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RISK FACTORS OF EXPOSURE TO *BRUCELLA* THROUGH MILK CONSUMPTION IN CATTLE KEEPING HOUSEHOLDS IN RWANDA

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ABSTRACT

Milk produced in Rwanda and consumed in cattle keeping households poses undocumented food safety risks including the transmission of the zoonotic brucellosis from animals to humans. The aim of this study was, therefore, to determine the risk factors of exposure to *Brucella* species through milk consumption in zero grazing and open grazing cattle keeping households in Rwanda. The study was a cross-sectional study which involved 198 and 132 households practicing zero grazing and open grazing cattle production systems, respectively. To determine the risk factors exposure to *Brucella* through milk consumption, a questionnaire was used to collect data on milk consumption habits and indirect Enzyme-Linked Immuno-Sorbent Assay (i-ELISA) was used to collect data on farm bulk milk contamination with *Brucella*. Collected questionnaire and i-ELISA data were then analyzed using SPSS descriptive statistics and logistic regression. In nearly half (49.1 %; 162/330) of all surveyed households, raw milk was consumed. And overall, 14.2% (47/330) of all surveyed households were exposed to *Brucella* by having at least one household member consuming raw milk in a household for which the farm bulk milk sample tested positive for *Brucella*. The proportion of open grazing households in which raw milk was consumed and from which the farm bulk milk sample tested positive for *Brucella* (34.8 %; 46/132) was significantly high ($p < 0.05$) compared to the proportion of zero grazing households consuming raw milk and having a *Brucella* positive farm bulk milk sample (0.5 %; 1/198). While in total 4.8 % (77/1589) of all surveyed individual household members were exposed to *Brucella* by consuming raw milk in a household for which the farm bulk milk sample had tested positive for *Brucella*, the cattle keeper was the most exposed household member (OR=50.82, 95 % CI [17.9-143.9], $p < 0.05$). Practicing open grazing cattle production system was significantly associated with raw milk consumption and raw milk consumption in a household with a *Brucella* positive farm bulk milk. There is a risk of exposure to *Brucella* through milk consumption especially in households practicing open grazing cattle production in Rwanda. Educational campaigns are needed to raise awareness about the dangers of drinking raw milk in regards to zoonotic brucellosis.

Key words: *Brucella*, consumption, exposure, grazing, household, milk, risk factor, *Brucella* positive

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INTRODUCTION

Brucella species (*Brucella abortus*, *Brucella melitensis*, *Brucella ovis* and *Brucella suis*) are zoonotic bacteria which cause brucellosis in both animals and humans [1]. In animals, brucellosis causes abortion and other reproductive disorders including stillbirths, weak calves, retained placenta and longer calving intervals [2]. Human brucellosis results in an illness and patients experience symptoms of intermittent fevers with high body temperatures, sweats, chills, weakness, malaise, headache, insomnia, anorexia and joint and muscle pain [1, 2, 3]. Human brucellosis originates from animals and one way through which brucellosis is transmitted from infected animals to humans is through the consumption of unpasteurized milk from infected animals [4].

In Rwanda, 36.7 % of the total milk production is consumed on producing farms [5] and milk consumed on farms and sold through other informal channels is not monitored by regulators [6] and poses a risk of causing foodborne infections including zoonotic brucellosis. Animal brucellosis exists in Rwanda [7, 8, 9, 10] and *Brucella* has been recently detected in raw milk in Rwanda [11]. Although information on the consumption of raw milk and raw milk products in Rwanda is limited, a recent study reported that more than 21.7 % of cattle keepers at the wildlife-livestock-human interface indicated they drank raw milk [10].

With the reported animal brucellosis, the detection of *Brucella* in raw milk and data on raw milk consumption in Rwanda, the aim of this study was to determine the risk factors of exposure to *Brucella* through milk consumption in zero grazing and open grazing cattle keeping households.

MATERIALS AND METHODS

Study design

A cross-sectional study was carried out where a mobile electronic structured questionnaire was used to collect information on households and household members' milk consumption habits in order to determine the risk factors of exposure to *Brucella* through milk consumption. In addition, farm bulk raw milk samples were collected from each interviewed farm.

Study sites

The study was conducted in selected districts across Rwanda. The target population was rural cattle keeping households.

To determine the risk factors of exposure to *Brucella* through milk consumption in cattle keeping households in Rwanda, cattle keeping households were selected from five study districts (Nyanza, Gicumbi, Rwamagana, Nyagatare and Nyabihu) across Rwanda (Figure 1). The five districts were selected based on their location

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in the targeted milk shed areas in the country: Nyanza and Gicumbi districts are located in the Southern and Northern milk sheds, respectively. Rwamagana and Nyagatare districts are located in the largest Eastern milk shed while Nyabihu district is located in the North-Western milk shed. The five districts were also selected to represent the two main grazing cattle production systems (zero grazing and open field grazing) practiced in Rwanda.

