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Investigation of the food value chain of ready-to-eat chicken and the associated risk for staphylococcal food poisoning in Tshwane Metropole, South Africa

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ABSTRACT

The objective of the study was to better understand the informal markets for ready-to-eat (RTE) chicken in Tshwane Metropole, Gauteng Province, South Africa, and in particular the links between the formal and informal sector. As part of this, we assessed the risk of a common food poisoning (staphylococcal) through consumption of RTE chicken sold by informal vendors. We used participatory risk assessment, a novel approach to understanding food safety in data scarce environments to collect information. Structured interviews and focus group discussions with informal vendors ($n = 237$) were conducted to understand poultry value chains for informal RTE chicken, business operation and hygiene practices. Samples ($n = 100$) of RTE were collected from informal vendors in six major taxi ranks. *Staphylococcus aureus* counts were determined using 3M™ Petrifilm™ plates. Data collected in this present study plus information obtained from reviewing of literature, were used to develop a stochastic risk model. The number of colonies which were too numerous to count (TNTC) was artificially modeled.

A mapping of the informal food value chain revealed that there are four possible value chains and that chicken spilled over from formal to informal markets. The prevalence of *S. aureus* in RTE chicken samples (44%; 90% CI: 36.1%–52.2%) was high. The mean *S. aureus* counts in the ready to eat chicken was $10^{3.6}$ (90%CI: $10^{3.3}$–$10^{3.9}$), and the risk of purchasing chicken of unsatisfactory quality (>10^3 cfu/g) was 32.9% (90%CI: 25.5%–40.4%). The probability of food poisoning due to consumption of RTE chicken contaminated with staphylococcal enterotoxin was estimated to be 1.3% (90% CI: 0%–2.7%). Sensitivity analysis showed that the probability of *S. aureus* having the enterotoxin gene was the most sensitive parameter for food poisoning. This was followed by *S. aureus* concentration in RTE chicken and lastly the prevalence of *S. aureus* in ready-to-eat chicken.

This study demonstrates the existence of a strong link between formal and the informal market. In view of the low risk observed, the relevant authorities in Tshwane should continue to support the informal sale of RTE chicken. However, there is still a need for provision of hygiene training to reduce the concentration levels of *S. aureus* on the RTE chicken, and to promote the sale of safer affordable source of protein for the large urban poor population in South Africa. This will also help secure the opportunities for employment associated with the trade.

1. Introduction

The great majority of poor people in developing countries obtain food from informal or "wet markets" but these are often neglected by food safety authorities and little is known about their impacts on public health (Grace et al., 2008; Grace, Makita, Kang'ethe, & Bonfoh, 2010). In South Africa, the first comprehensive study into the safety of street vended foods was conducted at a major taxi rank

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in Johannesburg central business district (Masupye & von Holy, 1999). This has been followed by a few other studies, with the most recent study conducted in Bloemfontein, Free State Province (International Union of Microbiological Societies, International Committee on Food Microbiology and Hygiene (IUM-ICFMH) and South Africa, 2005; Lues, Rasephei, Venter, & Theron, 2006). Some of these studies have suggested opportunities for improving safety of street vended foods (von Holy & Makhoane, 2006), and other studies indicate the importance and the benefits associated with the informal sector (Steyn, Labadaries, & Nel, 2011).

Food that is contaminated, irrespective of whether it has unacceptable levels of pathogens or chemical contaminants or other hazards, poses health risks to consumers and economic burdens on individual communities and nations (KZN-DOH, 2001; Mensah, Mwamakamba, Mohamed, & Nsue-Milang, 2012); but quantifying these burdens is essential for rational resource allocation. Previous studies done in South Africa which focused on detecting the presence of hazards could not predict the risk to human health. However, quantitative risk assessment (QRA) can predict health risk along with margins of uncertainty. This information is important to decision makers in developing countries who have to allocate scarce resources across competing health priorities. The application of QRA has been limited in Africa because of the high requirements of data and skilled personnel. In the past decade, participatory risk assessment has been developed as a method that integrates participatory techniques, long used in rural and urban development, with conventional risk assessment (Grace et al., 2008, 2010). Although participatory risk assessment has been applied to several food safety problems in Africa (Appiah, 2010; Grace et al., 2008, 2010), this is the first study on its use in South Africa to address a key hazard of informally marketed food.

