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Original Research Article

Market Characteristics, *Salmonella* Prevalence and Associated Risk Practices in Poultry Processing Environments in Wet Markets in Sri Lanka

J. K. H. Ubeyratne[1*], M. D. N. Jayaweera[2,] L. G. S. Lokugalappatti[3], S. Wickramasinghe[4], H. M. Tun [5]

[1] *Central Veterinary Investigation Centre, Veterinary Research Institute, Gannoruwa, Peradeniya 20400, Sri Lanka*
[2] *Head Office, Department of Animal Production and Health, Getambe, Peradeniya*
[3] *Department of Basic Veterinary Sciences, Faculty of Veterinary Medicine & Animal Science, University of Peradeniya, Peradeniya 20400, Sri Lanka*
[4] *Department of Parasitology, Faculty of Medicine, University of Peradeniya, Peradeniya 20400, Sri Lanka*
[5] *Faculty of Medicine, School of Public Health, University of Hong Kong, Hong Kong*

SUMMARY: Poultry selling is beyond the ambit of industrial processing and marketing trade at Wet Market (WM) operations. Contaminated meat from such WM is being increasingly recognized as a potential source of foodborne diseases including salmonellosis. At present, limited information is available on processing and marketing of live birds in informal WM operations in Sri Lanka. This cross-sectional study was carried out to describe the characteristics of WM and to determine the prevalence of *Salmonella* with special emphasis on the risk practices that could lead to cross-contamination. We analysed 123 WM operations in Sri Lanka using a pretested and structured questionnaire, visual observations by trained enumerators, and culture and isolation of *Salmonella*. The observed characteristics of the WM in Sri Lanka were generally similar to those operated in other Asian countries even though there were minor variations. Overcrowding of live birds, keeping meat at ambient temperatures, improper evisceration practices, cleanliness of the floors and tables, using wood as cutting boards and hygiene of butchers leading to cross-contamination were some common characteristics seen in most WM operations. Regarding *Salmonella* prevalence, overall prevalence was moderate in WM of Sri Lanka (47.97 %) while a low prevalence was observed in poultry meat (30.89%) and meat contact surfaces (<25%). Wet market operations showed moderately positive correlations for *Salmonella* prevalent meat samples (r =0.69), cutting boards (r=0.59) and knives (r =0.57). We observed that there was no use of disinfectants to clean the premises in the wet market leading to a higher prevalence of *Salmonella*. Overcrowding of live birds before slaughter and the use of dirty waste trays underneath stacked bird crates were the other contributing factors observed in this study. Our findings indicate that poultry WM in Sri Lanka is a potential source of foodborne infections such as salmonellosis. Therefore, government agencies should design policies and strategies to prevent Salmonella contamination and improve the quality standards of WM in Sri Lanka.

KEYWORDS: wet market, *Salmonella*, risk practices, Surveillance, Sri Lanka

INTRODUCTION

Marketing poultry at live animal markets is an age-old practice in the world (Cardona *et al*., 2009). Live animal market or wet market is a place where the public buy live and slaughtered animals. The markets can be fixed or temporary (Webster, 2004). In Asia, established Wet Markets (WM) are seen in China, Thailand, Philippines, Vietnam, Laos, Myanmar, Bangladesh, India, Nepal and Sri Lanka. These markets appear to be preferred by certain populations and ethnic groups for cultural, culinary or religious reasons (Imanishi *et al*., 2014). Furthermore, traditional local demands for warm meat or freshly slaughtered meat seem to sustain the wet markets (Webster, 2004). Wet markets usually gather native chickens and other

