

# Accepted Manuscript

Consumption patterns, bacteriological quality and risk factors for *Salmonella* contamination in meat-based meals consumed outside the home in Kigali, Rwanda

Eugène Niyonzima, Martin Patrick Ongol, Yves Brostaux, Nicolas Korsak Koulagenko, Georges Daube, Anastase Kimonyo, Marianne Sindic



PII: S0956-7135(16)30496-0

DOI: [10.1016/j.foodcont.2016.09.004](https://doi.org/10.1016/j.foodcont.2016.09.004)

Reference: JFCO 5224

To appear in: *Food Control*

Received Date: 11 July 2016

Accepted Date: 2 September 2016

Please cite this article as: Niyonzima E., Ongol M.P., Brostaux Y., Korsak Koulagenko N., Daube G., Kimonyo A. & Sindic M., Consumption patterns, bacteriological quality and risk factors for *Salmonella* contamination in meat-based meals consumed outside the home in Kigali, Rwanda, *Food Control* (2016), doi: 10.1016/j.foodcont.2016.09.004.

This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting proof before it is published in its final form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

1 **TITLE PAGE**

2

3 **Article Title:**

4 **Consumption patterns, bacteriological quality and risk factors for *Salmonella***  
5 **contamination in meat-based meals consumed outside the home in Kigali, Rwanda**

6

7 **Authors' names and affiliations:**

8 *Eugène Niyonzima<sup>1,4</sup>, Martin Patrick Ongof<sup>4</sup>, Yves Brostaux<sup>2</sup>, Nicolas Korsak Koulagenko<sup>3</sup>,*  
9 *Georges Daube<sup>3</sup>, Anastase Kimonyo<sup>4</sup>, and Marianne Sindic<sup>1</sup>*

10 <sup>1</sup>*University of Liège - Gembloux Agro Bio-Tech. Analysis Quality and Risk Unit. Laboratory of*  
11 *Agro-food Quality and Safety. Passage des Déportés 2, 5030 Gembloux, Belgium.*

12 <sup>2</sup>*University of Liège - Gembloux Agro-Bio Tech. Applied Statistics, Computer Science and*  
13 *Modeling Unit. Passage des Déportés 2, 5030 Gembloux, Belgium.*

14 <sup>3</sup>*University of Liège, Faculty of Veterinary Medicine, Fundamental and Applied Research for*  
15 *Animal & Health (FARAH), Food Science Department, Microbiology Section, Quartier Vallée*  
16 *2, Avenue de Cureghem 10, B-4000 Liège, Belgium*

17 <sup>4</sup>*University of Rwanda, College of Agriculture Animal Science and Veterinary Medicine,*  
18 *School of Food Science and Technology, Food Safety and Quality Management Department.*  
19 *Avenue de l'armée P.O. Box 3900, Kigali, Rwanda.*

20

21 **Corresponding author:**

22 Eugène Niyonzima, University of Liège - Gembloux Agro Bio-Tech. Analysis Quality and Risk  
23 Unit. Laboratory of Agro-food Quality and Safety. Passage des Déportés 2, 5030 Gembloux,  
24 Belgium. E-mail: eugeneniyo@yahoo.fr; Telephone: +32466245 080

25

26

27

## 28 Abstract

29 Meat-based meals are consumed as a source of animal proteins and constitute one of the  
30 leading vehicles for food borne infections in humans. The main objective of this study was to  
31 determine the consumption pattern and the bacteriological quality of meat-based meals  
32 consumed outside households in Kigali. A survey on meat consumption patterns was carried  
33 out in 400 households by using a questionnaire, whereas different meat-based meals were  
34 sampled from 150 snack bars and restaurants. Enumeration of hygiene indicator bacteria  
35 (total mesophilic bacteria and *Escherichia coli*) and the qualitative detection of *Salmonella*  
36 were carried out by using conventional culture methods. The results indicated that goat was  
37 the type of meat that was consumed the most outside the home in Kigali and the meat intake  
38 varied significantly ( $p \leq 0.05$ ) with the social category of the household. The average levels of  
39 total aerobic bacteria and *E. coli* in meat-based meals were found to be 4.7 and 1.4 log cfu/g,  
40 respectively, whereas *Salmonella* was detected in 11.7% of all meat-based meals. Eight  
41 factors mostly linked to the cooking treatments and hygienic handling practices for cooked  
42 meals were found to be significantly ( $p \leq 0.05$ ) associated with the risk of *Salmonella*  
43 occurrence in meat-based meals consumed outside the home in Kigali. The findings from  
44 this study strongly suggest the need for proper cooking and/or improvements in hygiene in  
45 the establishments selling ready-to-eat meat-based meals in Kigali, particularly those located  
46 in rural localities.

47 **Key words:** meat consumption, *Salmonella*, hygiene indicator bacteria, ready-to-eat food,  
48 risk factors, Kigali.

## 49 1. Introduction

50 Meat is an important source of valuable proteins for different populations in the world.  
51 However, it constitutes an important vehicle for microbial pathogens responsible for food  
52 borne infections in humans as its composition and physical characteristics are favourable to  
53 the growth of a wide range of microorganisms including pathogens (Doulgeraki, Ercolini,  
54 Villani, & Nychas, 2012; Scallan et al., 2011). Furthermore, animals often carry germs on the  
55 hide or in their digestive tract, and cross-contamination during slaughtering operations is  
56 hardly avoidable (Niyonzima, Ongol, Kimonyo, & Sindic, 2015).

57 Salmonellosis is known as one of the leading food borne infections in humans (Centers for  
58 Disease Control and Prevention (CDC) (CDC, 2013; EFSA & ECDC, 2015). Though it is  
59 recognised that meat is one of the vehicles of *Salmonella* infection in humans, the proportion  
60 of human salmonellosis attributable to the consumption of contaminated meat is difficult to

61 estimate accurately. This is mainly due to the fact that only a limited number of illness cases  
62 are officially reported. Furthermore, even within the reported cases, a very small proportion  
63 allows the identification of the food vehicle (Greig & Ravel, 2009; Scallan et al., 2011). The  
64 lack of operational disease surveillance systems, particularly in developing countries, has  
65 been identified as the main factor hampering the reporting and determination of causative  
66 agents for food borne diseases (Newell et al., 2010; Stevens et al., 2006).

67 Meat-based meals have traditionally been consumed within households. However, the  
68 consumption of foods including meat-based meals away from home as ready-to-eat food has  
69 significantly increased during the last decades in both developed and developing countries.  
70 In the United States for example, the share of the household budget allocated to food  
71 consumption outside the home has increased from 20 to 37% in the period between 1960  
72 and 1990 (Lachat et al., 2012). The rising consumption of foods outside the household is  
73 attributable to a number of factors including the affordable prices of ready-to-eat foods as  
74 well as their readily availability to the consumers (Cardinale et al., 2015). Moreover, the  
75 urbanisation of rural areas and the increase of the financial capacity of city dwellers  
76 contribute significantly to the growing consumption of foods outside the household as wealth  
77 was reported to be an important determinant of food consumption away from home (Ma,  
78 Huang, Fuller, & Rozelle, 2006).

79 Ready-to-eat foods are generally consumed without any other treatment such as cooking  
80 intended to eliminate or reduce their microbial load. Therefore, the occurrence of microbial  
81 pathogens such as *Salmonella* in those food products constitutes a great public health  
82 problem. Several authors have reportedly associated food borne disease outbreaks to the  
83 consumption of contaminated ready-to-eat foods (Campos, Gil, Mourão, Peixe, & Antunes,  
84 2015; Gurler, Pamuk, Yildirim, & Ertas, 2015; Osaili et al., 2014; Yang et al., 2016).

85 The consumption of meat-based meals within Rwandan households has been thoughtfully  
86 reviewed by Niyonzima et al. (2016). However, to our knowledge, no published study has  
87 yet assessed either the consumption patterns nor the bacteriological quality and safety of  
88 meat-based meals consumed outside the home, though a wide variety of meat-based meals  
89 are commonly consumed in the majority of Rwandan snack bars and restaurants.

90 The objective of the present study was to assess the modes of consumption, and the  
91 bacteriological quality and safety of meat-based meals consumed outside the households of  
92 Kigali. Data collected through this study can have significant applications in conducting an  
93 exposure assessment of Kigali city inhabitants to meat borne bacterial pathogens such as  
94 *Salmonella*.

95 **2. Material and method**

96 **2.1. Meat consumption survey**

97 The present study was conducted in the households of Kigali, which constitutes the most  
98 populated city of Rwanda with more than 10% of the national population (National Institute of  
99 Statistics of Rwanda, 2012). The number of sampled households was determined by using  
100 the formula proposed by Yamane (1967):

101 
$$n = \frac{N}{1 + N(e)^2}$$

102 where  $n$  is the sample size,  $N$  is the population size, and  $e$  is the level of precision. According  
103 to the most recent statistics, the population of Kigali is estimated to be 1,135,428 inhabitants  
104 (National Institute of Statistics of Rwanda, 2012). With a precision level  $e$  of 0.05, the sample  
105 size was estimated to be 400 households.