Staphylococcal food poisoning (SFP) is one of the most common food-borne diseases that affects hundreds of thousands of people each year worldwide (Asao et al., 2003; Hazariwala et al., 2002; Hennekinne, De Buyser, & Dragacci, 2012; Ji-Yeon et al., 2013). According to the Centers of Disease Control and Prevention (CDC), USA, 240, 000 illnesses with 1000 hospitalizations and 6 deaths associated with staphylococcal food poisoning occur annually (Tallent, DeGrasse, Wang, Mattis, & Kranz, 2013). The role of poultry in SFP has been recognized, and in one study 6.8% of the 236 outbreaks were associated with poultry (Hennekinne et al., 2012; Ji-Yeon et al., 2013).

The cause of SFP is staphylococcal enterotoxins produced by enterotoxigenic strains of coagulase-positive staphylococci (CPS), among which *Staphylococcus aureus* is the main cause with other species such *Staphylococcus intermedius* very occasionally implicated (Hennekinne et al., 2012). While there is evidence for coagulase negative strains being enterotoxigenic, only CPS have been evidenced in food poisoning incidence. In view of this, the present study considers CPS *S. aureus* the main causative agent described in SFPOs (Hennekinne et al., 2012).

In milk *S. aureus* starts producing SE when the population density reaches about $10^{6.5}$ cfu/ml (Fujikawa & Morozumi, 2006). However in low a_w conditions, such as in salted RTE chicken, *S. aureus* accumulate low molecular weight compounds called compatible solutes, which stimulate not only growth but also toxin synthesis (Qi & Miller, 2000). In food, a slightly lower population density of 10^6 CFU/g of *S. aureus* is able to produce sufficient amounts of SEs to cause SFP (Min et al., 2013), but SFP is in many cases confirmed by recovery of at least 10^5 *S. aureus* from food remnants (Hennekinne et al., 2012). Therefore, the present study considers that SFP from consumption of RTE chicken occurs when the chicken is contaminated with *S. aureus* with its concentration higher than 10^5 cfu/g.

The motivation for this study is based on following facts: there is a paucity of data on street foods in South Africa, and to our knowledge, there is no study that has looked at the links between the formal and informal food sectors. Furthermore, quantitative microbial risk assessment (QMRA) of the risk of SFP through consumption of RTE sold by informal traders in Tshwane, South Africa has not been conducted.

2. Material and methods

2.1. Study sites

The study was conducted in Tshwane Metropole with a population of 2,345,908. The Metropole includes Pretoria, the capital city of South Africa.

2.2. Study design

Participatory risk assessment (Grace et al., 2008) was applied in the present study following the procedure of the Codex Alimentarius Commission system framework (CAC (Codex Alimentarius Commission), 2010). Participatory methods are well suited where there is a need to improve understanding of issues and yet data is scarce. Methods that can be employed in such situations include interviews and focus group discussions, visualizations, matrix scoring and proportional piling (Catley & Berhanu, 2003).

2.3. Sampling strategy

Past studies on informal markets in South Africa show that informal food vendors tend to concentrate in and around taxi ranks and railway stations (Lues et al., 2006). In view of this, taxi ranks and railway stations with higher vendor concentration were targeted. Given that the location and population of vendors is continually fluctuating in these informal markets, it was difficult to design a formal sampling frame. Therefore six larger clusters were purposively selected out of a possible 13 markets identified in the Tshwane Metropolitan. The markets that were sampled in this study include; Marabastad, Mabopane, Soshanguve, Belle Ombre/Prinsloo, Mamelodi and Sausville (Fig. 1). With the exception of Belle Ombre that serves a nearby railway and a bus station as well as a taxi rank, the rest are located at taxi ranks. Where the railway stations and taxi ranks are in close proximity to each other, the market is more closely related with the taxi rank. In that case one informal market serves both the railway station and the taxi rank.

While the markets/taxi ranks formed clusters, the units of concern were the vendors selling RTE chicken. All vendors encountered in each of the selected clusters/markets were invited to participate in the study. Verbal and written consent was obtained from each vendor prior to purchase of RTE chicken samples for microbial analysis. Sampling was conducted in April and May 2011 and in total, 100 samples were collected from six markets. The sample size was determined basing on the expected prevalence and the available budget.

2.4. Enumeration of bacteria

Enumeration of *S. aureus* was performed on 3M™ Petrifilm™ Staph Express Count Plate (3M, st. Paul. Mn, USA), which uses a selective and differential medium for *S. aureus* (Merck, 2007), chromogenic modified Baird–Parker medium, following instructions by the manufacturer. When the numbers of colonies on a plate was greater than 150, the count was recorded as too numerous to count (TNTC). In cases where background flora (colonies with non-red-violet color i.e. black colonies or blue-green colonies) were encountered on the plates, as recommended by the manufacturer, 3M Petrifilm Staph Express Discs (3M, st. Paul.

