# Title: Risk Assessment for *Brucella abortus* Infected Milk in Urban Areas of Kampala, Uganda

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## ABSTRACT

A stochastic risk assessment involving two field surveys (cattle farms and milk shops) was conducted to assess the risk of purchasing raw milk infected with *Brucella abortus* in urban Kampala and to identify the best control options.

In a cattle farm survey, sera taken from 425 cows from 177 herds in 56 Local Councils (LC1s) from the Kampala economic zone were sampled and diagnosed with brucellosis using a competitive enzyme-linked immunosorbent assay (CELISA). Farmers were interviewed for information regarding dairying practice. In a survey of milk shops, 59 milk shop proprietors in 24 urban LC1s were interviewed to identify the informal dairy market chains. These shops, wholesalers and boiling centers traced back and milk venders encountered during the survey were interviewed and milk was sampled; in total, 138 sellers were interviewed and 117 milk samples were collected and tested using an indirect enzyme-linked immunosorbent assay (IELISA). A risk model was developed synthesizing data from these two surveys. Possible control options were prepared based on the model and the reduction of risk was simulated for each scenario.

Overall, 12.2 % (6.3-19.0: 90%CI) of milk consumed in urban Kampala was infected with *B. abortus* at purchase. The best control option was to construct a milk boiling centre either in Mbarara, the largest source of milk, or in peri-urban Kampala and to ensure that milk traders to sell milk to the boiling centre, of which 90% success of enforcement would reduce risk by 62.6% and 75.3%, respectively.

## KEYWORDS

Brucellosis, risk assessment, milk, urban, Kampala, Uganda

## INTRODUCTION

Brucellosis is one of the world's most widespread zoonoses (WHO 2009). In Kampala, Uganda, studies have shown a significant prevalence of human brucellosis, and the poor correlation between the distribution of human cases (urban) and cows (peri-urban and rural) suggested that brucellosis infections are occurring through dairy market chains (Makita *et al.* 2008). Bernard (2005) reported high cattle herd prevalence of brucellosis (55.6%: 95% CI 50.0–61.2) in Mbarara, the largest dairy production area in Uganda. This paper assesses the risk of purchasing raw milk infected with *Brucella abortus* for urban populations living in Kampala (rainy season) and identifies the best options for control of human brucellosis in the areas.

## MATERIAL AND METHODS

A stochastic risk assessment involving two field surveys (cattle farms and milk shops) was conducted in the Kampala economic zone, Uganda using the Codex Alimentarius Commission risk assessment system. In the beginning, 87 LC1s (Local Council 1: village) were randomly selected from 790 LC1s in the 10 LC3s (Sub-counties) where more than half of the area is located between 5 to 20 km distance from the Kampala city centroid. These 87 LC1s were classified into 48 urban, 11 peri-urban and 16 rural LC1s according to the criteria developed by the author (publication in preparation) and LC1 leaders and residents were interviewed for dairy information. Cattle were kept in 56 (29 urban, 11 peri-urban and 16 rural) out of 87 LC1s, and 24 of 48 urban LC1s had informal milk shops selling unpackaged milk.

The survey of farm cattle was conducted in the 56 LC1s using multistage random sampling. Sera from 425 milking cows in 177 herds were sampled during October and November 2007and diagnosed with brucellosis using a competitive enzyme-linked immunosorbent assay (CELISA). During the survey, farmers were interviewed for information about their farms, milking cows, sales destination and milk yielding using a structured questionnaire.

The milk shop survey was conducted at 59 milk shops selling unpackaged milk in the 24 urban LC1s to identify the informal dairy market chains. These shops, wholesalers and boiling centers traced back and milk venders encountered during the survey were interviewed and milk was sampled; in total, 138 sellers were interviewed and 117 unpackaged milk samples were collected during September and October, the rainy season of 2007 and tested using an indirect enzyme-linked immunosorbent assay (IELISA).