106 Selected households were grouped into three (3) socio-economic categories, namely  
107 households with low, medium and high income according to the Rwandan mutual health  
108 insurance scheme (Government of Rwanda, 2008). The main characteristics of these  
109 categories are described in Table 1.

110 From the database of household socio-economic status (data for the year 2012) provided to  
111 us by the Local Development Agency of the Rwandan Ministry of Local Government, 21% of  
112 the sampled households were selected from low income households, whereas 75 and 4%  
113 were chosen from households with medium and high income, respectively. These  
114 proportions are in accordance with the percentages of different social categories of  
115 households in Kigali. The random selection of households for the survey was carried out by  
116 using Microsoft Office Excel 2007 (Microsoft Corporation, Redmond, Washington, USA).

117 In each household, one member aged 18 years or over was randomly selected and his/her  
118 meat consumption outside the household was monitored through a food frequency  
119 questionnaire for a period of 60 days from February to June 2015. The questionnaire was  
120 composed of two parts. The first section provided socio-demographic information including  
121 the physical address of the household, the household's social category, as well as the age  
122 and gender of the selected household member. The second section supplied meat  
123 consumption information, namely, the type of meat-based dish consumed by the selected  
124 household member and the consumption frequency.

125 The weight of meat components of different meat-based meals consumed by the selected  
126 household member was estimated by using two-dimensional pictures of cooked meat  
127 portions. The use of two-dimensional pictures to estimate food intake has been validated in  
128 several studies as an alternative to conventional weighting methods, which, in some  
129 circumstances, are not suitable because of cultural considerations (Dhingra, Sazawal,  
130 Menon, Dhingra, & Black, 2007; Williamson et al., 2004).

## 131 **2.2. Microbiological analyses**

### 132 **2.2.1. Collection of meat samples**

133 Meat samples were collected from the establishments selling meat-based meals in the urban  
134 and peri-urban areas of Kigali. From the database of registered establishments selling meat-  
135 based meals in Kigali provided to us by local municipalities, 300 snack bars and restaurants  
136 were selected randomly by using Microsoft Office Excel 2007 (Microsoft Corporation,  
137 Redmond, Washington, USA). The selected establishments were visited one by one and the  
138 objectives of the study were explained to their managers. From those who agreed to  
139 participate in the study (n=203), a second random selection was carried out to retain 150  
140 snack bars and restaurants in which the survey and sample collection were performed.

141 Each snack bar or restaurant was visited once. Information regarding the type of meat used,  
142 meat handling and storage conditions, management of non-meat ingredients, cooking  
143 procedures, management of leftovers, utensil and kitchen hygiene, staff hygiene, cleaning  
144 and disinfection procedures and pest control measures were collected through a  
145 questionnaire administered to the manager of the establishment. After the interview, the  
146 answers were verified by a direct observation on the site, and where necessary, the  
147 corrections were performed.

148 In each snack bar or restaurant, two meat-based meals were aseptically collected and  
149 placed in separate sterile stomacher bags (VWR, Belgium). The transport of meat samples to  
150 the laboratory was carried out within 2 hours in a cold box with freeze packs. In the  
151 laboratory, meat samples were stored in a freezer at -30 °C and microbiological analyses  
152 were carried out within 24 hours. Table 2 describes the numbers and the types of meat  
153 samples collected.

### 154 2.2.2. Analytical methods

155 Meat samples were analysed for the total mesophilic bacteria count (TMC), *E. coli* count  
156 (ECC) and *Salmonella* detection. The ISO 7218:2007 Standard protocol (International  
157 Organization for Standardization, 2007) was followed to prepare meat samples. The  
158 determination of total mesophilic bacteria count was performed by using the pour plate  
159 method on plate count agar (VWR, Belgium) as described in ISO 4833:2003 Standard  
160 protocol (International Organization for Standardization, 2003), whereas the *E. coli* count was  
161 carried out on tryptone bile X-glucuronide agar (Bio-Rad, France) by following the ISO  
162 16649-2:2001 standard protocol (International Organization for Standardization, 2001). When  
163 a sample was found with bacterial numbers below the enumeration threshold for TMC or  
164 ECC subsequent calculations were performed with the value of the detection limit. The ISO  
165 7218:2007 standard indicates that in solid samples, the limit of detection for TMC and ECC  
166 by using, respectively, the ISO 4833:2003 and ISO 16649-2:2001 standard protocols is 1 log  
167 cfu/g (International Organization for Standardization, 2007).

168 The qualitative detection of *Salmonella* was performed in 25 grams of meat by following the  
169 ISO 6579:2002 standard protocol (International Organization for Standardization, 2002) with  
170 a non-selective enrichment in buffered peptone water (VWR, Belgium), a selective  
171 enrichment in Rappaport Vassiliadis with soya (Sigma-Aldrich, Belgium) and Muller-Kaufman  
172 tetrathionate novobiocin (Sigma-Aldrich, Belgium) broths and the isolation on xylose-lysine  
173 desoxycholate agar (Sigma-Aldrich, Belgium) and brilliant green agar (Bio-Rad, France). The  
174 biochemical confirmation of characteristic or suspected colonies of *Salmonella* was  
175 performed by using API20E gallery (bioMérieux, France).

### 176 2.3. Statistical analyses

177 The results from bacterial counts were transformed into log cfu scale base 10 before  
178 subsequent calculations and statistical treatments. One way analysis of variance was used to  
179 assess the variability for normally distributed variables, whereas Kruskal-Wallis (KW) and  
180 Mann-Whitney U (MWU) tests were used for non-normally distributed variables. The  
181 normality of the distributions was assessed by using the Shapiro-Wilk test, whereas the  
182 Pearson chi-square (PCS) test was used to compare the variable proportions.

183 On the same sample, a correlation between the total bacteria and *E. coli* counts (continuous  
184 variables) was determined by using Spearman's rank correlation ( $r_s$ ) whereas the point-  
185 biserial correlation ( $r_{pb}$ ) was used to determine a correlation between ECC and *Salmonella*  
186 occurrence (binary variable).

187 The determination of risk factors for *Salmonella* occurrence in cooked meat was carried out  
188 by using a binary logistic regression analysis. The outcome variable was the occurrence of  
189 *Salmonella* positive meals in the snack bar or restaurant. Meat-based meals in a snack bar  
190 or restaurant were declared contaminated by *Salmonella* if at least one sample was  
191 *Salmonella* positive. Potential risk factors were first screened to assess their association to  
192 the outcome variable by using the Pearson chi-square test, and only factors significantly  
193 ( $p \leq 0.05$ ) associated with the outcome variable were considered eligible for the logistic  
194 regression analysis. All statistical analyses were carried out by using SPSS 16.0 Software  
195 (IBM, USA).

### 196 **3. Results**

#### 197 **3.1. Meat consumption outside the household**

198 The results from the survey showed that meat was consumed in 89% of households, and  
199 goat was found to be the most consumed meat outside the home in Kigali. The average meat  
200 intake outside the household was estimated to 49.6 grams per person and per day (Table 3)  
201 and appeared to significantly differ with the household social category (low-income  
202 households (LI) versus middle-income households (MI): MWU test=369.0, degree of freedom  
203 (df) =1,  $p=0.000$ ; middle-income households (MI) versus high-income households (HI): MWU  
204 test=0.0, df=1,  $p=0.000$ ; high-income households (HI) versus low-income households (LI):  
205 MWU test=699.0, df=1,  $p=0.000$ ). The consumption of meat was significantly high in men  
206 compared to women (MWU test=9998.0, df=1,  $p=0.000$ ) and appeared to increase with age  
207 (Figure 1). Nevertheless, the localisation of the household (urban versus peri-urban zone)  
208 was not found to significantly influence the meat consumption rate in Kigali (MWU  
209 test=8905.0, df=1,  $p=0.305$ ).

#### 210 **3.2. Preparation of meat-based meals**

211 Table 4 describes the level of utilisation of meat from different animal species within the  
212 establishments selling meat-based meals in Kigali. Bovine and goat meat were found to be  
213 the most used type of meat as they were reported to be used in 58.7 and 50.0%,  
214 respectively, of the establishments selling meat-based meals in Kigali. Bovine meat  
215 appeared to be most used in restaurants, whereas goat meat was predominantly used in  
216 snack bars. Boiling was found to be the cooking method used in the majority of Kigali city  
217 restaurants but in snack bars, meat-based meals were mostly prepared by grilling (Table 5).  
218 The cooking durations were predominantly long in restaurants compared to snack bars  
219 (Table 6).