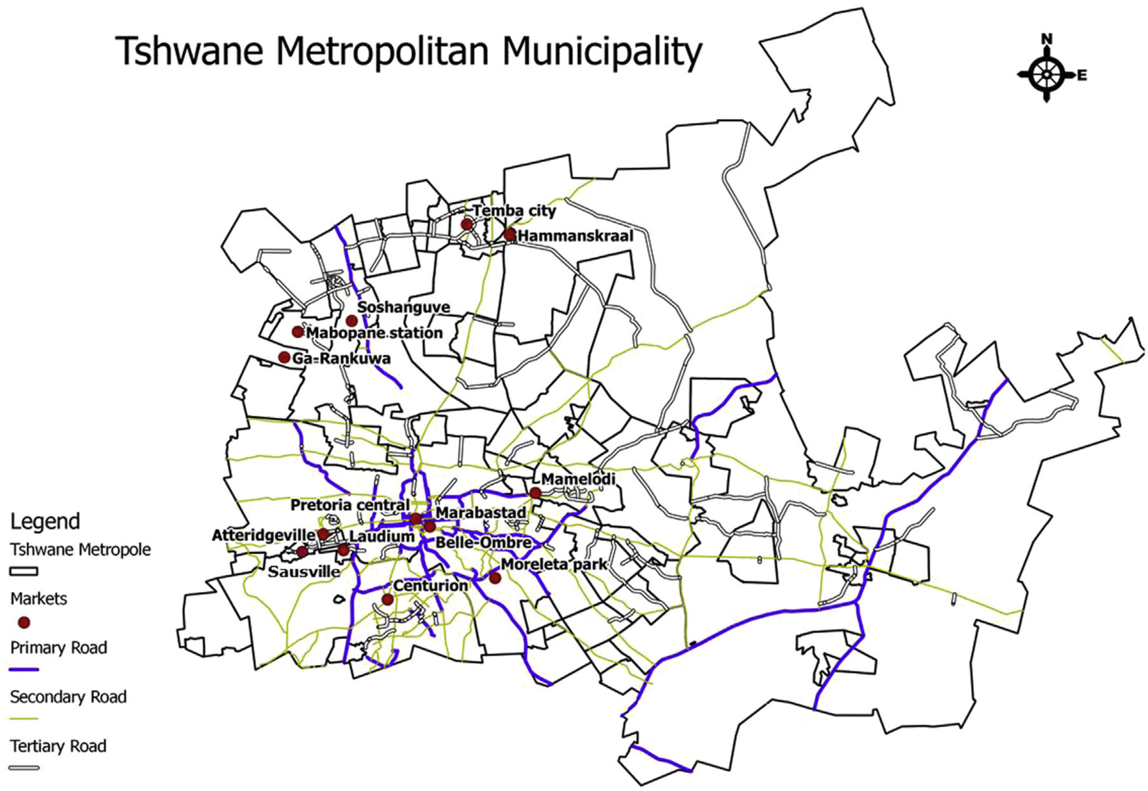

Fig. 1. A map showing the informal markets studied in Tshwane Metropolitan City, South Africa.

Mn, USA) were used to confirm the colony as *S. aureus*. In the present study, only the colonies of coagulase positive *Staphylococcus* (*S. aureus*, *S. intermedius* and *Staphylococcus hyicus*), which produces deoxyribonuclease (DNase) were counted as *S. aureus*.

The prevalence of *S. aureus* in ready-to-eat chicken meat was compared among the six markets studied using Generalized Linear Models (GLMs) with binomial errors in statistic software R version 2.14.2.

2.5. The value chain and sales survey

The value chains of informal RTE chicken from producer to sales were studied in the focus group discussions and informal interviews. Using structured questionnaires, operation of business and hygienic practice were studied among 237 informal vendors in the 13 taxi ranks. Verbal and written consent was obtained from each vendor who participated in the survey prior to collection of information. The information gathered from interviews was triangulated by focus group interviews.

2.6. Relative quantities of ready-to-eat (RTE) chicken sales

In order to estimate the overall risks of SFP from consumption of RTE chicken in entire Tshwane Metropole, the prevalence at the markets studied, should be weighted by the quantity of sales at the respective six taxi ranks. As rigorous random sampling could not be

Table 1
Parameters used to model the risk of staphylococcal poisoning due to consumption of ready-to-eat chicken sold in informal markets in Tshwane Metropolitan area, South Africa.