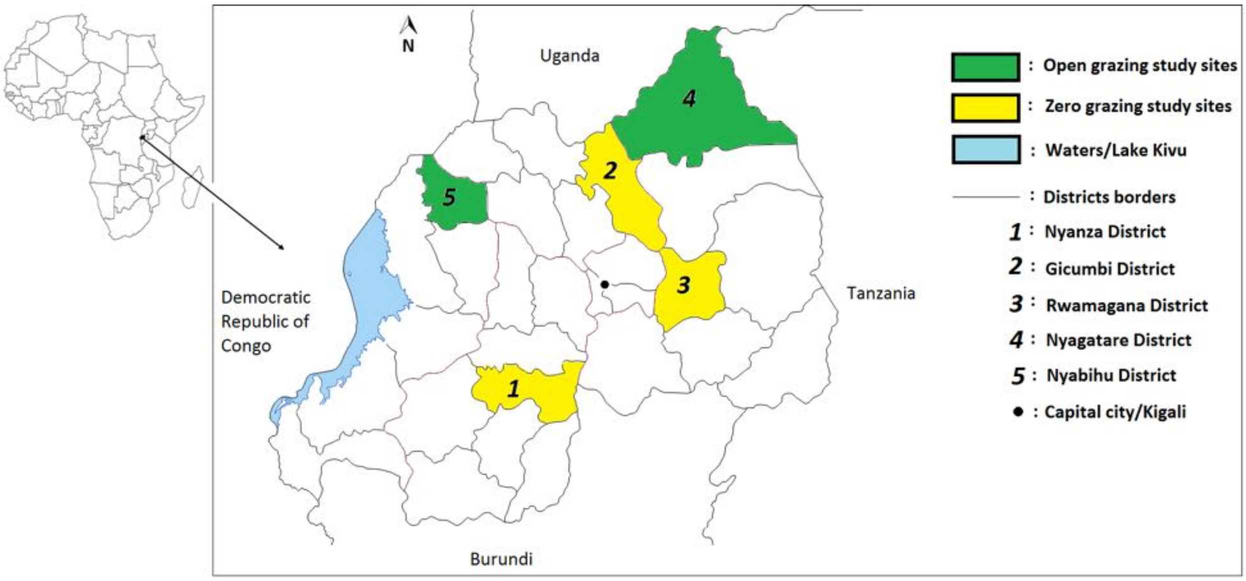

Figure 1: Map showing the study districts (namely, Nyanza, Gicumbi, Rwamagana, Nyagatare and Nyabihu) and the cattle production systems (open and zero grazing) practiced in the study sites

Study population

The study population consisted of rural dairy cattle keeping households randomly selected from the five study districts.

Sample size

The sample size for rural cattle keeping households to be included in the study to determine the risk factors of exposure to *Brucella* through milk consumption was determined using Fischer's formula [12].

$n = \{z_\alpha{}^2 * P * (1-P)\} / d^2$, where:
n: is the sample size
z_α: is 1.96 which is the statistic corresponding to a level of confidence of 95 %
P: is 68.8 %, the percentage of cattle keeping households among rural households in Rwanda [13].
d: is the level of precision set at 5 %

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A total sample size of 330 cattle keeping households was determined. An equal sample size of 330/5 = 66 of cattle keeping households was then considered per study district.

Sampling

Selection of cattle keeping households was conducted randomly and systematically by selecting the first household, skipping the next household and selecting the next one until required sample size was reached. To be considered, the randomly selected cattle keeping household had to have at least one lactating cow, to have at least one household member consuming milk and/or milk products, to be willing to provide needed information, to be willing to provide a farm bulk raw milk sample, to have a household member available and able to provide the needed information for the questionnaire and to be geographically located within the district of interest. A cattle keeping household was excluded if they did not have a lactating cow, if they were not willing to provide needed information and/or to provide a milk sample, if they did not have at least a member consuming milk and/or milk products and if there was no household member available and able to provide needed information. For each selected cattle keeping household fulfilling the criteria, a questionnaire was administered to collect information on household characteristics and household's and household members' milk consumption habits.

Data collection

Questionnaire and Interview

Using a pre-prepared and pre-tested structured questionnaire, data was collected on the household characteristics and on the milk consumption habits of the household and household's individual members. Key information collected included the household's location, practiced grazing system, herd size and milk production; forms in which milk is consumed in the household, raw milk consumption at the household and household member level; forms in which individual household members consume milk and individual household members' relationships to the household head. Questionnaire data was collected using Open Data Kit (ODK) with https://ona.io as the server.