### 220 3.3. Bacteriological quality and safety of meat-based meals

221 Meat-based meals including boiled beef, grilled goat brochettes, fried pork, grilled chicken  
222 and grilled rabbit were analysed for the detection of *Salmonella* and the assessment of  
223 contamination levels by hygiene indicator bacteria, namely, total mesophilic bacteria and  
224 *E. coli*. Table 7 describes the levels of hygiene indicator bacteria and the occurrence of  
225 *Salmonella* in different meat-based meals consumed in Kigali. The mean microbial counts  
226 ranged from 3.25 and 6.61 log cfu/g for total mesophilic bacteria and from 1.32 to 1.70 log  
227 cfu/g for *E. coli*. *Salmonella* was isolated from 18.7% of snack bars and restaurants (n=150)  
228 and from 11.7% of all meat samples (n=300). A significant Spearman's rank correlation was  
229 observed between TMC and ECC ( $r_s=0.637$ , n=300,  $p<0.01$ ) for the same sample and the  
230 point-biserial correlation between *E. coli* counts and the occurrence of *Salmonella* appeared  
231 to be significant ( $r_{pb}=0.445$ , n=300,  $p<0.01$ ).

232 The average TMC level of 6.18 log cfu/g observed in snack bars appeared to be significantly  
233 higher when compared to the average TMC (3.25 log cfu/g) recorded in restaurants (MWU  
234 test=1505.0, df=1,  $p=0.000$ ). However, the levels of ECC in snack bars and restaurants (1.5  
235 versus 1.3 log cfu/g, respectively) were not found to be statistically different (MWU  
236 test=2417.5, df=1,  $p=0.127$ ). The proportion of *Salmonella* positive samples appeared to be  
237 significantly (PCS test=11.7, df=1,  $p=0.001$ ) higher in meat-based meals served in snack  
238 bars (18.0%) than in the restaurants (5.3%).

239 The microbiological contamination of meat-based meals appeared to be high in rural areas  
240 compared to urban localities of Kigali. The average TMC level recorded in snack bars and  
241 restaurants of urban Kigali (2.92 log cfu/g) was significantly lower than that of 6.60 log cfu/g  
242 observed in rural areas (MWU test=1686.5, df=1,  $p=0.000$ ). A comparable trend was  
243 observed in ECCs and the occurrence of *Salmonella* (Figure 2).

### 244 3.4. Risk factors for *Salmonella* contamination in meat-based meals

245 The binary logistic regression analyses revealed that the risk of *Salmonella* contamination to  
246 occur in cooked meat meals was four times higher in snack bars than in restaurants  
247 (OR=4.77; 95% confidence interval = 1.81–12.61;  $p=0.001$ ). Furthermore, factors such as  
248 'not changing the knife while cutting meat from another animal species or non meat  
249 ingredients', 'cooking by grilling or frying rather than boiling', 'not wearing specific work  
250 clothing while handling meat' and 'absence of pest control measures in the kitchen' were  
251 found to be associated with an increasing risk of *Salmonella* contamination. However,

252 cooking for a long period, reheating foods prior to serving and a frequent cleaning of the  
253 kitchen decreased the risk of *Salmonella* occurrence in cooked meat meals (Table 8).

## 254 **4. Discussion**

### 255 **4.1. Consumption of meat-based meals**

256 Beef and goat meat were found to be the types of meat consumed the most outside the  
257 home in Kigali. The high consumption of these two types of meat could be explained by their  
258 affordability to the population of Kigali. Due to the lack of public slaughterhouses for animal  
259 species other than bovines and small ruminants in Rwanda in general and particularly in  
260 Kigali (Rwandan Ministry of Agriculture and Animal Resources, 2012), pigs, poultry and  
261 rabbits are general slaughtered in private meat abattoirs. This result in an increased  
262 production cost for meat from animals other than bovines (and small ruminants), and  
263 consequently, higher prices on Kigali city markets. Recent statistics indicate that beef and  
264 goat meat represent 51.6% of the Rwandan meat production (Food and Agriculture  
265 Organisation, 2015).

266 The consumption of meat in Kigali was found to be high in people from households with high  
267 incomes compared to those from other social categories. This may be justified by the  
268 purchasing power of people from that particular category as the wealth was reported to be  
269 the major determinant of meat consumption (McAfee et al., 2010; Sans & Combris, 2015;  
270 Speedy, 2003). Our findings are in agreement with the studies conducted in different  
271 countries such as the United states (Daniel, Cross, Koebnick, & Sinha, 2011), China (Ma et  
272 al., 2006), Brazil (de Carvalho, César, Fisberg, & Marchioni, 2014), Equatorial Guinea (East,  
273 Kümpel, Milner-Gulland, & Rowcliffe, 2005; Fa, Albrechtsen, Johnson, & Macdonald, 2009)  
274 and Gabon (Wilkie et al., 2005), where a positive correlation between meat consumption and  
275 the wealth of the population was reported.

276 The meat intake outside the home by females was found to be low compared to males,  
277 probably because, in the Rwandan culture, women do not frequent bars as men do.  
278 According to Rwandan customs, the consumption of alcoholic beverages is generally  
279 reserved for men (Adekunle, 2007). Therefore, Rwandan women frequent less often than  
280 men the establishments such as snack bars where alcoholic beverages are more consumed  
281 by men. Another reason would be the low financial capacity of Rwandan women to afford the  
282 purchase of meat-based meals outside their household. Previous studies highlighted that in  
283 developing countries, the purchasing power was significantly low for women compared to  
284 men (Bastos, Casaca, Nunes, & Pereirinha, 2009; Burnet, 2011; Quisumbing, Haddad, &

285 Peña, 2001). The findings from our study are in agreement with the study by de Carvalho et  
286 al. (2014) in Sao Paulo (Brazil) where an average daily meat intake of 200.2 g was reported  
287 for males versus 130.6 g for females. A comparable trend was reported by Daniel et al.  
288 (2011) in Unites States (158.3 and 103.2 g of total meat per day for males and females,  
289 respectively) and in European countries where the consumption of all categories of pork was  
290 reported to be significantly low in women compared to men (Verbeke, Pérez-Cueto,  
291 Barcellos, Krystallis, & Grunert, 2010).

292 The low meat consumption observed in young adults (18–30 years old) may be due to their  
293 limited financial capacity to afford the purchase of meat-based meals outside their  
294 households compared to people from other age categories. Comparable findings were  
295 reported in Ireland (Cosgrove, Flynn, & Kiely, 2005) where an average daily meat intake of  
296 128.5 g was observed in young adults (18–35 years old) versus 134.5 g in adults (36–50  
297 years old). However in Brazil (de Carvalho et al., 2014), the consumption of meat (including  
298 meat consumed within the household) appeared to be higher among youth than adults  
299 (178.6 g of total meat per day for adolescents versus 167.7 g for adults). A similar trend was  
300 reported in the United States of America where an average daily meat intake was estimated  
301 at 149.0 g in people aged from 20 to 49 years versus 130.9 g for people aged from 50 to 69  
302 years (Daniel et al., 2011).

303 Contrary to other studies conducted in developing countries that have reported low meat  
304 intake in rural communities (Ayele & Peacock, 2003; Delgado, 2003; Heinz & Hautzinger,  
305 2007), the meat intake recorded in the peri-urban region of Kigali was found to be equivalent  
306 to that observed in city dwellers. Different studies have reported that people living in rural  
307 areas but near large cities had the opportunity to get jobs in these cities and their income  
308 was found to be comparable to that of city dwellers (Eliasson, Westlund, & Johansson, 2014;  
309 Wang, Huang, Zhang, & Rozelle, 2011). This could explain the equivalent meat intake  
310 recorded in both urban and peri-urban areas of Kigali city as wealth is recognised to be the  
311 main determinant of meat consumption (McAfee et al., 2010; Sans & Combris, 2015;  
312 Speedy, 2003).

313 Previous studies have reported that the average meat intake within the households of Kigali  
314 was 34.4 grams per person, per day (Niyonzima et al., 2016). Therefore, the global meat  
315 intake (within and outside the home) is estimated to be 84.0 grams per person, per day.  
316 Although the meat consumption rate observed in Kigali seems to be low in relation to the  
317 average meat intake of 93.9 grams per person, per day recorded in developing countries  
318 (Food and Agriculture Organization, 2014), it appears to have significantly increased with the

319 country's growing economy. In the 2000s, the Rwandan global meat intake was estimated to  
320 be 13.3 grams per person, per day (Speedy, 2003).

#### 321 **4.2. Bacteriological quality of the consumed meat**

322 The selection of the establishments from which meat samples were collected required the  
323 willingness of their managers to participate in the study, and this could have introduced a  
324 bias in the recorded findings. However, as a large proportion (68%) of the establishments  
325 agreed to participate in the study and the selection of these establishments was carried out  
326 randomly, the introduced bias is relatively minimal.