*Corresponding author: J. K. H. Ubeyratne, E-mail: kamalikau@yahoo.com

species that satisfy the local taste (Cardona *et al*., 2009). In most cases, birds received by WMs are contaminated with faeces and dust during transportation (Prakash *et al*., 2005). Caging birds in excess capacity and stacking cages on top of the other without waste trays underneath are considered potential hazards of WM operation as contamination with faecal droppings is unavoidable in such situations. Unsafe disposal of hazardous wastes and the possibility of cross-contamination of knives, utensils and chopping boards without thorough cleaning and sanitation could easily transmit pathogens. Furthermore, de-feathering could hamper the operation and allows potential contamination from feathers to meat (WHO, 2006). In Sri Lanka, a study showed WM processing of broiler chicken resulted in more contamination for *Campylobacter* (48%) than semi-automated processing (27.4%) (Kottawatta *et al.*, 2017). Another study depicted bacteria contamination of chilled raw meat, as *Salmonella* (10%), *Campylobacter* (21%) and *E. coli* (10%) at retail markets in Sri Lanka (Kulasooriya *et al*., 2019). Thus, WMs can provide ideal conditions for the zoonotic transfer and evolution of pathogens by changing the patterns of disease emergence through an animal-human marketing system (Cardona *et al*., 2009; WHO, 2006). Lack of awareness of food safety and basic hygiene by the stall owners and food handlers in a wet market could aggravate the risk of transmission of zoonotic diseases (Nde *et al*., 2007; WHO, 2006).

Exposure to meat from WM is being increasingly recognized as a potential source of zoonosis (Fournié *et al*., 2012; Kirunda *et al*., 2014; Webster, 2004; Zhou *et al*., 2015) including salmonellosis (Imanishi *et al*., 2014; Naurin *et al*., 2013). Salmonellosis is one of the most important foodborne diseases in many countries and human salmonellosis is frequently associated with the consumption of poultry products (Antunes *et al*., 2003; Hanning *et al*., 2009). Furthermore, poultry carcasses obtained from WM have been reported to be contaminated with *Salmonella* species having varying degrees of pathogenicity and drug resistance (Aditya, 2015; Rusul *et al*., 1996; Wang *et al*., 2013). However, the risk of *Salmonella* contamination could vary among the countries due to differences in control measures and practices implemented throughout the production chain (Madec *et al*., 2010).

The poultry meat industry in Sri Lanka consists of a well-established standard processed meat industry and an informal WM, which has a significant market share and is distributed mainly in certain urban areas of the country (Annual report 2014, Biraha Farms Plc). The statistics and characteristics of poultry WM, as well as risk assessments of transmission of diseases through WM in Sri Lanka, are limited. A few studies have attempted to investigate the risk of zoonotic transfer of campylobacteriosis (Kalupahana *et al*., 2013) and salmonellosis (Alwis *et al*., 2014) through the poultry retail market in Sri Lanka. Therefore, the objectives of this study were to describe the WM characteristics with special emphasis on the risk practices leading to cross contamination and to establish baseline prevalence for *Salmonella* in WM over a wide geographical distribution in Sri Lanka. We envisioned the outcome of the study would be useful to public health, food safety, and animal health personnel to design policies and strategies to reduce *Salmonella* contamination and improve the quality standards of the poultry WM in Sri Lanka.

MATERIALS AND METHODS

Definition of wet market

A live animal market or wet market is a place where the public buy live and slaughtered animals. The markets can be fixed or temporary (Webster, 2004). In Sri Lankan context, raw, chilled and frozen meat are sold following the traditional slaughtering method at the wet markets.

Sample collection

A total of 123 WM vendors representing 22 sampling sites (cities) in Sri Lanka were recruited in the study (Figure 1). Our sampling frame covered seven out of nine provinces of Sri Lanka and included both high and low poultry producing areas of the country. Within each selected site, WM vendors were selected randomly. A team of trained enumerators were employed to make observations on the wet market sites and to collect samples for *Salmonella* isolations. In addition, a pretested and structured questionnaire was used to collect data. A verbal agreement was taken from vendors before conducting the questionnaire survey. Meat samples (n=123) were collected from each selected vendor separately for the isolation of *Salmonella*. A standard aseptic procedure was followed for the collection of meat samples. Samples were transported to the Central Veterinary Investigation Centre, Gannoruwa, Peradeniya in a cool box at 4^{o}C. In addition, swabs were obtained from meat contact surfaces including

knives (n=123) and chopping boards (n=123) from all selling sites following the standard aseptic procedures. The sampling area of contact surfaces was approximately 25 cm^2. Swabs were transported to the laboratory in a cool box at 4ºC.