Parameter	Model	Source of information
Probability of chicken contaminated with *S. aureus* purchased in a market studied i: $Pcont_i$	$Beta(s_i + 1, n_i - s_i + 1)$ where s_i is the number of samples contaminated with *S. aureus* in a market i n_i is the number of samples tested for *S. aureus* in a market i	Survey data
Relative quantity of sales in a market i: $Sales_i$	$\frac{Q_i}{50}$ Where Q_i is the number of pebbles placed to represent the relative quantity of sales in a market i	Proportional piling
Log_{10}Cfu/g of *S. aureus* when the bacteria were too numerous to count: *Logtn*	*Uniform*(4.2, 8.5)	Minimum: the largest Log_{10} Cfu/g observed was 4.19 in a survey Maximum: Fujikawa and Morozumi (2006)
Probability that the bacteria concentration of a sample contaminated with *S. aureus* exceeds $10^{6.5}$ cfu/g: *Pexc*	Average of *If* (Non-parametric bootstrap of Log_{10}Cfu/g including *Logtn* >6.5, 1, 0)	*Logtn* Survey data
Probability of *S. aureus* having SE gene: *Pgene*	$Beta(s + 1, n - s + 1) = Beta\ (110, 183)$	Of 291, 109 *S. aureus* had SE gene (Arcuri et al., 2010)

achieved in informal markets, proportional piling, a participatory technique commonly used in participatory rural appraisals (PRA) (Mariner & Paskin, 2000) to establish the significance of animal and public health problems was adopted for the present study. Three key informants who know the markets studied well and were willing to participate in this section of the study. As prescribed (Mariner & Paskin, 2000), fifty pebbles were distributed among the six markets studied by the key informants to reflect the numbers of customers that patronize the respective markets. These pebbles were then counted to determine the relative quantities of ready-to-eat chicken sales.

2.7. Risk assessment

Microbiological food safety risk assessment involves hazard identification, hazard characterization, exposure assessment and risk characterization (CAC, 2010). Hazard identification (the identification of the agent which can cause adverse health effects to humans) and hazard characterization (the qualitative and/or quantitative evaluation of the adverse health effects associated with the hazard), were described in the introduction section.

Exposure assessment was conducted using parameters collected through the field work and literature review (Table 1). In the present study, given the high toxicity of SE, which causes SFP with very little amount, such as 20–100 ng for SEA (Asao et al., 2003), probability of exposure to the hazard was modeled to be an exposure to the population of *S. aureus* with more than 10^5 CFU/g as a proxy, because *S. aureus* may produce SE under such concentration (Hennekinne et al., 2012), as explained in the introduction. For *S. aureus* to produce SEs, they must be carrying the enterotoxigenic genes. However, the proportion of *S. aureus* isolates with enterotoxigenic genes varies considerably between different populations. For example, the proportions of *S. aureus* having enterotoxigenic genes have been reported to be 25% by Le Loir, Baron, and Gautier (2003), 37.5% by Arcuri et al. (2010), and 57% by Normanno et al. (2005). In the present paper, the proportion reported most recently, and the middle value among them, 37.5% by Arcuri et al. (2010) was used. Below formula shows the model of exposure to SE, *Pingest* as the probability of ingesting SE:

$$Pingest = PexcPgene\sum_{i=1}^{6} Pcont_i Sales_i$$

Where *Pexc* is the probability that the bacterial concentration of a sample contaminated with *S. aureus* equals to or exceeds 10^5 cfu/g, *Pgene* is the probability of *S. aureus* having the SE gene, $Pcont_i$ is the probability of purchasing RTE chicken in a market studied i (six markets were studied) and $Sales_i$ is the relative quantity of sales in a market i.

The additive set of the multiplication of $Pcont_i$ and $Sales_i$ is calculating the overall prevalence of *S. aureus* in ready-to-eat chicken in Tshwane, weighing the difference of prevalence among the markets, although it was statistically not significant (see Results section).

In order to model the bacterial concentration in RTE chicken contaminated with *S. aureus*, the Log_{10} cfu/g values of contaminated samples were bootstrapped. However, there were samples that exceeded the countable limit i.e. colonies were TNTC. Therefore, a Uniform distribution was used to model the Log_{10} cfu/g of such samples by considering a value between the slightly greater value than the maximum countable value for the tool used in the survey, and the maximum *S. aureus* population at the static phase of the bacterial growth (Fujikawa & Morozumi, 2006).

Risk characterization was carried out by combining the exposure assessment and dose–response relationship. The dose–response relationship was modeled to be 100% given ingestion of enterotoxin; the probability of illness (*Pillness*) was modeled to be identical to *Pingest*. There is a limitation in this dose–response relationship in that the proportion of SE with emetic ability and proportion of susceptible population were not modeled due to lack of information in literature.