327 The total mesophilic bacteria and *E. coli* counts are respectively recognised as indicators of  
328 general hygiene and fecal contamination in foods (International Organization for  
329 Standardization, 2001, 2003). In our study, the levels of hygiene indicator bacteria in different  
330 meat-based meals were found to be relatively high. This could be attributed to a deficient  
331 cooking process and/or a post-cooking contamination of meat-based meals. It is generally  
332 recognised that main enteric bacteria are destroyed at conventional pasteurisation  
333 temperatures (Jay, Loessner, & Golden, 2005; Korsak, Clinquart, & Daube, 2004). However,  
334 as cooking times and temperatures may vary from one meat product or establishment to  
335 another, the possibility of inadequate cooking treatments should not be excluded. Several  
336 authors have reportedly associated the survival of enteric bacteria in cooked meat to  
337 deficient cooking treatments (Breslin et al., 2014; Lahou et al., 2015; Roccato et al., 2015;  
338 Silva & Gibbs, 2012). The bacterial contamination of meat products from the handlers or the  
339 processing environment can also occur after cooking. Factors such as dirty utensils, unclean  
340 works surfaces and deficient hygiene for personnel were reported to be associated with the  
341 bacterial contamination of cooked meat products (Cardinale, Perrier Gros-Claude, Tall,  
342 Guèye, & Salvat, 2005; Cardinale et al., 2015).

343 The mean TMC (4.7 log cfu/g) recorded in meat-based meals consumed in Kigali was found  
344 to be comparable to those recorded in other developing countries. The studies conducted in  
345 Cameroon (Yannick, Niba, & Akwah, 2013) and in Sudan (Abdalla, Suliman, & Bakhiet,  
346 2009) showed average total bacteria loads of 4.5 and 4.6 log cfu/g in cooked pork and  
347 chicken meals, respectively. In Taiwan, mean total bacteria loads of 5.7 and 5.6 log cfu/g  
348 were respectively reported in street vended chicken and pork meals (Manguiat & Fang,  
349 2013), whereas TMC levels as high as 7.2 log cfu/g were recorded in street meat-based  
350 sandwiches in Ethiopia (Muleta & Ashenafi, 2001). Nevertheless, Mosupye and Von Holy  
351 (2000) reported lower TMC levels (1.9–2.6 log cfu/g) in beef and chicken-based street foods  
352 sold in Johannesburg (South Africa).

353 Concerning *E. coli*, a mean count of 1.4 log cfu/g was recorded in the present study. Our  
354 findings are comparable to *E. coli* loads of 1.3 and 1.4 log cfu/g, respectively reported in  
355 grilled pork and chicken meals in Philippines (Manguiat & Fang, 2013). However, higher  
356 counts were reported in Lubumbashi (the Democratic Republic of Congo) where *E. coli* loads  
357 as high as 4.2 log cfu/g were recorded in street goat brochettes (Kabwang, 2013) and in  
358 Sudan, where a mean *E. coli* load of 3.2 log cfu/g was observed in street cooked beef and  
359 chicken meals (Abdalla et al., 2009).

360 As for hygiene indicator bacteria, the occurrence of *Salmonella* was found to significantly ( $p \leq$   
361 0.05) vary in different types of meat-based meals. The prevalence of *Salmonella* was found  
362 to be significantly lower in boiled beef comparatively to grilled or fried meat. This could be  
363 attributed to higher time and temperature treatments applied to beef during the cooking  
364 process. In our study, all beef samples were collected in restaurants where beef is generally  
365 prepared in sauces and the cooking duration is relatively long. Ninety-four per cent of 75  
366 restaurants reported boiling beef for more than one hour, whereas in snack bars, meat was  
367 grilled or fried for shorter periods. The temperature and the cooking duration were found to  
368 be important factors in the destruction of microorganisms in foods and several studies have  
369 reported the survival of *Salmonella* in undercooked meat products (Breslin et al., 2014;  
370 Lahou et al., 2015; Roccato et al., 2015). Another reason for higher prevalence of *Salmonella*  
371 in grilled or fried meat would be their contamination from the non-meat components of the  
372 dish. In most snack bars in Kigali, grilled or fried meat was generally served with uncooked  
373 vegetable salads that could be a source of *Salmonella* through cross-contamination. Several  
374 studies have reported the occurrence of *Salmonella* in ready-to-eat raw vegetable salads  
375 (Gómez-Aldapa, Rangel-Vargas, & Castro-Rosas, 2013; Gurler et al., 2015; Wijnands et al.,  
376 2014).

377 In our study, the overall *Salmonella* prevalence in ready-to-eat meat-based meals was found  
378 to be 11.7%. Ours findings are comparable to the prevalence of 15.1% in grilled goat  
379 brochettes ( $n=139$ ) and 10.1% in street poultry meals ( $n=444$ ), respectively reported in the  
380 Democratic Republic of Congo (Kabwang, 2013) and Senegal (Cardinale et al., 2005).  
381 Nevertheless, *Salmonella* prevalence as low as 2.6% in ready-to-eat pork based meals  
382 ( $n=117$ ) and 0.2% in beef based meals ( $n=478$ ) were reported in China (Yang et al., 2016)  
383 and Jordan (Osaili et al., 2014), respectively.

384 The levels of hygiene indicator bacteria and the occurrence of *Salmonella* were found to be  
385 significantly higher in meat-based meals sold in peri-urban areas of Kigali compared to urban  
386 localities. This could be associated with the lack of hygiene and sanitary facilities such as

387 proper running water in rural areas, but most importantly, to less frequent sanitary controls by  
388 competent authorities in rural meat selling establishments. Our findings are in agreement  
389 with a study conducted in Lubumbashi (the Democratic Republic of Congo) that revealed that  
390 hygiene conditions in the restaurants were less satisfactory in rural areas than in cities  
391 (Kabwang, 2013).

392 A significant and positive correlation was observed between total mesophilic bacteria and  
393 *E. coli* counts for the same sample and between ECC and the occurrence of *Salmonella*,  
394 indicating that the prevalence of *Salmonella* increases with the levels of hygiene indicator  
395 bacteria in meat samples. This would suggest that hygiene improvements in the  
396 establishments selling meat-based meals can significantly contribute to a reduction in the risk  
397 of *Salmonella* contamination in meat-based meals.

#### 398 **4.3. Risk factors for *Salmonella* contamination in meat-based meals**

399 Eight risk factors were found to be significantly associated with the occurrence of *Salmonella*  
400 in meat-based meals served in snack bars and restaurants of Kigali. The risk of *Salmonella*  
401 contamination was high in meat-based meals sold in snack bars than in restaurants. This can  
402 be explained by the fact that meat-based meals served in the restaurant (in most cases  
403 sauces) undergo a long heat treatment likely to destroy all bacterial pathogens present in  
404 meat. In snack bars, the cooking duration was relatively shorter and may suggest an  
405 undercooking and a possible survival of *Salmonella* particularly in depth of large piece of  
406 meat. Furthermore, uncooked vegetable salads generally served together with meat-based  
407 meals in snack bars could significantly contribute to the increased risk of *Salmonella*  
408 occurrence.

409 Not changing the knife used while cutting meat from another animal species or non-meat  
410 ingredients such as vegetables, was found to be associated with a high risk of *Salmonella*  
411 contamination in meat-based meals. In kitchens where diverse meat-based meals are  
412 prepared, raw materials of various kinds are generally handled closely together to create  
413 numerous opportunities for cross-contamination. Therefore, the utilisation of the same knife  
414 for cutting different raw material may contribute significantly to the dissemination of bacterial  
415 pathogen such as *Salmonella* into the processed meat products. Previous studies have  
416 reportedly associated *Salmonella* cross-contamination during the processing of meat  
417 products with the use of contaminated cutting equipment, particularly the knives (Hald,  
418 Wingstrand, Swanenburg, Von Altrock, & Thorberg, 2003; Mackey & Derrick, 1979).

419 The absence of pest control measures in the kitchen of restaurants and snack bars  
420 increased the risk of *Salmonella* contamination in the served meat-based meals. This could  
421 be explained by the possible dissemination of *Salmonella* on raw material and/or cooked  
422 meat meals through cross contamination by pests. Vermin such as flies were found to be  
423 implicated in the dissemination of bacterial pathogens on food products from the soiled  
424 environment (Jay et al., 2005; Niyonzima et al., 2015). Nevertheless, the risk of *Salmonella*  
425 contamination was reduced by a frequent cleaning of the kitchen and utensils used for meat  
426 preparation. Our findings corroborated the studies by Christison et al. (2007, 2008) where the  
427 kitchen utensils, food handlers and work surfaces were identified as potential sources of  
428 bacterial contaminations in ready-to-eat foods in Johannesburg (South Africa). It was also  
429 found that reheating meat-based meals prior to serving resulted in reducing the risk of  
430 *Salmonella* contamination. This could be attributed to the additional thermal destruction of  
431 residual *Salmonella* cells and/or new bacterial contaminants introduced into meat after the  
432 cooking process. Post-cooking contamination in ready-to-eat foods including meat has been  
433 reported in different countries such as Madagascar (Cardinale et al., 2015), Senegal  
434 (Cardinale et al., 2005), South Africa (Mosupye & Von Holy, 2000) and Trinidad (Badrie,  
435 Joseph, & Chen, 2003).