Detection of *Brucella* in farm bulk raw milk samples

To obtain data on milk contamination or not with *Brucella*, collected farm bulk raw milk samples were analysed using SVANOVIR® *Brucella*-Ab Indirect ELISA (i-ELISA) kit. According to the manufacturer, the kit detects antibodies to major species of *Brucella* (*B. abortus* and *B. melitensis*) in cattle and has a specificity of 99 % when compared to the reference complement fixation test.

Data analysis

Collected questionnaire data on households' characteristics and milk consumption habits were exported from ODK to Microsoft Excel for data cleaning. Indirect ELISA data on the presence or absence of anti-*Brucella* antibodies in farms' bulk raw milk were also entered into Microsoft Excel and considered for determining the risk factors of exposure to *Brucella* through milk consumption.

Data on households' characteristics, household's and household members' milk consumption habits and data on the presence or absence of anti-*Brucella* antibodies in milk samples were then analyzed by Microsoft Excel for descriptive statistics to obtain proportions and compute averages where needed. Obtained analyses on consumption proportions (in percentages) of households and household members, and on the presence or absence of anti-*Brucella* antibodies in milk samples were then presented in graphs and tables. Comparisons of raw milk consumption habits between households and household members from different study districts and study cattle production systems were drawn using Pearson's chi square and logistic regression with SPSS (IBM SPSS Statistics version 20).

The risk factors of exposure to *Brucella* for milk consumers in the studied households were determined with regard to households' and household members' characteristics influencing drinking raw milk and drinking raw milk from households with *Brucella* positive farm bulk milk samples. Practiced cattle production system; location of the household; gender, age, education level of the household head and household size are the characteristics that were analyzed to determine their influence on raw milk being consumed or not consumed in a given household. To further determine the risk factors of exposure to *Brucella* through milk consumption, the odds of consuming raw milk and the odds of consuming raw milk in a household with a *Brucella* positive farm bulk milk sample were determined for households and households' members by their different characteristics. The odds were determined using binary logistic regression (where consumption or not of raw milk and consumption or not of raw milk in a household with *Brucella* positive farm bulk milk were set as the dependent/outcome variables) with a 95 % confidence interval (CI). To check the goodness-of-fit of the logistic regression models, the Hosmer and Lemeshow (HL) model fit test was used. The HL statistic indicated a poor fit, if $p < 0.05$ and a good fit, if $p > 0.05$.

RESULTS AND DISCUSSION

Cattle keeping households' characteristics

The majority (80.0 %; 264/330) of household heads in the surveyed 330 cattle keeping households were male. The overall mean age for household heads was 50.8 ± 10.7 years. More than half the households' heads (60.3 %; 199/330) had some or full primary school education while only 1.8 % (6/330) of the households' heads had some tertiary/university education. A total of 1,589 members resided in the 330 surveyed households. The average household size (members per household) was 4.8 ± 1.6 members. More than half of all households' members (61.8 %; 982/1589) were under 30 years of age. Each household was also a dairy farm and of the surveyed 330 households, 198 practiced zero grazing cattle production in their farm while 132 practiced open grazing. The average herd size was significantly higher ($p < 0.05$) in households practicing open grazing (17 ± 5.8) compared to the average herd size in households practicing zero grazing (2.2 ± 1.2). The average milk production per farm and per day was higher in open grazing households/farms (78.4 ± 27.3 liters) compared to the average milk production per farm and per day in zero grazing farms of only 7.1 ± 5.2 liters. From the daily average milk production in households practicing open grazing, 70.8 ± 27.0 liters (≈ 90.3 %) was sold while the remaining 7.6 ± 3.4 liters (≈ 9.7 %) was kept for home consumption. In households practicing zero grazing, 5.0 ± 4.8 liters (≈ 70.0 %) of the daily average milk production was sold and the remaining 2.1 ± 1.7 liters (≈ 30 %) was kept for home consumption.

Milk and milk products' consumption patterns

Milk and milk products were consumed in 329 of the 330 surveyed cattle keeping households. Milk was consumed as fresh raw milk, fresh boiled milk, tea milk, porridge milk, fermented milk from raw milk and fermented milk from boiled milk. In Nyagatare and Nyabihu districts, milk was also consumed in other forms including the traditional ghee and butter used for cooking and kawunga, a maize dough preparation in which boiled milk is used to cook the dough.

The most popular milk product consumed at the level of households was fresh boiled milk being consumed by at least one member in 57.3 % (189/330) of all surveyed households. Fresh boiled milk was closely followed by tea milk and fresh raw milk which were consumed by at least one household member in 53.6 % and 49.1 % of surveyed households, respectively.