A risk model was developed synthesizing the data from these two surveys for the exposure assessment. The risk in this model was expressed with a proportion of milk infected with *Brucella* as $R_i = I_i \times P_i$, when R is risk, I is infection rate, and P is proportion of milk distributed through the risk pathway $i$ among total daily quantity of unpackaged milk consumption in urban Kampala. Firstly, milk shops were categorized as wholesalers, milk shops with a bulk cooler, with a small refrigerator and without refrigerator, traders with milk cans on a bicycle and roadside venders. Milk source was also categorized as Mbarara dairy production areas, Nakasongola/Luwero production areas, rural Mukono and Kayunga, and urban and peri-urban areas of Kampala. Secondly, infection rate of milk at farms and probability of boiling at each step of the value chain were calculated. Finally, a dairy value chain tree model, starting from the farms to consumers, was constructed on an Excel worksheet. On a worksheet, data and formulae were entered in each destination node describing about the risk pathway flowing into the node. Data and formulae entered were the quantity and the proportion of milk entering the destination node, infection rate at the previous node before treatment (boiling/not boiling), probability of boiling milk at the previous node, infection rate of milk and the risk at the destination node. The infection rate at the destination node ($I_i$) was fed into the calculation at the next destination node ($i$+1) to calculate the risk ($R_{i+1}$), until the pathway reaches to the consumers. When several pathways flow into a node, the infection rate at the previous node before treatment ($I_{i-1}$) was calculated as $I_{i-1} = \Sigma R_i / \Sigma P_i$. The final risks of all the pathways reached to the consumers were added up to calculate the total risk. The stochastic risk inputs used in this model were (1) quantity of milk with daily variety of a week (as to operate the shop or not) using Discrete distribution with the same probability of selection of a day of a week, (2) infection rate at the dairy production areas obtained from the milk IELISA using Beta distribution and (3) infection rate at the urban and peri-urban farms obtained from farm cattle survey using Trigen distribution with a mode which makes the mean calculated as same as the division of sum of total milk produced by CELISA positive herds by sum of total milk yielded by the herds tested, and $5^{th}$ and $95^{th}$ percentiles estimated from the mean and the number of herds tested (177) using one proportion Chi square test. Trigen distribution was used as the herd level brucellosis prevalence: 6.2% (95% CI: 2.7-9.8) differed from the proportion of milk produced by the infected herds. Infection rates (IELISA) were corrected to a true rate (Rogan 1978) with sensitivity 0.953 and specificity 0.951 for pooled bulk milk samples (Rivera 2003). Monte Carlo simulation was then performed with 10,000 iterations with @Risk (Palisade).

Hazard and risk characterizations were performed qualitatively with six point scale measurements (negligible, very low, low, moderate, harmful and very harmful; and negligible, very low, low, moderate, high and very high, respectively).

Eight possible control options were prepared based on the model and the risk was simulated with @Risk for each scenario assuming 90% of enforcement was achieved. Reduction of risk were calculated using the point estimates, and necessary inputs, challenge, feasibility, sustainability and negative impact were assessed qualitatively to find the best control option of human brucellosis in urban areas of Kampala.

## RESULTS

In urban and peri-urban Kampala, 18.6% of milk produced was infected. The mean infection rates and 90% confidence intervals of raw milk sourced from Mbarara, Nakasongola and Mukono dairy production areas were 11.4% (9.1-25.9), 24.7% (9.6-56.0) and 36.1% (14.2-72.8), respectively. The boiling of unpackaged milk was not common in Kampala; none of 48 wholesale and milk shops with a bulk cooler and 4.5% (1/22) of bicycle venders sold boiled milk. In total, 8.2% of unpackaged milk sold was boiled before selling. Overall, 12.2% (6.3-19.0: 90%CI) of milk consumed in urban Kampala was infected with *B. abortus* at purchase. The most significant source of risk was milk shops with bulk coolers which accounted for 67.5% of total risk and 96.6% of the risk sourced from Mbarara dairy production areas. Purchasing infected milk does not necessarily cause brucellosis; however considering the high prevalence of human brucellosis reported (Makita *et al*. 2008), the chronic nature of the infection and confusion in diagnosis with malaria, the hazard of purchasing infected milk was deemed as harmful and considering the results of exposure assessment, the risk was judged as high.

The greatest reduction in mean risk (75.3%) could be achieved by the introduction of boiling centers in peri-urban areas and by enforcing traders and peri-urban dairy farms to sell milk to these centers. However the cost of the construction, legislation, enforcement present challenges and the retail price of milk would increase. The next greatest reduction (69.2%) could be achieved by enforcing milk shops to boil milk or to sell only boiled milk; however this option is not feasible as most shops could ill afford this in terms of cost and space of installation of such a facility. Constructing a boiling centre in Mbarara production areas and enforcing traders and farmers to sell milk to it would be another good option and this would reduce risk by 62.6%. This would be efficient since the majority of milk sold in the shops with a bulk cooler is from Mbarara production areas. A ban on farming in urban areas would reduce risk by 15.3% but it would affect the livelihoods of many farmers and impact on the availability of milk for the urban consumers. A ban on milk sales by traders with milk cans on a bicycle (6.2%), roadside vendors (0.6%), milk shops without a refrigerator (0.7%) and at the farm gate (11.9%) would not change the risk since it would not assure that milk is boiled by the alternative distributors.

## CONCLUSION

The risk of purchasing raw milk infected with *B, abotus* in urban areas of Kampala during rainy season is high. A recommendation to reduce the risk would be to construct a milk boiling centre either in Mbarara, the largest source of milk, or in peri-urban Kampala and to ensure that milk traders to sell milk to the boiling centre. This option is expensive and would require legislation and may be difficult to enforce. The urban residents will be affected by the increase of retail price of milk. However, these challenges should be overcome in order to secure the food safety in Kampala. Awareness of this important public health problem among health policy makers as well as consumers needs to be raised.

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