## 436 **5. Conclusions**

437 The findings from this study indicate that meat is regularly consumed outside the home in  
438 Kigali, and goat brochettes constitute the most consumed meat-based dish. The levels of  
439 hygiene indicator bacteria in different meat-based meals as well as the prevalence of  
440 *Salmonella* appeared to be relatively high. Therefore, there is a need to improve hygienic  
441 meat handling and/or cooking practices in the establishments selling meat-based meals in  
442 Kigali to limit the transmission of bacterial pathogens to humans through the consumption of  
443 contaminated meat.

## 444 **6. Acknowledgements**

445 The present study was carried out thanks to the financial support of the Rwandan Ministry of  
446 Education through the Rwanda Education Board. The authors thank the support from the  
447 University of Rwanda for providing laboratory facilities. The authors are also thankful to the  
448 Local Development Agency (LODA) for facilitating the access to data on the socio-economic  
449 status of Kigali city households and Kigali city local authorities (Gasabo, Kicukiro and  
450 Nyarugenge districts) for providing data on the establishments selling meat-based meals.  
451 The participation of different snack bars and restaurants as well as the households of Kigali  
452 in this study is gratefully appreciated.

453 **Highlights**

- 454 1. Goat is the most consumed type of meat outside the home in Kigali.
- 455 2. The meat consumption rate grows with the social category of the household.
- 456 3. The prevalence of *Salmonella* in the consumed meat-based meals is relatively high.
- 457 4. Hygiene improvements are needed in the establishments selling meat-based meals.

458

459

ACCEPTED MANUSCRIPT

460 **6. References**

- 461 Abdalla, M., Suliman, S. E., & Bakhiet, A. O. (2009). Food safety knowledge and practices of  
462 street food vendors in Atbara city (Naher Elneel State Sudan). *African Journal of*  
463 *Biotechnology*, 8(24), 6997–6971.
- 464 Adekunle, J. (2007). Social custom and life style. In *Culture and Customs of Rwanda* (1st  
465 ed., pp. 115–132). Westport Connecticut, USA: Greenwood.
- 466 Ayele, Z., & Peacock, C. (2003). Improving access to and consumption of animal source  
467 foods in rural households: the experiences of a women-focused goat development  
468 program in the highlands of Ethiopia. *Journal of Nutrition*, 133, 3981S–3986S.
- 469 Badrie, N., Joseph, A., & Chen, A. (2003). An observational study of food safety practices by  
470 street vendors and microbiological quality of street-purchased hamburger beef patties in  
471 Trinidad, West Indies. *Internet Journal of Food Safety*, 3, 25–31.
- 472 Bastos, A., Casaca, S. F., Nunes, F., & Pereirinha, J. (2009). Women and poverty: A gender-  
473 sensitive approach. *The Journal of Socio-Economics*, 38(5), 764–778.
- 474 Breslin, T. J., Tenorio-Bernal, M. I., Marks, B. P., Booren, A. M., Ryser, E. T., & Hall, N. O.  
475 (2014). Evaluation of Salmonella Thermal Inactivation Model Validity for Slow Cooking  
476 of Whole-Muscle Meat Roasts in a Pilot-Scale Oven. *Journal of Food Protection*, 77(11),  
477 1897–1903.
- 478 Burnet, J. E. (2011). Women have found respect: Gender quotas, symbolic representation,  
479 and female empowerment in Rwanda. *Politics & Gender*, 7(03), 303–334.
- 480 Campos, J., Gil, J., Mourão, J., Peixe, L., & Antunes, P. (2015). Ready-to-eat street-vended  
481 food as a potential vehicle of bacterial pathogens and antimicrobial resistance: An  
482 exploratory study in Porto region, Portugal. *International Journal of Food Microbiology*,  
483 206, 1–6.
- 484 Cardinale, E., Abat, C., Bénédicte, C., Vincent, P., Michel, R., & Muriel, M. (2015).  
485 *Salmonella* and *Campylobacter* Contamination of Ready-to-Eat Street-Vended Pork  
486 Meat Dishes in Antananarivo, Madagascar: A Risk for the Consumers? *Foodborne*  
487 *Pathogens and Disease*, 12(3), 197–202.
- 488 Cardinale, E., Perrier Gros-Claude, J. D., Tall, F., Guèye, E. F., & Salvat, G. (2005). Risk  
489 factors for contamination of ready-to-eat street-vended poultry dishes in Dakar,  
490 Senegal. *International Journal of Food Microbiology*, 103(2), 157–65.

- 491 Centers for Disease Control and Prevention (CDC). (2013). *National Enteric Disease*  
492 *Surveillance: Salmonella Annual Report, 2011*. Atlanta.
- 493 Christison, C. A., Lindsay, D., & von Holy, A. (2007). Cleaning and handling implements as  
494 potential reservoirs for bacterial contamination of some ready-to-eat foods in retail  
495 delicatessen environments. *Journal of Food Protection*, 70(12), 2878–2883.
- 496 Christison, C. A., Lindsay, D., & von Holy, A. (2008). Microbiological survey of ready-to-eat  
497 foods and associated preparation surfaces in retail delicatessens, Johannesburg, South  
498 Africa. *Food Control*, 19(7), 727–733.
- 499 Cosgrove, M., Flynn, A., & Kiely, M. (2005). Consumption of red meat, white meat and  
500 processed meat in Irish adults in relation to dietary quality. *British Journal of Nutrition*,  
501 93, 933–942.
- 502 Daniel, C. R., Cross, A. J., Koebnick, C., & Sinha, R. (2011). Trends in meat consumption in  
503 the United States. *Public Health and Nutrition*, 14(4), 575–583.
- 504 de Carvalho, A. M., César, C. L. G., Fisberg, R. M., & Marchioni, D. M. (2014). Meat  
505 consumption in São Paulo-Brazil: trend in the last decade. *PloS One*, 9(5), e96667.
- 506 Delgado, C. L. (2003). Rising Consumption of Meat and Milk in Developing Countries Has  
507 Created a New Food Revolution. *The Journal of Nutrition*, 133(11 Suppl 2), 3875S–  
508 4061S.
- 509 Dhingra, P., Sazawal, S., Menon, V. P., Dhingra, U., & Black, R. E. (2007). Validation of  
510 Visual Estimation of Portion Size Consumed as a Method for Estimating Food Intake by  
511 Young Indian Children. *Journal of Health, Population, and Nutrition*, 25(1), 112–115.
- 512 Doulgeraki, A. I., Ercolini, D., Villani, F., & Nychas, G.-J. E. (2012). Spoilage microbiota  
513 associated to the storage of raw meat in different conditions. *International Journal of*  
514 *Food Microbiology*, 157(2), 130–41.
- 515 East, T., Kümpel, N. F., Milner-Gulland, E. J., & Rowcliffe, J. M. (2005). Determinants of  
516 urban bushmeat consumption in Río Muni, Equatorial Guinea. *Biological Conservation*,  
517 126(2), 206–215.
- 518 EFSA & ECDC. (2015). The European Union Summary Report on Trends and Sources of  
519 Zoonoses, Zoonotic Agents and Food-borne outbreaks in 2014. *EFSA Journal*, 13(12),  
520 4329.
- 521 Eliasson, K., Westlund, H., & Johansson, M. (2014). Determinants of Net Migration to Rural  
522 Areas, and the Impacts of Migration on Rural Labour Markets and Self-Employment in