Wet market characteristics

A pretested and structured questionnaire (Table 1) was administered to all selected vendors after obtaining verbal consent to determine the WM characteristics with special emphasis on the risk practices leading to cross-contamination. Specific and targeted questions were included in the questionnaire to determine the source of birds, selling sites, type of birds/meat sold, how live birds are kept on site, slaughtering and processing methods, cleaning methods, source of water, use of chlorinated water, storage of dressed meat and waste management. The field enumerators consist of a veterinarian, validated survey responses by direct visual inspection including the five variables such as overcrowding of live birds kept in WMs before slaughter, use of unclean waste trays underneath the stacked cages and crates, scalding practised before plucking feathers to increase contamination, improper evisceration practices lead to cross-contamination and lack of usage of disinfectant/ detergent to clean the WM premises. The pre-slaughtering, slaughtering, scalding, defeathering, evisceration, rinsing, and further processing methods were physically inspected by the veterinarian.

Informal verbal consent was taken from vendors to get samples and to obtain the data required for the questionnaire.

***Salmonella* isolation and confirmation**

Twenty-five grams from each collected meat sample was homogenized aseptically in 225 ml of Buffered Peptone Water (BPW) while each collected swab (n=246) was transferred into 5 ml of Buffered Peptone Water (BPW). All the samples were then incubated at 37ºC for 24 hours. From each incubated sample, 0.1 ml of stock was transferred to 10 ml of Rappaport Vassiliadis (RV) medium. The RV media were then incubated at 42°C for 24 hours. One loopful of RV media from each sample was streaked onto Xylose Lysine Deoxycolate (XLD) agar plates, Brilliant-green Phenol-red Lactose Sucrose (BPLS) agar plates and Rambach agar plates respectively. The plates were incubated at 37°C for 24 hours. Presumptively positive colonies were bio-chemically confirmed with Triple Sugar Iron (TSI) agar, Simmons Citrate agar, Urease and Sulfide Indole Motility (SIM) medium (ISO 6579:2002). Serological confirmation was done using *Salmonella* O polyvalent antiserum (Kauffmann-White Scheme)

Assessing associated risk practices

Five variables were investigated to determine the associated risk practices including 1) Overcrowding of live birds kept in WMs before slaughtering, 2) Use of unclean waste trays underneath the stacked cages and crates, 3) Scalding practice before plucking feathers, 4) Inappropriate evisceration practices, 5) Usage of disinfectant/ detergent to clean the WM premises (Table 2). We assessed the inappropriate evisceration practices, using isolation and confirmation of *E. coli* from the same meat samples used for *Salmonella* isolation. After the completion of the pre-enrichment step of *Salmonella* isolation from meat, a loopful of the sample was cultured on MacConkey agar and then incubated at 37ºC for 24 hrs for the isolation of *E. coli*. Presumptive colonies were cultured on Eosine Methylene Blue (EMB) agar for confirmation (Kulasooriya *et al*., 2019).

Data analyses

For analysis, one operation (selling unit) was considered as one WM. Data collected from each WM operation through structured questionnaire and visual observations as well as confirmed bacteriological culture and isolation results were tabulated with Microsoft Excel 2013 software and manually analyzed after codifying the variables into numbers. The prevalence of *Salmonella* was calculated at a 95% confidence interval. The strength and the direction of linear relationships between *Salmonella* positive WMs and *Salmonella* positive meat, cutting board and knives were determined using the Correlation coefficient (r). The relationship between potential risk practices (Table 2) and the prevalence of *Salmonella* (positive WM operations) were assessed using logistic regression models with the XL Miner tool kit in Microsoft Excel 2013. Our dependent variable for all logistic regression analyses was the prevalence of *Salmonella* (positive WM operations) in WM. We ran a simple logistic regression analysis for all five independent variables (Table 2) and examined the Odds ratios and *p* values for statistical significance. We excluded all statistically non-significant independent variables from the multiple logistic regression model using $p > 0.05$ as the criterion of elimination.

