicacies. A simplified retail to consumption pathway was constructed as series of unit operations. The assessment started with the prevalence and concentration of \textit{E. coli} at postproduction/retail in packages of these cassava-based delicacies and traced growth of the microbial population in contaminated product through to the point where the consumer eats a portion. Cross-contamination was not considered. This was to simulate the prevalence and levels of \textit{E. coli} in those portions that, along with serving size, determine the size of the dose of \textit{E. coli} that a consumer might ingest. To characterize the risk to consumers, the variables that were considered in this exposure assessment include: \textit{E. coli} prevalence and concentration in the cassava-based delicacies, growth rate, pH, water activity and time and temperature during transport and storage.

2.2 \textit{Approach taken/ model design}

A simplified post-production to consumption pathway was constructed as series of unit operations along with their associated variables for microbial events (Figure 1). The pathway comprised of initial contamination after production (node 1), growth during transport from production area to market (node 2), growth during storage at market (node 3), growth during transport from market to home (node 4), growth during storage at home prior to consumption (node 5) and dose response after consumption (node 6).
Figure 1. Simplified post-production to consumption pathway of the cassava-based delicacies alongside with the variables influencing E. coli growth in different node.

The input settings for initial contamination at retail in node 1 are contributed by the level of E. coli contamination and the prevalence of E. coli in cassava-based delicacies at post production. Primary data of the initial contamination of the products were used: minimum and maximum contamination of 0.48 and 1 log CFU/g respectively. In node 2 through 6, microbial growth was expected due to pH, water activity (a_w) and transport and storage variables such as temperature and time. Combase growth predictor was used to predict the growth of E. coli in each step of the chain. The pH value of 5.97 (primary data) and a_w of 0.97 were made constant. The time required to transport from the production area to market were presumably between 1-2.25 hours based on a typical production to retail set up in the country. A maximum time required for storage at market of 8 hours, maximum time for transport from market to home of 2.25 hours and maximum storage time at home prior to consumption of 12.25 hours were used in modelling the growth of the E. coli. The surrogate temperatures used were the recorded minimum and maximum ambient temperature in the Philippines, 26.9°C and 31°C respectively (Philippine Atmospheric Geophysical and Astronomical Services Administration). Since the available data was for generic E. coli and only a portion of them can be pathogenic, 4.5 and 5% of pathogenic E. coli specifically for ready to eat products were used to determine the number of pathogenic E. coli from the total concentration obtained. The fraction of pathogenic E. coli in street-vended cassava delicacies was obtained by multiplying the fraction of pathogenic E. coli by that of the total E. coli.

For the dose response, infective doses of $10^6$ to $10^8$ CFU for enterotoxigenic (ETEC), enteroinvasive (EIEC) and enteropathogenic E. coli (EPEC) were used. ETEC is recognized as the causative agent of travelers’ diarrhea and illness is characterized by watery diarrhea with little or no fever and occurs commonly in under-developed countries. EIEC closely resemble Shigella and causes an invasive, dysenteric form of diarrhea in humans while EPEC causes a profuse watery diarrheal disease and it is a leading cause of infantile diarrhea in developing countries (USFDA). Pert distribution was used for the dose-response assessment with a minimum value of $10^5$, most likely value of $10^6$ and a maximum of $10^8$. The risk on illness per serving was obtained by dividing the exposure per serving by the dose response.

2.3 Model simulation

The @Risk software package version 6 (Palisade USA) was used to run the simulations. Monte Carlo simulations were run three times using 10,000 iterations.
2.4 Sensitivity analysis
Various scenarios in the post-production to consumption pathway were simulated. The effect was then assessed in relation to exposure to the defined infective dose. First scenario evaluated was the impact of the temperature all throughout the chain. Three temperature conditions were evaluated: Philippines’ average maximum temperature (29°C), average minimum temperature (22°C) and refrigeration temperature (10°C) was used since this is the lowest possible temperature in Combase). The second scenario dealt with the effect of lag time after production prior to consumption: after 13, 19, 25 and 37 hours.

3. Results and discussion
3.1 Frequency distribution of E. coli concentration at the time of consumption
As depicted in figure 2, in 100% of the cases, the consumers would be exposed to the infective dose of 6-8 log CFU of E. coli per serving. A minimum and most likely concentration of 6.3 and 7.8 log CFU of E. coli per serving were observed. The risk on illness per serving was 63.61. The result was anticipated in this case since aside from the initial concentration of E. coli contamination used, the surrogate storage and transport time/temperature combination was at its maximum or in the worst case scenario.