- 523 Rural Sweden. *European Planning Studies*, 23(4), 693–709.
- 524 Fa, J. E., Albrechtsen, L., Johnson, P. J., & Macdonald, D. W. (2009). Linkages between  
525 household wealth, bushmeat and other animal protein consumption are not invariant:  
526 Evidence from Rio Muni, Equatorial Guinea. *Animal Conservation*, 12, 599–610.
- 527 Food and Agriculture Organization. (2014). Meat and meat products. In *Food Outlook:  
528 Biannual report on global food markets* (pp. 52–57). Rome Italy: Food and Agriculture  
529 Organization.
- 530 Food and Agriculture Organization. (2015). Food Production by Countries. Retrieved 18  
531 September 2015, from <http://faostat3.fao.org/download/Q/QL/E>
- 532 Gómez-Aldapa, C. A., Rangel-Vargas, E., & Castro-Rosas, J. (2013). Frequency and  
533 Correlation of Some Enteric Indicator Bacteria and *Salmonella* in Ready-to-Eat Raw  
534 Vegetable Salads from Mexican Restaurants. *Journal of Food Science*, 78(8), M1201–  
535 M1207.
- 536 Government of Rwanda. (2008). Law No. 62/2007 of 30/12/2007 Establishing and determining  
537 the organization, functioning and management of the mutual Health Insurance Scheme.  
538 *Rwanda Official Gazette*, 47(20th March), 1–53.
- 539 Greig, J. D., & Ravel, A. (2009). Analysis of foodborne outbreak data reported internationally  
540 for source attribution. *International Journal of Food Microbiology*, 130(2), 77–87.
- 541 Gurler, Z., Pamuk, S., Yildirim, Y., & Ertas, N. (2015). The microbiological quality of ready-to-  
542 eat salads in Turkey: A focus on *Salmonella* spp. and *Listeria monocytogenes*.  
543 *International Journal of Food Microbiology*, 196, 79–83.
- 544 Hald, T., Wingstrand, A., Swanenburg, M., Von Altrock, A., & Thorberg, B. M. (2003). The  
545 occurrence and epidemiology of *Salmonella* in European pig slaughterhouses.  
546 *Epidemiology and Infection*, 131, 1187–1203.
- 547 Heinz, G. & Hautzinger, P. (2007). Principle of meat processing technology. In *Meat  
548 Processing Technology for Small to Medium Scale Producers* (pp. 17–43). Rome Italy:  
549 Food and Agriculture Organization.
- 550 International Organization for Standardization. (2001). *Microbiology of food and animal  
551 feeding stuffs — Horizontal method for the enumeration of  $\beta$ -glucuronidase-positive  
552 *Escherichia coli*. Part 2: Colony-count technique at 44°C using 5-bromo-4-chloro-3-  
553 indolyl  $\beta$ -glucuronide . ISO 16649-2: 2001 (Vol. 2001). Geneva: International  
554 Organization for Standardization.*

- 555 International Organization for Standardization. (2002). *Microbiology of food and animal*  
556 *feeding stuffs—Horizontal method for the detection of Salmonella spp. ISO 6579:2002*  
557 (Vol. 6). Geneva: International Organization for Standardization.
- 558 International Organization for Standardization. (2003). *Microbiology of food and animal*  
559 *feeding stuffs—Horizontal method for the enumeration of microorganisms—Colony-*  
560 *count technique at 30 °C . ISO 4833:2003* (Vol. 1). Geneva: International Organization  
561 for Standardization.
- 562 International Organization for Standardization. (2007). *Microbiology of food and animal*  
563 *feeding stuffs—General requirements and guidance for microbiological examinations.*  
564 *ISO 7218:2007*. Geneva: International Organization for Standardization.
- 565 Jay, M. J., Loessner, J. M., & Golden, A. D. (2005). Food Borne Diseases. In *Modern Food*  
566 *Microbiology* (7th ed., pp. 619–650). California: Springer.
- 567 Kabwang, R. (2013). *Prevalence of enteropathogenic bacteria isolated from meat sold at*  
568 *retail outlet in Lubumbashi, R.D. Congo*. University of Liege.
- 569 Korsak, N., Clinquart, A., & Daube, G. (2004). Salmonella spp. dans les denrées alimentaires  
570 d'origine animale: un réel problème de santé publique? *Annales de Médecine*  
571 *Vétérinaire*, 148, 174–193.
- 572 Lachat, C., Nago, E., Verstraeten, R., Roberfroid, D., Van Camp, J., & Kolsteren, P. (2012).  
573 Eating out of home and its association with dietary intake: a systematic review of the  
574 evidence. *Obesity Reviews*, 13(4), 329–346.
- 575 Lahou, E., Wang, X., De Boeck, E., Verguldt, E., Geeraerd, A., Devlieghere, F., &  
576 Uyttendaele, M. (2015). Effectiveness of inactivation of foodborne pathogens during  
577 simulated home pan frying of steak, hamburger or meat strips. *International Journal of*  
578 *Food Microbiology*, 206, 118–129.
- 579 Ma, H., Huang, J., Fuller, F., & Rozelle, S. (2006). Getting Rich and Eating Out:  
580 Consumption of Food Away from Home in Urban China. *Canadian Journal of*  
581 *Agricultural Economics*, 54(1), 101–119.
- 582 Mackey, B. M., & Derrick, C. M. (1979). Contamination of the Deep Tissues of Carcasses by  
583 Bacteria Present on the Slaughter Instruments or in the Gut. *Journal of Applied*  
584 *Bacteriology*, 46(2), 355–366.
- 585 Manguiat, L. S., & Fang, T. J. (2013). Microbiological quality of chicken- and pork-based  
586 street-vended foods from Taichung, Taiwan, and Laguna, Philippines. *Food*

- 587 *Microbiology*, 36(1), 57–62.
- 588 McAfee, A. J., McSorley, E. M., Cuskelly, G. J., Moss, B. W., Wallace, J. M. W., Bonham, M.  
589 P., & Fearon, A. M. (2010). Red meat consumption: an overview of the risks and  
590 benefits. *Meat Science*, 84(1), 1–13.
- 591 Mosupye, F. M., & Von Holy, A. (2000). Microbiological hazard identification and exposure  
592 assessment of street food vending in Johannesburg, South Africa. *International Journal*  
593 *of Food Microbiology*, 61, 137–145.
- 594 Muleta, D., & Ashenafi, M. (2001). Salmonella, Shigella and growth potential of other food-  
595 borne pathogens in Ethiopian street vended foods. *East African Medical Journal*, 78(11),  
596 576–580.
- 597 National Institute of Statistics of Rwanda. (2012). *Rwanda Fourth Population and Housing*  
598 *Census. Thematic Report: Characteristics of households and housing*. Kigali, Rwanda.
- 599 Newell, D. G., Koopmans, M., Verhoef, L., Duizer, E., Aidara-Kane, A., Sprong, H., ... Kruse,  
600 H. (2010). Food-borne diseases—The challenges of 20years ago still persist while new  
601 ones continue to emerge. *International Journal of Food Microbiology*, 139(SUPPL. 1),  
602 S3–S15.
- 603 Niyonzima, E., Ongol, M. P., Brostaux, Y., Korsak, N., Daube, G., Kimonyo, A., & Sindic, M.  
604 (2016). Daily intake and bacteriological quality of meat consumed in the households of  
605 Kigali, Rwanda. *Food Control*, 69, 108–114.
- 606 Niyonzima, E., Ongol, M. P., Kimonyo, A., & Sindic, M. (2015). Risk Factors and Control  
607 Measures for Bacterial Contamination in the Bovine Meat Chain: A Review on  
608 Salmonella and Pathogenic E. coli. *Journal of Food Research*, 4(5), 98–121.
- 609 Osaili, T. M., Al-Nabulsi, A. A., Shaker, R. R., Jaradat, Z. W., Taha, M., Al-Kherasha, M., ...  
610 Holley, R. (2014). Prevalence of Salmonella Serovars, Listeria monocytogenes, and  
611 Escherichia coli O157:H7 in Mediterranean Ready-to-Eat Meat Products in Jordan.  
612 *Journal of Food Protection*, 77(1), 106–111.
- 613 Quisumbing, A. R., Haddad, L., & Peña, C. (2001). Are women overrepresented among the  
614 poor? An analysis of poverty in 10 developing countries. *Journal of Development*  
615 *Economics*, 66(1), 225–269.
- 616 Roccato, A., Uyttendaele, M., Cibin, V., Barrucci, F., Cappa, V., Zavagnin, P., ... Ricci, A.  
617 (2015). Survival of Salmonella Typhimurium in poultry-based meat preparations during  
618 grilling, frying and baking. *International Journal of Food Microbiology*, 197, 1–8.