The consumption of raw milk was recorded across all five study districts. The districts practicing the open grazing cattle production system (Nyagatare and Nyabihu) had the highest proportions (92.4 % and 98.5 %, respectively) of households in which fresh raw milk was consumed by at least one household member. The district of Nyagatare was also the district in which fresh boiled milk was consumed in most households (92.4 %; 61/66) (Figure 2). Porridge milk was popular in households from Gicumbi district with 89.4 % of households having at least a member consuming it (Figure 2).

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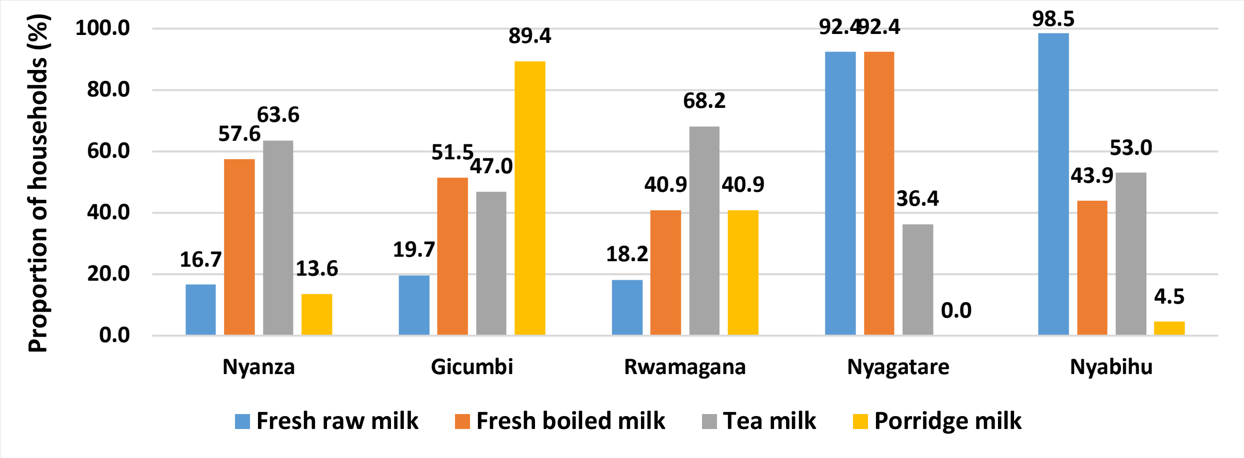

Figure 2: Proportions (%) of cattle keeping households having at least one household member consuming fresh milk, fresh boiled milk, tea milk and porridge milk in different study areas in Rwanda

The consumption of fermented milk from both fresh raw milk and fresh boiled milk was reported across all study districts with Nyagatare district having a higher proportion (47.0 %; 31/66) of households in which fermented milk from fresh raw milk was consumed (Figure 3). No cattle keeping household across all five study districts reported consuming industrially processed milk or milk products. Milk was also consumed in other forms, especially in the open grazing study districts of Nyagatare and Nyabihu. In Nyabihu districts, cattle keepers from 75.8 % (50/66) of surveyed households reported consuming milk in other forms including mainly using fresh boiled milk for the preparation of kawunga, a maize dough (Figure 3).