In the present study, the growth of *S. aureus* between the times of purchase and consumption was not taken into account in modeling, because according to participatory assessment in the markets, consumers do not preserve the product and consume it within a short period of time. The model was constructed using @Risk version 5.7 (Palisade Corporation, USA) and Monte Carlo simulation was run for 10,000 iterations.

According to the NSW Food authority of Australia (2009), food that is contaminated with 10^3 cfu/g or more should be considered unsatisfactory. Based on this, the risk of purchasing an unsatisfactory quality of chicken (*Punsatis*), was assessed using the formula below.

$$Punsatis = \sum_{i=1}^{6} Punsatis_i Sales_i$$

Where $Punsatis_i$ is the probability that RTE chicken sold in a market i is contaminated with more than 10^3 cfu/g of *S. aureus*. $Punsatis_i$ was modeled using the Beta distribution.

Sensitivity analysis was performed using the uncertainty parameters listed in Table 1. Monte Carlo simulation was run for 1000 iterations.

3. Results

3.1. Semi-quantitative value chain of ready-to-eat chicken (RTE)

From focus group discussions and structured interviews using questionnaires, four types of food value chains – one formal chain, two formal-informal hybrid chains and one purely informal chain – were identified for RTE chicken sold in the informal markets in Tshwane (Fig. 2). The formal value chain starts from commercial poultry farms and mainly provides broilers. The broilers are slaughtered and processed in formal abattoirs and distributed to butchers, supermarkets and retail shops where consumers purchase (to the left side of Fig. 2). In the first formal-informal hybrid value chain, spill over from formal to informal chain occurs at the retailer level. Here the informal vendors purchase raw chicken meat from butchers, supermarkets and retail shops. They then cook and sell the chicken in informal markets. The second hybrid chain enters into the informal chain from commercial producers of off-layers (spent hens). These are either bought by the middle men who slaughter them informally before selling carcasses to vendors. Alternatively, the informal food vendors buy these spent hens and do the slaughtering. The purely informal value chain on the other hand starts from backyard small scale poultry producers. The chicken is directly sold to informal vendors who slaughter and cook them before selling them to their customers in informal markets (Fig. 2).

Because of lack of cooperation from the informal vendors for the information of the specific source of chicken which they purchase, complete quantitative value chain was not established; however, the categories of the sources were provided in the informal interviews. Table 2 shows the sources of chicken from where informal vendors purchase. Multiple answers were allowed in this question and 24 of 234 vendors (10.3%) who provided answers purchased from more than two source categories. Majority of informal

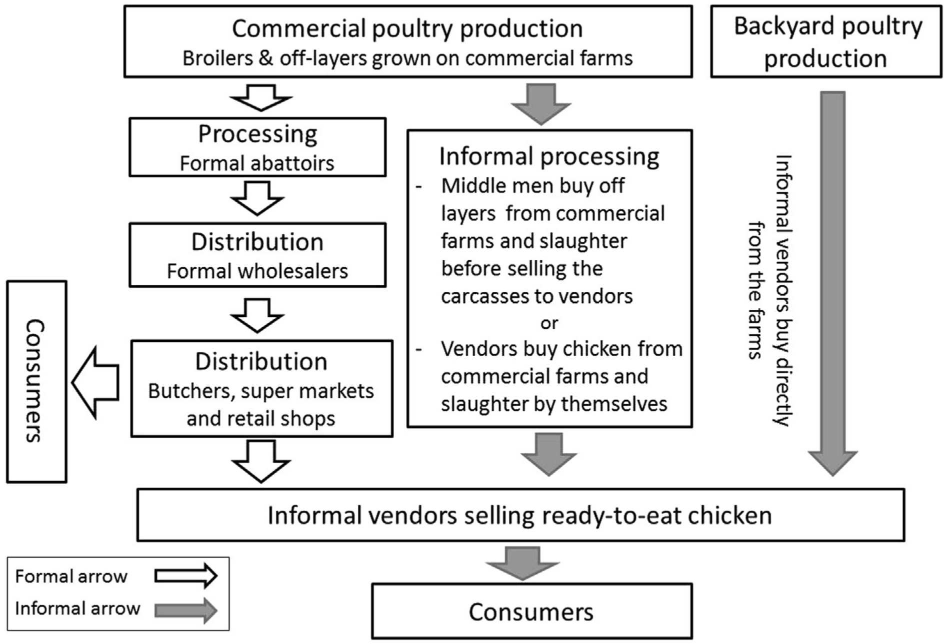

Fig. 2. Informal value chains of ready-to-eat chicken sold in informal markets in Tshwane Metropole, South Africa.

vendors (217/237, 91.6%) purchased processed or slaughtered chicken and supermarkets were the most common source (79.3%) overall. Thirty vendors (12.7% of 237) purchased live birds and slaughter by themselves. Thirteen vendors (5.5% of total respondents, 237) purchased both live and non-live birds. The most common sources of live birds were middle men (25/30, 83.3% (10.5% of 237)) and only a few vendors purchased live birds at farms (3 vendors from small scale and 2 from commercial farms).