- 619 Rwanda Ministry of Local Government. (2012). *Rwanda Local development support Fund*  
620 *annual report 2011/2012*. Kigali, Rwanda.
- 621 Rwandan Ministry of Agriculture and Animal Resources. (2012). *Strategic and Investment*  
622 *Plan to strengthen meat industry in Rwanda*. Kigali, Rwanda.
- 623 Sans, P., & Combris, P. (2015). World meat consumption patterns: An overview of the last  
624 fifty years (1961–2011). *Meat Science*, 109, 106–111.
- 625 Scallan, E., Hoekstra, R. M., Angulo, F. J., Tauxe, R. V., Widdowson, M.-A., Roy, S. L., ...  
626 Griffin, P. M. (2011). Foodborne Illness Acquired in the United States—Major  
627 Pathogens. *Emerging Infectious Diseases*, 17(1), 7–15.
- 628 Silva, F. V. M., & Gibbs, P. a. (2012). Thermal pasteurization requirements for the  
629 inactivation of Salmonella in foods. *Food Research International*, 45(2), 695–699.
- 630 Speedy, A. W. (2003). Animal Source Foods to Improve Micronutrient Nutrition in Developing  
631 Countries. *Journal of Nutrition*, 133, 4048–4053.
- 632 Stevens, A., Kaboré, Y., Perrier-Gros-Claude, J.-D., Millemann, Y., Brisabois, A., Catteau,  
633 M., ... Dufour, B. (2006). Prevalence and antibiotic-resistance of Salmonella isolated  
634 from beef sampled from the slaughterhouse and from retailers in Dakar (Senegal).  
635 *International Journal of Food Microbiology*, 110(2), 178–186.
- 636 Verbeke, W., Pérez-Cueto, F. J. A., Barcellos, M. D. de, Krystallis, A., & Grunert, K. G.  
637 (2010). European citizen and consumer attitudes and preferences regarding beef and  
638 pork. *Meat Science*, 84(2), 284–292.
- 639 Wang, X., Huang, J., Zhang, L., & Rozelle, S. (2011). The rise of migration and the fall of self  
640 employment in rural China's labor market. *China Economic Review*, 22(4), 573–584.
- 641 Wijnands, L. M., Delfgou-van Asch, E. H. M., Beerepoot-Mensink, M. E., van der Meij-Florijn,  
642 A., Fitz-James, I., van Leusden, F. M., & Pielaat, A. (2014). Prevalence and  
643 Concentration of Bacterial Pathogens in Raw Produce and Minimally Processed  
644 Packaged Salads Produced in and for The Netherlands. *Journal of Food Protection*,  
645 77(3), 388–394.
- 646 Wilkie, D. S., Starkey, M., Abernethy, K., Effa, E. N., Telfer, P., & Godoy, R. (2005). Role of  
647 prices and wealth in consumer demand for bushmeat in Gabon, Central Africa.  
648 *Conservation Biology*, 19(1), 268–274.
- 649 Williamson, D. A, Allen, H. R., Martin, P. D., Alfonso, A, Gerald, B., & Hunt, a. (2004).  
650 Digital photography: a new method for estimating food intake in cafeteria settings.

- 651 *Eating and Weight Disorders*, 9(1), 24–8.
- 652 Yamane, T. (1967). *Statistics; An Introductory Analysis* (2<sup>nd</sup> ed.). New York: Harper and Row.
- 653 Yang, X., Huang, J., Wu, Q., Zhang, J., Liu, S., Guo, W., ... Yu, S. (2016). Prevalence,  
654 antimicrobial resistance and genetic diversity of *Salmonella* isolated from retail ready-to-  
655 eat foods in China. *Food Control*, 60, 50–56.
- 656 Yannick, N., Niba, R., & Akwah, E. (2013). Assessment of bacteriological quality of cooked  
657 pork meat sold along the commercial streets of Nkwen through Bambili Metropolis,  
658 Cameroon. *African Journal of Food Science*, 7(12), 441–445.
- 659

660 **Table 1.** Numbers and main characteristics of different categories of households

Category of the households	Number	Main characteristics of the household
Low-income household	70	Has no farmland or livestock. Does not have or has a poor shelter. The household food needs are not regularly fulfilled. The household cannot afford the payment of school fees for children or the basic medical care for any member of the household.
Middle-income household	270	Has farmland, livestock and/or practices a revenue generating activity. Does have a shelter and can fulfill regular food needs. Can afford the payment of school fees for children up to the secondary school level and the basic medical care for any member of the household.
High-income household	17	Has farmland, livestock and/or practices a revenue generating activity. The household food needs are regularly fulfilled. The household owns one or many houses and/or vehicles. It can afford the payment of school fees for children up to the university level and any medical care for all household members.

661 (\*) Source: Rwanda Ministry of Local Government (2012)

662

663 **Table 2. Types and numbers of collected meat samples**

Type of meat	Cooking process	Number of bars or restaurant	Number of samples collected
Bovine meat	Boiling <sup>(a)</sup>	75	150
Goat meat	Grilling	42	84
Pork	Frying	15	30
Chicken	Grilling	10	20
Rabbit	Grilling	8	16

664 <sup>(a)</sup>In most of the establishments, meat was first fried and then boiled with different ingredients.

665

666

667 **Table 3.** Daily meat intake in different social categories of households. Values are means ( $\pm$  standard deviation) of meat intakes (g/pers.day). In  
 668 the same column, different superscript letters indicate a significant difference ( $p \leq 0.05$ ).

	n	Daily meat intake					
		Beef	Goat/ mutton	Pork	Chicken	Rabbit	All species
Low-income households	70	0.4 $\pm$ 0.7 <sup>a</sup>	0.2 $\pm$ 1.0 <sup>a</sup>	0.0 $\pm$ 0.0	0.0 $\pm$ 0.0	0.0 $\pm$ 0.0	0.7 $\pm$ 1.3 <sup>a</sup>
Middle-income households	270	11.2 $\pm$ 13.4 <sup>b</sup>	39.5 $\pm$ 54.7 <sup>b</sup>	0.7 $\pm$ 2.8 <sup>a</sup>	2.7 $\pm$ 9.0 <sup>a</sup>	1.1 $\pm$ 5.6 <sup>a</sup>	56.0 $\pm$ 57.0 <sup>b</sup>
High-income households	17	53.2 $\pm$ 26.2 <sup>c</sup>	62.5 $\pm$ 112.5 <sup>c</sup>	10.4 $\pm$ 32.7 <sup>b</sup>	42.1 $\pm$ 83.5 <sup>b</sup>	2.6 $\pm$ 7.3 <sup>a</sup>	150.4 $\pm$ 137.7 <sup>c</sup>
Total	357	11.1 $\pm$ 16.5	32.9 $\pm$ 55.8	1.0 $\pm$ 7.6	4.0 $\pm$ 21.2	0.9 $\pm$ 5.1	49.6 $\pm$ 65.5

669

670

671 **Table 4.** Utilisation of meat from different animal species in snack bars and restaurants of Kigali. Values are numbers (percentages) of  
 672 establishments using meat from a given animal species for the preparation of meat-based meals.

	n	Type of meat				
		Beef	Goat /mutton	Chicken	Pork	Rabbit
Snack bars	75	21 (28.0%)	61 (81.3%)	46 (61.3%)	24 (32.0%)	42 (56.0%)
Restaurants	75	67 (89.3%)	14 (13.3%)	0 (0.0)	0 (0.0)	0 (0.0)
Total	150	88 (58.7%)	75 (50.0%)	46 (30.7%)	24 (16.0%)	42 (28.0%)

673

674 **Table 5.** Utilisation of different cooking methods in snack bars and restaurants of Kigali. Values are percentages of snack bars (of restaurants)  
 675 using a given cooking method for the preparation of meat-based meals.

	Type of meat				
	Beef	Goat /mutton	Chicken	Pork	Rabbit
Boiling	0.0 (89.6)	0.0 (14.3)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Grilling	85.7 (0.0)	100.0 (0.0)	84.8 (0.0)	25.0 (0.0)	100 (0.0)
Frying	14.3 (10.4)	0.0 (85.7)	15.2 (0.0)	75.0 (0.0)	0.0 (0.0)

676

677

678

679 **Table 6.** Estimated cooking duration for meat in snack bars and restaurants of Kigali. Values are percentages of snack bars (of restaurants)  
 680 cooking meat-based meals during a given period.

	Type of meat				
	Beef	Goat /mutton	Chicken	Pork	Rabbit
30-45 min	85.7 (0.0)	95.1 (85.7)	45.7 (0.0)	87.5 (0.0)	92.9 (0.0)
45-60 min	0.0 (6.0)	4.9 (0.0)	43.5 (0.0)	12.5 (0.0)	7.1 (0.0)
60 min <	14.3 (94.0)	0.0 (14.3)	10.9 (0.0)	0.0 (0.0)	0.0 (0.0)

681

682 **Table 7.** Bacteriological quality of meat-based meals. Bacteriological counts: values are means ( $\pm$ standard deviation) of bacteriological counts.  
 683 *Salmonella* detection: values are numbers and percentages of *Salmonella* positive samples. In the same column, different superscript letters  
 684 indicate a significant difference ( $p \leq 0.05$ ).

	n	Bacteriological counts (log cfu/g)		<i>Salmonella</i> detection	
		Total mesophilic bacteria	<i>E. coli</i>	Num. of positive samples	Percent
Boiled beef	150	3.6 $\pm$ 1.9 <sup>a</sup>	1.3 $\pm$ 0.4 <sup>a</sup>	8	5.3% <sup>a</sup>
Grilled goat meat	84	6.0 $\pm$ 3.5 <sup>b</sup>	1.4 $\pm$ 0.5 <sup>a</sup>	16	19.0% <sup>b</sup>
Fried pork	30	6.6 $\pm$ 3.1 <sup>b</sup>	1.3 $\pm$ 0.4 <sup>a</sup>	6	20.0% <sup>bc</sup>
Grilled chicken	20	6.2 $\pm$ 3.4 <sup>b</sup>	1.5 $\pm$ 0.5 <sup>a</sup>	3	15.0% <sup>abc</sup>
Grilled rabbit	16	6.4 $\pm$ 3.5 <sup>b</sup>	1.7 $\pm$ 0.7 <sup>a</sup>	2	12.5% <sup>abc</sup>
Total	300	4.7 $\pm$ 3.1	1.4 $\pm$ 0.5	35	11.7%

685

686 **Table 8.** Risk factors for *Salmonella* occurrence in the establishments selling meat-based  
 687 meals in Kigali.