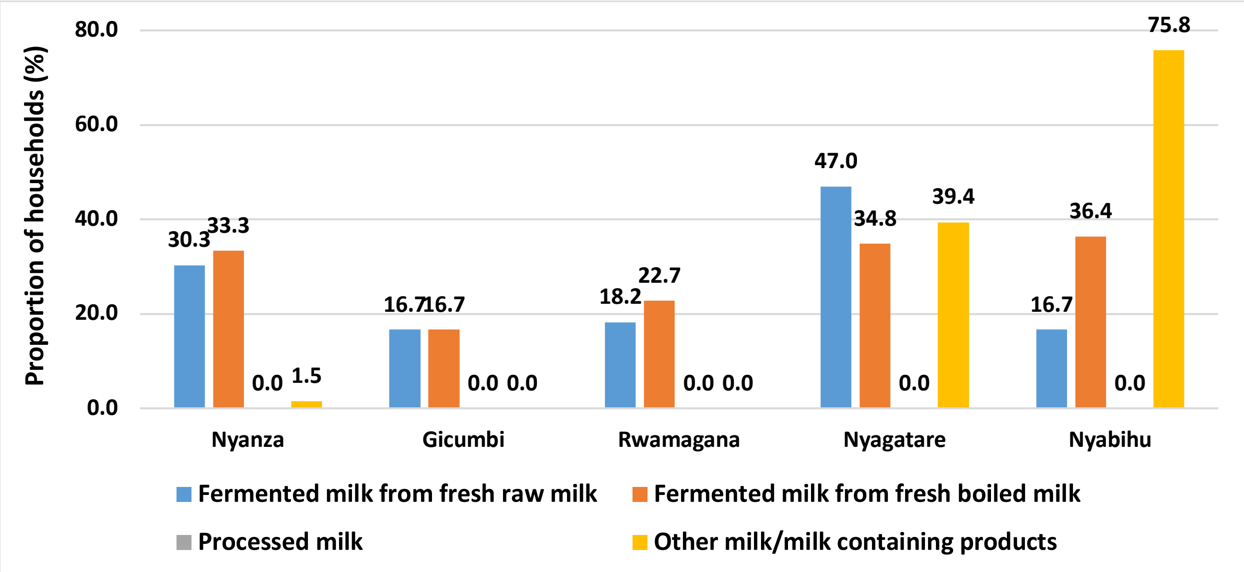

Figure 3: Proportions (%) of cattle keeping households with at least one household member consuming fermented milk, processed milk and other milk products in different study areas in Rwanda

All 330 surveyed households across the five study districts had a total of 1589 members. The majority of this study population (93.8 %; 1490/1589) consumed milk or milk products. At the level of individual household members, the most popular milk products were, again, fresh boiled milk and tea milk which were consumed by 46.2 % and 44.1 % of all surveyed household members across all study households, respectively (Table 1) while raw milk was consumed by 18.3 % of all household members. The proportion of household members consuming fresh raw milk was the highest in open grazing study districts (Nyagatare and Nyabihu) with 29.8 % and 26.0 % of surveyed household members in Nyagatare and Nyabihu districts, respectively, reporting to consume fresh raw milk (Table 1).

Among the milk products consumed at both household and household member levels, fresh boiled milk and tea milk were the most recorded. The fact that boiled milk and tea milk are easy to prepare with a short amount of time could be contributing to the popularity of such milk products. In line with our findings, a study conducted in Eldoret, Kenya, reported that tea milk was the predominant use of milk among households who were using milk for one or more domestic purposes [14].

In this study, the consumption of raw milk was important and the third in popularity after fresh boiled milk and tea milk. A very similar rate of milk consumption among the study population was reported in Ethiopia where 20 % of the study population indicated consuming raw milk [15]. Similarly, to the widespread raw milk consumption observed in rural open grazing households in this study, a study conducted on milk consumers in rural and urban households in Semi-arid areas in Kenya, also, reported that 99 % of rural households were consuming raw milk [16].

Consumption of raw milk is generally not recommended due to food safety related risks and foodborne infections that have been associated with raw milk [17, 18]. Despite the associated food safety risks, there are different reported reasons for consuming raw milk including preferring raw milk for its freshness, higher nutritional value, and superior taste [19, 20]. Constraints related to time, cost of charcoal or wood used to boil milk in rural areas have, also, been reported as hindrances to boiling or not properly boiling milk in rural households in Rwanda [21].

Risk of exposure to Brucella through milk consumption

Detection of anti-*Brucella* antibodies in raw milk

Out of 330 farm bulk raw milk samples collected from the 330 visited households, 65 (19.7 %) contained anti-*Brucella* antibodies (Table 2). Farm bulk raw milk samples collected from households practicing zero grazing contained anti-*Brucella* antibodies at a lower proportion (7.6 %) compared to farm bulk raw milk samples collected from households practicing open grazing (37.9 %). Nyagatare district had the highest proportion (51.5 %) of households with a positive farm bulk milk sample while Nyanza district had the lowest proportion (4.5 %) of households with a positive farm bulk milk sample (Table 2).

Proportions and risk factors of raw milk consumption

At the level of households, raw milk was consumed by at least one household member in nearly half (49.1 %; 162/330) of all surveyed households. Raw milk was especially consumed in households practicing the open-grazing cattle production system. The proportion of households practicing open grazing in which raw milk was consumed by at least one household member (95.5 %; 126/132) was significantly ($p < 0.05$) higher compared to the proportion of households practicing zero grazing in which raw milk was consumed (18.2 %; 36/198).

With univariate logistic regression analysis, the practiced cattle production system; the location of the household and male gender of the household head were individually and significantly associated ($p < 0.05$) with the consumption of raw milk at the household level.

The individual three significant household's characteristics influencing the consumption of raw milk at household level were further analyzed with multivariate logistic regression (Table 3) to determine which household characteristics were better predictors of whether raw milk would be consumed in a cattle keeping household. The practiced cattle production system was the best household characteristic in predicting the consumption of raw milk at household level and households in which open grazing was practiced had the highest odds (OR=274.19, 95 % CI [34.4-2181.0], $p < 0.05$) of raw milk consumption by at least one household member. The used logistic model adequately fitted the data with an insignificant ($p > 0.05$) HL statistic of 0.7.