In addition, proportional piling technique (Mariner & Paskin, 2000) was adopted to the quantify structure of markets surveyed (Table 3). Consequently it was determined that Mamelodi contributed most (32%) while Belle-Ombre/Prinsloo contributed the least (6%) of the RTE chicken sold in the six markets surveyed.

3.2. Hygiene of informal chicken sales

Interviews were conducted with 237 vendors in total. The majority of vendors started business in the morning, with 87.3% (207) saying that they started before the morning rush hour, 9.7% (23) started a bit later, while 7 did not provide clear answers to the question as to when they start. The time when they close the business was diverse; 12 vendors (5.1%) indicated that they close after the morning rush hour, 102 vendors (42.6%) closed after the evening rush hour and 100 (42.2%) closed only when all the RTE chicken had been bought.

The majority of vendors (227/234, 97%) prepare chicken at the vending site. Only seven vendors (3%) indicated that they prepared the chicken from home and bring it to the market as RTE chicken. The rest of the vendors (three vendors) did not answer this question.

In terms of access to water, of the 76 vendors who responded, 42 (55.2%) said they used water from a tank, while 24 (31.6%) said that they brought water from home, and 10 vendors (13.2%) obtained water from sources such as bore hole, toilets nearby and from garages close by. Only one respondent indicated that water used at the vending site was sourced from a river.

Hygiene assessment of the operations revealed that out of 112 vendors who responded, 95 (84.8%) brought soap from home, while three of the vendors said that their customers used soap that is available at a toilet facility close by. Only 14 vendors (12.5%) indicated that soap was not available at the vending site for use by their customers to wash their hands.

Out of 237 vendors who replied to the question on plates used to serve their customers, 209 (88.2%) said that they served RTE chicken on a washable plates, while 10 (4.2%) served using disposable plates, and 7 (3%) used a plastic paper bag to serve RTE chicken. The remaining 11 vendors preferred not to answer the question.

Exposure to training was very low. Only seventy five (31.6%) of the vendors interviewed indicated that they had received some training on food hygiene.

Table 2
Source of chicken from where informal vendors purchase ($n = 237$).

Source category	Respondents	Percentages out of 237 vendors
Source of processed chicken	217	91.6
Supermarket	188	79.3
Middle men (source not known)	20	8.4
Slaughtered at farm	12	5.1
Retail shop/butcher	6	2.5
Abattoir	2	0.8
Source of live birds	30	12.7
Middle men (source not known)	25	10.5
Small scale backyard farm	3	1.3
Commercial farm	2	0.8
Answer not provided	3	1.3

Table 3
Proportional piling results showing the relative quantities of ready-to-eat chicken sales in the informal markets studied.

Markets	Pebbles	Relative quantity of sales
Marabastad	11	0.22
Mabopane	9	0.18
Shoshanguve	7	0.14
Bell Ombre/Prinsloo	3	0.06
Mamelodi	16	0.32
Sausville	4	0.08
Total	50	1

Table 4
The prevalence of *S. aureus* on ready-to-eat chicken and unsatisfactory quality chicken samples (*S. aureus* greater than 10^3 cfu/g) according to the markets.

Markets	Sample	*S.aureus* isolated	Prevalence (%)	Unsatisfactory	Prevalence (%)
Marabastad	21	9	42.9	4	19.0
Mabopane	11	5	45.5	4	36.4
Soshanguve	21	8	38.1	2	9.5
Belle Ombre/ Prinsloo	12	4	33.3	4	33.3
Mamelodi	24	12	50.0	10	41.6
Sausville	11	6	54.5	5	45.5
Total	100	44	44.0	29	29.0

3.3. Microbial test results

Table 4 shows the microbiological test results. The overall prevalence of *S. aureus* was 44%. There was no significant difference in the prevalence among the markets (DF = 5, $p = 0.885$). The overall prevalence of unsatisfactory quality chicken was 29.0%. These are RTE chicken contaminated with *S. aureus* at a concentration greater than 10^3 cfu/g (Table 3). Likewise, there was no significant difference observed between the markets (DF = 5, $p = 0.097$). The mean cfu/g observed on RTE chicken was $10^{3.6}$ (90% CI: $10^{3.3}$–$10^{3.9}$).