Variable	Percentage of <i>Salmonella</i> positive establishments (*).	Binary logistic regression		
		Odds ratio	95% CI	p-value
<i>Type of the establishment selling meat-based meals</i>				
Snack bar	29.3	4.774	1.81–12.61	0.001
Restaurant	8.0	1		
<i>Changing knife to cut meat from different animal species and non-meat ingredients</i>				
Yes	3.0	1		
No	23.1	9.600	1.25–73.56	0.009
<i>Cooking method for meat-based meals preparation</i>				
Boiling	8.0	1		
Grilling	28.3	4.547	1.66–12.43	
Frying	33.3	5.750	1.48–22.39	0.003
<i>Estimated duration of the cooking process</i>				
30–45 min	30.1	1		
45–60 min	8.3	1		
60 min<	7.7	0.193	0.07–0.55	0.002
<i>Previously cooked foods and only reheating at consumption</i>				
Yes	7.6	0.217	0.08–0.61	0.002
No	27.4	1		
<i>Frequency of cleaning the kitchen</i>				
Only once a day	36.8	1		
Several times	7.5	0.140	0.06–0.36	0.032
<i>Specific work clothing for personnel</i>				
Yes	4.5	1		
No	24.5	6.825	1.54–30.16	0.004
<i>Presence of measures against vermin in the establishment</i>				
Yes	6.8	1.0		
No	30.7	5.989	2.14–16.80	0.000

688 (\*) Meat-based meals served in a given establishment were considered contaminated by  
 689 *Salmonella* if at least one meat sample was found to be *Salmonella* positive.

690

691

692

693

694

695

696

697

698

699

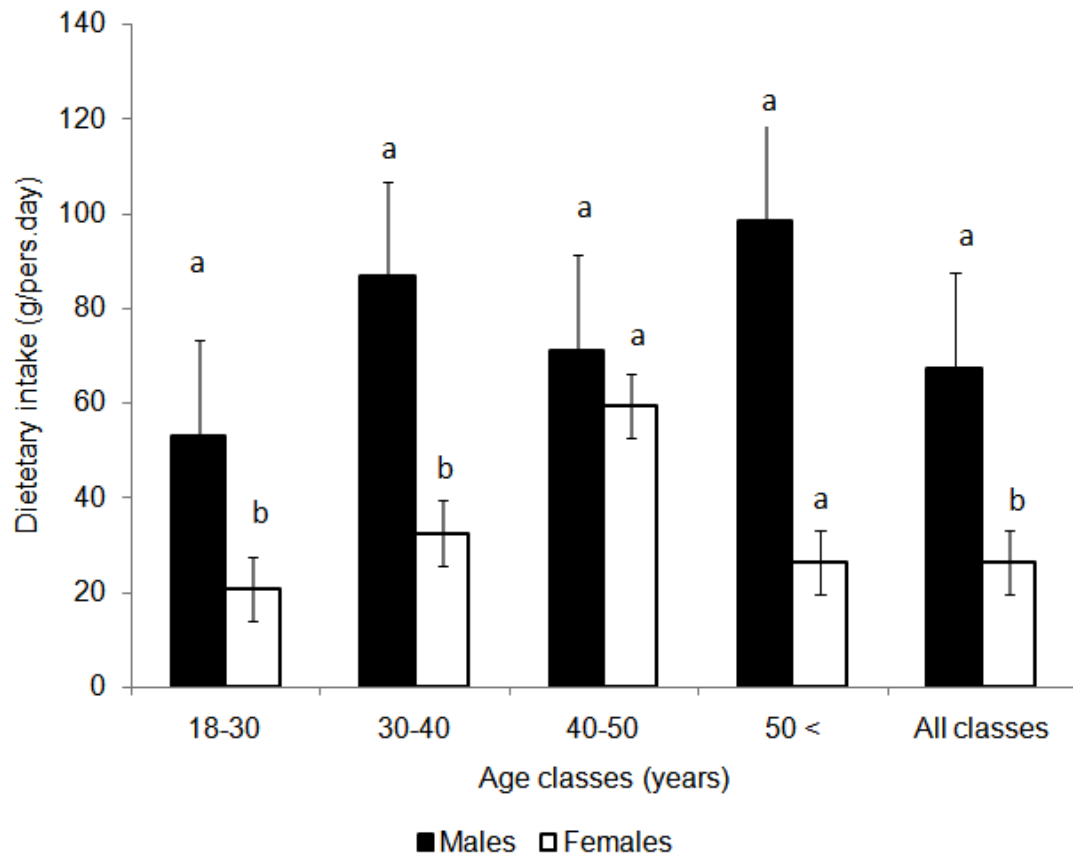
700

701

702

703

704



705 **Figure 1.** Meat consumption by age and gender category. Values are mean daily meat  
 706 intakes (g/person). Errors bars represent standard error. For the same age category,  
 707 different letters indicate a significant difference ( $p \leq 0.05$ ).

708

709

710

711

712

713

714

715

716

717

718

719

720

721

722

723

724

725

726

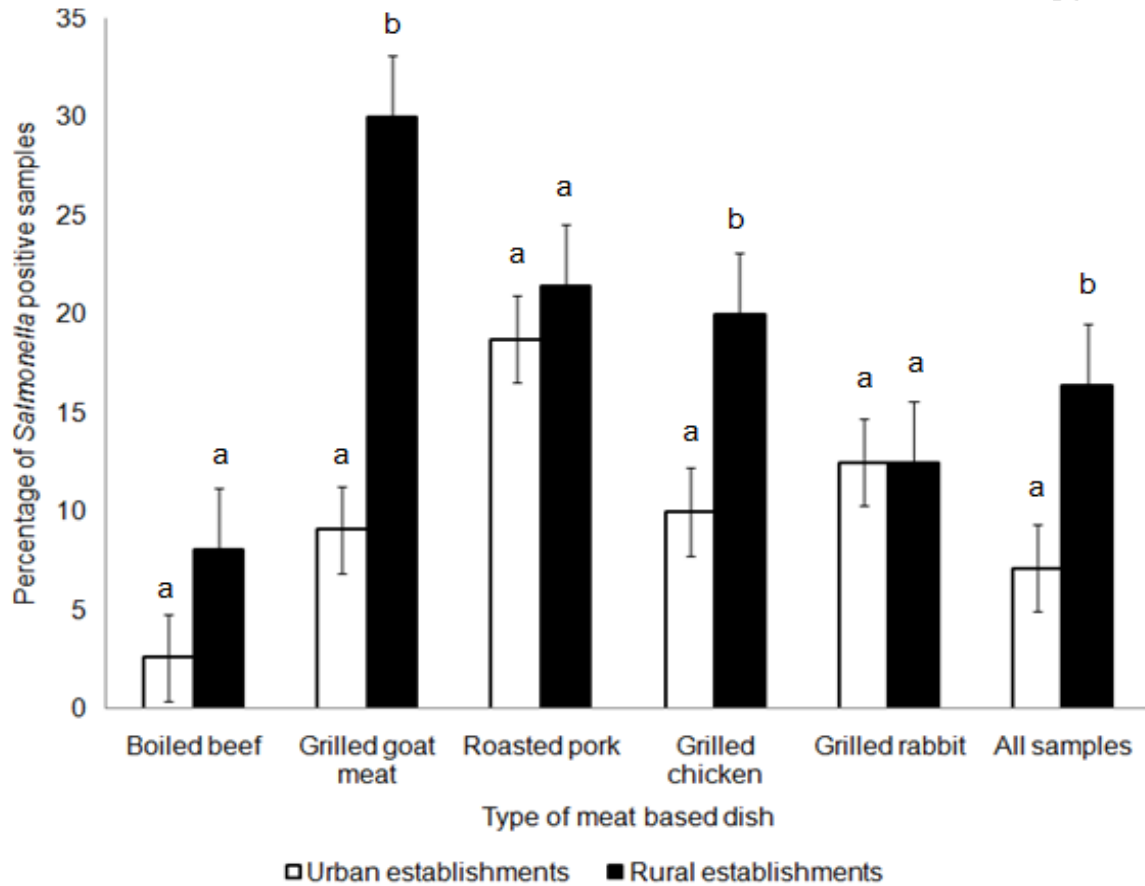
727

728

729

730

731



732 **Figure 2.** Occurrence of *Salmonella* in meat-based meals sold in urban and rural localities of  
 733 Kigali. Values are proportions (percentage) of *Salmonella* positive samples. Errors bars  
 734 represent standard error. For the same type of meat-based dish, different letters indicate a  
 735 significant difference ( $p \leq 0.05$ ).

736

737