This finding is consistent with other studies which have, also, observed that milk is widely consumed raw in pastoralist communities where open grazing is also practiced [20, 22]. The fact that, in this study, the odds of raw milk consumption in a given household were high if the household was practicing open grazing could be explained by quantity and availability of raw milk in households and traditions and milk consumption habits. Farmers from open grazing areas have more cattle, produce more milk, have easy access to milk and are, therefore, more exposed to milk, in general, and raw milk, in particular. Farmers practicing open grazing like pastoralists tend to, also, have a tradition of raw milk consumption and a belief that raw milk is wholesome, more nutritious and tastier [15, 20]. In addition to traditions and beliefs, raw milk requires no preparation and may therefore be opted. On the other hand, and as recorded in this study, households practicing zero grazing have smaller farms with about 2 cows per farm (compared to about 18 cows per open grazing farm), with a daily milk production of only 7 liters (compared to 78 liters per open grazing farm). With 70 % of the little daily milk production sold, zero grazing households retain about 2 liters for home consumption. This amount of milk may be insufficient for direct consumption as raw milk and may instead be boiled and left for smaller children to consume or be made into tea milk or porridge milk for the whole family to share. This, therefore, reduces the odds of raw milk consumption in zero grazing households; not necessarily because the household is aware of dangers associated with milk consumption, but because of insufficient available raw milk.

At the level of individual household members, 18.3 % (290/1589) of all household members consumed raw milk (Table 1). The proportions of individual household members consuming raw milk were significantly higher ($p < 0.05$) in study sites practicing the open grazing system (28.1 %; 181/643) compared to sites practicing zero grazing system (11.5 %; 109/946). Higher proportions of raw milk consumers were, also, recorded in the open grazing districts (Nyagatare, 29.8 % and Nyabihu, 26.0 %) compared to zero grazing study districts (Nyanza, 11.9 %; Gicumbi, 15.2 % and Rwamagana, 6.6 %) (Table 1). With univariate logistic regression analysis, the practiced grazing system, the household member's location, the household member's relationship to the household head, the household member's male gender and age group were all characteristics that were significantly ($p < 0.05$) associated to the consumption of raw milk by a given household member.

All household member's characteristics significantly associated with raw milk consumption by household members were further analyzed with multivariate logistic regression (Table 4) and all the household member's significant characteristics from univariate logistic regression remained significantly associated and good predictors of raw milk consumption by a given household member. The odds of raw milk consumption by household members remained the highest (OR=50.82, 95 % CI [17.9-143.9], $p < 0.05$) if the household member is a cattle keeper (Table 4). The used logistic model adequately fitted the data with an insignificant ($p > 0.05$) HL statistic of 0.1.

At the level of individual household members, more household members consuming raw milk were from open grazing areas. In this study, it was also revealed that the odds of consuming raw milk were especially high if the household member was the cattle keeper. A recent study conducted on cattle farmed at the wildlife-livestock-human interface in Rwanda, also reported that more than 21.7 % of cattle keepers consumed raw milk [10]. The high risk of raw milk consumption if the household member is the cattle keeper is consistent with how, among milk products, raw milk is the most available and most accessible for the cattle keeper who is usually in charge of milking the cows. Raw milk, also, requires no other energy and time-consuming preparations like boiling or fermentation. The easy accessibility and no preparation could, therefore, explain why the cattle keepers were found to have the highest risk of raw milk consumption compared to other household members.

Proportions and risk factors of exposure to *Brucella* by consuming raw milk in a household with *Brucella* positive farm bulk milk

At household level, at least one household member in 14.2 % (47/330) of all surveyed households was exposed to *Brucella* by consuming raw milk while the farm bulk milk sample was *Brucella* positive. The proportion of open grazing households in which raw milk was consumed and from which the farm bulk milk sample was positive to *Brucella* (34.8 %; 46/132) was significantly higher ($p < 0.05$) than the proportion of zero grazing households consuming raw milk and having a *Brucella* positive farm bulk milk sample (0.5 %; 1/198). The proportions of households consuming raw milk and having a *Brucella* positive farm bulk sample were also high in open grazing study districts (Nyagatare, 45.5 %, 30/66; Nyabihu, 24.2 %, 16/66) compared to zero grazing study districts (Nyanza, 0 %; Gicumbi, 0 %; Rwamagana, 1.5 %). With univariate logistic regression analysis, the household's practiced cattle production system and household location/district were significantly ($p < 0.05$) associated with consuming raw milk in a household with *Brucella* positive farm bulk milk. When the household's practiced cattle production system and the household's location were run in a multivariate model, practicing open grazing cattle production system was the best predictor (OR=20.80, 95 % CI [2.66-162.16], $p < 0.05$) of the risk of raw milk consumption by at least one member in a household with *Brucella* positive farm bulk milk (Table 5). The used logistic model adequately fitted the data with an insignificant ($p > 0.05$) HL statistic of 1.0.