3.4. Risk assessment

3.4.1. Exposure assessment

The prevalence of *S. aureus* in ready-to-eat (RTE) chicken samples was 44% (90% CI: 36.1%–52.2%) and the probability of purchasing unsatisfactory quality of chicken (>10^3 cfu/g, *Punsatis*) from an informal RTE vendor who sales RTE chicken was 32.9% (90% CI: 25.5%–40.4%). Mean $\log_{10}$ cfu/g of *S. aureus* on the ready-to-eat contaminated chicken was 3.6 (90% CI: 3.3–3.9). The probability of ingesting enterotoxin from consumption of RTE chicken (*Pingest*) was estimated to be 1.3% (90% CI: 0%–2.7%).

3.4.2. Risk characterization

The risk of SFP due to the consumption of ready-to-eat chicken sold in informal markets in Tshwane Municipality (*Pillness*) was estimated to be identical to *Pingest*, 1.3% (90% CI: 0%–2.7%). This probability is limited to the consumers of the RTE chicken in informal markets and is not a reflection of the risk to the whole population in the country.

Table 5 shows the results of the sensitivity analysis. The most sensitive factor in the risk assessed was probability of *S. aureus* having SE gene. The second sensitivity factor was Log_{10}Cfu/g of *S. aureus*, when the bacteria were TNTC (*Logtn*), and the third was Log_{10}Cfu/g of *S. aureus* of a contaminated sample. The latter includes, *Logtn*. These parameters represented the concentration of *S. aureus*, and they were more sensitive than the prevalence of *S. aureus* in ready-to-eat chicken.

4. Discussion

The present study provides the first map of the value chain for RTE chicken sold in the informal markets in Tshwane Metropol of South Africa. This can help establishing traceability of RTE chicken sold in the informal markets in Tshwane, although tracing informal part of this value chain was found to be challenging in the present study. Where traceability is possible, communication linkage for identifying, verifying and isolating sources of noncompliance to agreed standards and customer expectations can be implemented (Opara, 2003).

An important finding of the study of the food chain was the cross-over between formal and informal sectors. We did not observe extensive spillover from the formal to the informal sector in any published studies in sub Saharan Africa. This is probably related to the fact that unlike other parts of Africa, in South Africa supermarkets have gained a sizeable share of the fresh produce market (Louw, Jordaan, Ndanga, & Kirsten, 2008). It can therefore be postulated that if supermarket proliferation takes place in the rest of Africa, as is predicted, this model and its associated risks are likely to become more common. Furthermore, the linkage between the formal and informal food sector in the value chain shows that this informal sector provides a market opportunity for commercial poultry production. It is reported that such formal-informal spill over business represents millions of US dollars daily (Codjia, 2000).

Value chains were also found to be short: that is with few steps and a relatively short time between producer and consumer. This is good for food safety in relation to the RTE chicken. It is known that value chains that are multi-layered with poor visibility tend to be very vulnerable (Roth, Tsay, Pullman, & Gray, 2008).

The high prevalence of *S. aureus* (44%) on the RTE chicken sold in informal markets and the high unsatisfactory quality (RTE chicken with more than 10^3 cfu/g) is consistent with previous studies that reported that bacterial concentration on informally-sold RTE chicken ranged from 10^2 to 10^3 cfu/g (Lues et al., 2006).

Very importantly, this study also highlighted the fact that high prevalence of *S. aureus* does not translate into a high risk of illness due to ingestion of chicken with potentially enterotoxigenic *S. aureus* on RTE chicken bought from informal markets in Tshwane Metropole. The risk of illness due to consumption of ready-to-eat chicken sold in informal markets was found to be low (1.3% (90% CI: 0%–2.7%). This finding can be attributed to the fact that bacteria concentration of *S. aureus* on the chicken rarely exceeds 10^5 cfu/g (threshold for *S. aureus* required to produce sufficient toxins to cause SFP). The risk reported here is consistent with findings of earlier studies, which although purely hazard identification studies

Table 5
Sensitivity analysis results shown in the order of the sensitivity to the risk assessed.