![Figure 2. Frequency distribution of E. coli concentration in the street-vended cassava delicacies at the time of consumption. Values in x axis are in log CFU/serving](image)

3.2 Effect of temperature on the E. coli concentration: postproduction to consumption
The effect of temperature on the growth rate and concentration of E. coli in the street-vended cassava delicacies was observed distinctly in the simulation. Using the three different temperature conditions, results revealed that lowering the temperature in the chain considerably decreased the E. coli concentration prior to consumption (Table 1 and Figure 3). Subsequently, a decrease in percentage of exposure to the infective dose of E. coli was attained with lower temperature (Figure 4). It should be noted that at the average minimum temperature of 22°C and at 10°C, percentage exposure to 10⁸ infective dose is zero. However, for the infective dose of 10⁶, 0% exposure can be attained as the temperature approaches < 5°C. This implies for the importance of storing the cassava delicacies at refrigeration temperature at any point of the chain.

Using the average maximum temperature condition in the Philippines, the risk on probability of illness was 63.61 while 1.92 for average minimum temperature.
Table 1. Effect of temperature on the exposure per serving of *E. coli* (log cfu/serving) in the street-vended cassava delicacies.

| Philippine Temperature Condition | Min* | Max* | Mean* | SD  | 25  | 50  | 75  | 90  | 95  |
|----------------------------------|------|------|-------|-----|-----|-----|-----|-----|-----|
| Average Maximum Temperature (29°C) | 6.22 | 9.68 | 7.97  | 0.53| 7.60| 7.96| 8.34| 8.67| 8.84|
| Average Minimum Temperature (22°C) | 5.30 | 7.52 | 6.45  | 0.34| 6.21| 6.45| 6.68| 6.89| 7.01|
| At 10°C | 4.69 | 6.94 | 5.83  | 0.34| 5.60| 5.83| 6.06| 6.26| 6.38|

Min- minimum; Max- maximum; SD- Standard Deviation; * Values are in log cfu/serving

![Graph A](image1.png)

**Figure 3.** E. coli concentration plotted against percentile in street-vended cassava-based delicacies exposed to different temperature: retail to consumption

![Graph B](image2.png)

**Figure 4.** Effect of temperature in the exposure to the infective dose of *E. coli*

3.3 Effect of time on the *E. coli* concentration: postproduction to consumption
The impact of lag time from postproduction to consumption (13, 19, 25 and 37 hours) on the concentration of *E. coli* was also evaluated. Typically, cassava delicacies can last 2-7 days depending on the handling and storage condition. Based on the simulation, not much appreciable increase in the *E. coli* concentration was indicated within 24 hours and values lower than the minimum infective dose of 6 log cfu/serving were noted (Table 2 and Figure 5). On the other hand, exposure to infective dose was increased with longer lag time from postproduction to consumption (Figure 6).

**Table 2.** Effect of time on the exposure per serving of *E. coli* (log cfu/serving) in the street-vended cassava delicacies: retail to consumption period.

| Postproduction to Consumption Period | Min* | Max* | Mean* | SD    | 25   | 50   | 75   | 90   | 95   |
|-------------------------------------|------|------|-------|-------|------|------|------|------|------|
| After 13 hours                      | 5.08 | 7.24 | 6.17  | 0.33  | 5.94 | 6.18 | 6.40 | 6.59 | 6.71 |
| After 19 hours                      | 5.12 | 7.39 | 6.24  | 0.33  | 6.02 | 6.24 | 6.47 | 6.67 | 6.79 |
| After 25 hours                      | 5.30 | 7.52 | 6.45  | 0.34  | 6.21 | 6.45 | 6.68 | 6.89 | 7.01 |
| After 37 hours                      | 6.14 | 8.51 | 7.31  | 0.35  | 7.06 | 7.31 | 7.56 | 7.77 | 7.89 |

Min- minimum; Max- maximum; SD- Standard Deviation; * Values are in log cfu/serving

**Figure 5.** *E. coli* concentration plotted against percentile in street-vended cassava-based delicacies exposed to different time: retail to consumption.

**Figure 6.** Effect of time in the exposure to the infective dose of *E. coli*. 
4. Conclusion and recommendations
The risk assessment study revealed high exposure to the infective dose of E. coli with temperature and time abuse. Thus, both temperature and time should be controlled to reduce the risk of food borne illness from street-vended cassava delicacies. There is a need for stricter implementation of the food sanitation code. It is recommended that every food handler has to undergo proper training with regard to basic food hygiene, transport and storage of food and lag time between preparation and dispensing of food items to the consumers. Consumer awareness as to how to handle and store such products must also be promoted.

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Acknowledgement
The author would like to thank the Faculty of Bioscience Engineering, Department of Food Safety and Food Quality, Ghent University, Belgium and Flemish Interuniversity Council (VLIR—UOS) for organizing the training programme on Food Safety, Quality Assurance Systems and Risk Analysis. Above all, interminable thanks are due to the Philippine Council for Industry, Energy and Emerging Technology Research and Development (PCIEERD) Human Resource and Institution Development Division for the travel grant awarded to the author.