At individual household member level, 4.8 % (77/1589) of all surveyed individual household members were exposed to *Brucella* by consuming raw milk in a household for which the farm bulk milk sample was *Brucella* positive. The proportion of household members in open grazing study areas who consumed raw milk in a household with a *Brucella* positive farm bulk milk sample (11.7 %, 75/643) was significantly higher ($p < 0.05$) than the proportion of household members in zero grazing study areas who consumed raw milk in a household with a *Brucella* positive farm bulk milk sample (0.2 %, 2/946). In open grazing study districts, the proportions of individual household members consuming raw milk in households with *Brucella* positive farm bulk milk samples were 15.3 % (56/366) and 6.9 % (19/277) in Nyagatare and Nyabihu districts, respectively. In zero grazing study districts, there were no or very few raw milk consuming household members in households with *Brucella* positive farm bulk milk samples (Nyanza, 0 %; Gicumbi, 0

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%; Rwamagana, 0.7 %, 2/286). Following univariate logistic regression analysis of household member's characteristics, practiced cattle production system, household's location, household member's relationship to the household head and household member's gender were significantly ($p < 0.05$) associated with the risk of a household member consuming raw milk in a household with *Brucella* positive farm bulk milk.

With multivariate logistic regression analysis of household member's characteristics, practiced cattle production system, household's location and household member's relationship to the household head were the factors significantly ($p < 0.05$) associated with the risk of a household member consuming raw milk in a household with *Brucella* positive farm bulk milk (Table 6). The used logistic model adequately fitted the data with an insignificant ($p > 0.05$) HL statistic of 0.9.

The high exposure to *Brucella* through milk consumption established in open grazing areas in this study, is consistent with our observed higher proportion of *Brucella*-positive farm bulk milks from open grazing households and previously reported data on brucellosis prevalence in Rwandan cattle. Indeed, previous studies in Rwanda reported higher rates of prevalence of brucellosis in cattle in areas where open grazing was predominantly practiced [7, 9, 10] and lower prevalence rates in areas where zero grazing was predominantly practiced [8, 10]. The study by Ndazigaruye *et al*. [9], which focused on Nyagatare district, for example, reported an individual cattle brucellosis rate of 19.1 % in extensively grazed cattle and 0.0 % in intensively grazed cattle.

In this study, being a cattle keeper was associated with the highest risk of ingesting potentially *Brucella* containing raw milk. This study focused on the risk factors of exposure to *Brucella* through milk consumption. It should, however, be mentioned that cattle keepers, who were found to be the most exposed in this study, can also become infected with *Brucella* due to their occupational exposure [23].

CONCLUSION AND RECOMMENDATIONS FOR DEVELOPMENT

Milk consumers in cattle keeping households in Rwanda are exposed to *Brucella* through milk consumption, especially if the consumers are from households practicing open grazing cattle production and especially if the consumer is the cattle keeper in the household. Educational campaigns are, therefore, needed in Rwanda to raise awareness about the dangers of drinking raw milk in regards to zoonotic brucellosis.

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Table 1: Proportions (%) of household members consuming milk and milk products in different study areas

	Zero Grazing			Open grazing		
	Nyanza	**Gicumbi**	**Rwamagana**	**Nyagatare**	**Nyabihu**	**TOTAL**
% HH members who consume milk or milk products	95.5	95.4	96.2	99.7	79.4	93.8
% HH members who consume:						
Fresh raw milk	11.9	15.2	6.6	29.8	26.0	18.3
Fresh boiled milk	42.8	45.8	39.9	67.2	29.2	46.2
Tea milk	59.2	40.4	62.2	20.8	44.0	44.1
Porridge milk	11.6	78.8	40.2	0.0	2.5	27.2
Fermented milk from fresh raw milk	21.5	12.3	15.4	36.6	9.7	19.8
Fermented milk from fresh boiled milk	28.3	15.2	21.0	22.1	26.7	22.4
Processed milk	0.0	0.0	0.0	0.0	0.0	0.0
Other milk/milk containing products	1.3	0.0	0.0	22.1	27.4	10.1

HH: Household

Table 2: Detection of anti-*Brucella* antibodies in collected households' farm bulk raw milk samples

Cattle production system and Study districts	Household farm bulk milk samples (Positive samples by i-ELISA)	Anti-*Brucella* antibodies detection proportion (%)
Zero-grazing		
Nyanza	66 (3)	4.5
Gicumbi	66 (4)	6.1
Rwamagana	66 (8)	12.1
Total/Zero-grazing	198 (15)	7.6
Open grazing		
Nyagatare	66 (34)	51.5
Nyabihu	66 (16)	24.2
Total/Open grazing	132 (50)	37.9
TOTAL	**330 (65)**	**19.7**