Order	Parameters	Values at 50th, 5th & 95th percentiles	Mean probability of staphylococcal poisoning (%) at 50th, 5th & 95th percentiles
1	Log_{10}Cfu/g of *S. aureus* when the bacteria were too numerous to count: *Logtn*	6.4 (4.4–8.3)	0.52 (0.52–0.92)
2	Log_{10}Cfu/g of *S. aureus* of a sample contaminated	3.5 (2.3–7.3)	0.69 (0.69–1.08)
3	Probability of *S. aureus* having SE gene: *Pgene*	0.38 (0.33–0.42)	0.70 (0.62–0.79)
4	Prevalence of *S. aureus* in Mamelodi market	0.50 (0.34–0.66)	0.70 (0.63–0.78)
5	Prevalence of *S. aureus* in Mabopane market	0.46 (0.25–0.68)	0.71 (0.65–0.77)
6	Prevalence of *S. aureus* in Marabastard	0.43 (0.27–0.60)	0.70 (0.65–0.76)
7	Prevalence of *S. aureus* in Soshanguve	0.39 (0.23–0.56)	0.71 (0.67–0.74)
8	Prevalence of *S. aureus* in Sausville	0.54 (0.32–0.75)	0.70 (0.68–0.73)
9	Prevalence of *S. aureus* in Belle Ombre/Prinsloo	0.35 (0.17–0.57)	0.70 (0.69–0.72)

concluded that informal foods in South Africa have a low microbiological risk (Martins, 2006). However, as the present study does not take into account the proportion of SEs with emetic property and the proportion of susceptible population. Moreover, the microbiological tests could not show the true bacteria concentrates for the samples with TNTC. These are clear limitations and our assessment may be over estimating the risk. Too often, decisions on food safety are based on the presence of hazards rather than risks to human health. This can reduce accessibility of food to poor people and restrict income generating opportunities for poor producers and value chain actors without any commensurate benefit to human health.

Although, the risk of illness from *S. aureus* was not found to be high, there were several poor practices, which should be addressed as they might lead to contamination with other hazards. Unhygienic behaviors observed in the present study are consistent with previous studies as reflected in the following quote (Lues et al., 2006): "*hand and dish washing is usually done in one or more bowls, sometimes without soap; waste water and garbage are discarded in the street, providing food and harborage for flies and rodents; foods are usually not effectively protected from dust and flies that may harbor food borne pathogens, and temperature violation is common*".

The low direct access to tap water (water is not drawn directly from municipal taps but is delivered to the site via containers that might be of doubtable hygiene) can be attributed to the fact that the municipal taps are located a distance away from the vending sites. As a result vendors in most cases rely on water delivered to their site in containers. This is a concern as it has the potential of increasing the likelihood of contamination of water with hazards including *S. aureus* if the containers used to deliver and hold the water at the vending site are not cleaned regularly. This can in turn lead to contamination of the RTE chicken with hazards.

Since *S. aureus* on chicken carcasses or raw chicken can be eliminated by cooking, the contamination observed occurs because of poor post-cooking food handling. Previous studies reported that *S. aureus* is found on hands and finger tips of more than 50% of healthy individuals (IFT, 2004; Le Loir et al., 2003; Lues et al., 2006). However, focus group discussions conducted in the present study revealed that times between cooking and selling and between purchase and consumption were usually short. This has also been confirmed by previous studies (Campbell, 2011; Martins & Anelich, 2000).

Sensitivity analysis suggested that a control measure to decrease bacterial concentration would be most effective to improve food safety, as the biological variability, proportion of *S. aureus* with enterotoxigenic genes cannot be controlled. According to the guidelines for safe street foods, cleaner environment, separation of raw and cooked foods, thorough cooking, refrigeration, use of safe water and raw materials and raised awareness are recommended (INFOSAN, 2010). This is important because staphylococci are ubiquitous in the environment and can be found in the air, dust, sewage, water, environmental surfaces, humans and animals (Hennekinne et al., 2012). Provision of hygiene training, improvement of infrastructure and improved direct access to municipal tap water (minimizing or eradicating the practice of delivering of water in containers at the vending site), has the potential to improve on the safety or RTE chicken sold by informal vendors. Control of temperature is another effective measure to prevent SFP (IFT, 2004). However, achievement of this in informal markets is questionable.

Although the risk of SFP was low, there are many other microbiological and chemical hazards to consider and the importance of hygiene improvement should not be neglected. The low risk estimated is good news for both the vendors and customers as RTE chicken sold in informal markets is an affordable source of nutrition for a large population and is a good source of income as well for the informal vendors. Moreover the present study was able to show that the informal RTE chicken business offers opportunities for employment for those who cannot get employed in the formal sector. In view of this, consideration should be given to how to benefit from informal food businesses can be maximized instead of viewing them with suspicion as a source of food that is not safe. A holistic understanding of the risk, economics and sociological role played by informal vendors of RTE chicken is the key to improve food safety, job creation and poverty alleviation associated with poultry value chains in South Africa.

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