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Table 3: Multivariate logistic regression analysis of associations between household characteristics and raw milk consumption

Household's characteristic	Level	Coefficient (β)	Odds Ratio (OR)	95 % CI Lower	95 % CI Upper	Wald χ^2	p-value
Cattle production system	Open Grazing	5.61	274.19	34.47	2181.03	28.15	0.00*
	Zero grazing						[a]
Study District						2.53	0.47
	Nyanza	-0.14	0.86	0.34	2.13	0.10	0.74
	Gicumbi	-0.04	0.95	0.39	2.33	0.01	0.91
	Rwamagana						
	Nyagatare	-1.73	0.17	0.02	1.56	2.42	0.12
	Nyabihu						[a]
HHH's gender							
	Female	-0.59	0.55	0.22	1.34	1.70	0.19
	Male						

*Significant risk factors; [a] Reference value; HHH: Household head

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Table 4: Multivariate logistic regression analysis of associations between household members' characteristics and household members' raw milk consumption

Household's characteristic	Level	Coefficient (β)	Odds Ratio (OR)	95 % CI Lower	95 % CI Upper	Wald χ^2	p-value
Cattle production system	Open Grazing	0.88	2.42	1.24	4.69	6.83	0.00*
	Zero grazing						a
Study District						19.37	0.00*
	Nyanza	0.73	2.07	1.09	3.95	4.98	0.02
	Gicumbi	1.23	3.42	1.86	6.28	15.72	0.00
	Rwamagana						
	Nyagatare	0.46	1.58	0.95	2.62	3.20	0.07
	Nyabihu						a
Household member's relationship to HHH						99.08	0.00*
	Household head	0.74	2.10	0.67	6.58	1.64	0.20
	Wife	0.52	1.68	0.49	5.72	0.69	0.40
	Child	0.97	2.65	1.08	6.45	4.60	0.03
	Cattle keeper	3.92	50.82	17.94	143.90	54.72	0.00
	Relative						a
Household member's gender	Female	-1.03	0.35	0.23	0.53	24.99	0.00*
	Male						a
Household member's age group						14.01	0.00*
	0-15 years	1.21	3.35	0.39	28.49	1.23	0.26
	16-30 years	1.89	6.65	0.80	55.21	3.07	0.07
	31-50 years	1.33	3.78	0.467	30.60	1.55	0.21
	51-70 years	1.12	3.08	0.37	25.29	1.09	0.29
	More than 70 years						a

*Significant risk factors; [a] Reference value; HHH: Household head

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Table 5: Multivariate logistic regression analysis of associations between household characteristics and consumption of raw milk in a household with *Brucella* positive farm bulk milk

Household's characteristic	Level	Coefficient (β)	Odds Ratio (OR)	95 % CI Lower	95 % CI Upper	Wald χ^2	p-value
Cattle production system	Open Grazing	3.03	20.80	2.66	162.16	8.39	0.00*
	Zero grazing						a
Study District						6.37	0.09
	Nyanza	-17.02	0.00	0.00		0.00	0.99
	Gicumbi	-17.02	0.00	0.00		0.00	0.99
	Rwamagana						
	Nyagatare	0.95	2.60	1.23	5.47	6.37	0.01
	Nyabihu						a

*Significant risk factors; [a] Reference value

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Table 6: Multivariate logistic regression analysis of associations between household members' characteristics and consumption of raw milk in a household with *Brucella* positive farm bulk milk

Household's characteristic	Level	Coefficient (β)	Odds Ratio (OR)	95 % CI Lower	95 % CI Upper	Wald χ^2	p-value
Cattle production system	Open Grazing	1.68	5.38	1.19	24.26	4.80	0.028*
	Zero grazing						[a]
Study District						13.20	0.00*
	Nyanza	-16.29	0.00	0.00		0.00	0.99
	Gicumbi	-16.08	0.00	0.00		0.00	0.99
	Rwamagana						
	Nyagatare	1.09	2.98	1.65	5.38	13.20	0.00
	Nyabihu						[a]
Household member's relationship to HHH						24.98	0.00*
	Household head	-0.11	0.89	0.22	3.53	0.02	0.87
	Wife	0.89	2.45	0.32	18.73	0.75	0.38
	Child	0.05	1.05	0.28	3.94	0.00	0.93
	Cattle keeper	1.36	3.89	1.04	14.52	4.09	0.04
	Relative						[a]
Household member's gender	Female	-2.56	0.07	0.01	0.33	11.56	0.00*
	Male						[a]

*Significant risk factors; [a] Reference value

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