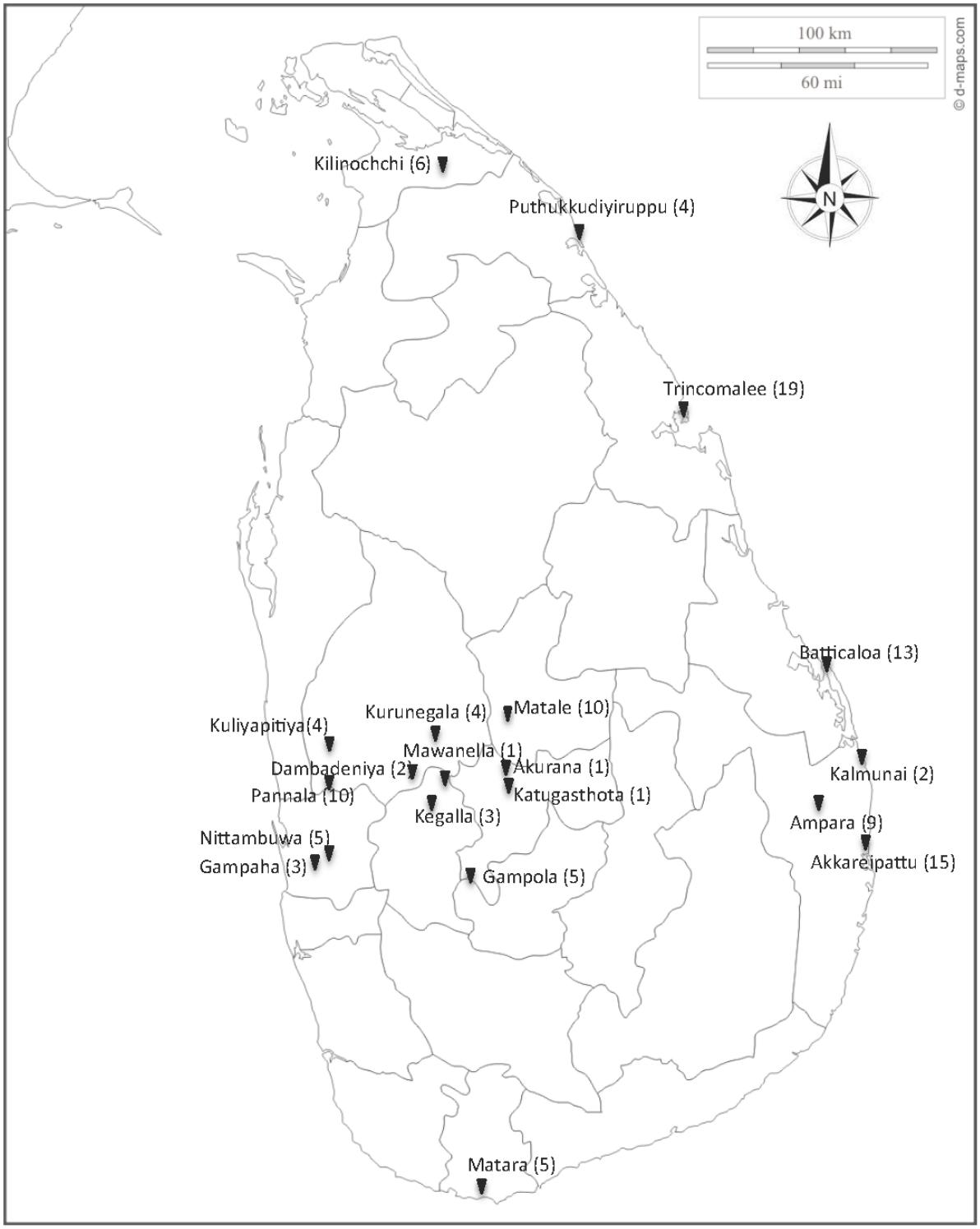

Figure 1: Sampling sites included in the study, Black wedges indicate the location of the cities where WM operations are common and numbers within brackets indicate the number of WM operations investigated in respective cities.

Table 1: Questionnaire used for wet market information collection

Questionnaire survey		
Date		
Name of the owner		
Address		
Age of the birds (in days)		
Source of birds		
Number of birds slaughter for meat/day		
Whether excess meat is freeze or not		
Where do you keep birds until slaughter		
Slaughter method		
Factors that lead for possible contamination		
1	Handling of different species of animals at the same place	
2	Stack of cages on top of the other without waste trays underneath the cages	
3	Caging of birds in excess capacity	
4	Defeathering without previous scalding	
5	Improper evisceration	
6	Improper handling of waste	
7	Unsafe disposal of hazardous wastes	
8	Cross contamination of knives, utensils and chopping boards without thorough cleaning and sanitation	
9	Lack of chill water	
10	Freezing facility	
11	Stall owners and food handlers in a wet market lack awareness about food safety and basic hygiene	
12	Cleaning methods (Whether use disinfectants/detergents)	
13	Source of water	
14	Lack of Chlorinated water	

Table 2: Odds ratios with 95% confidence interval and respective P values for the variables used for risk practices analysis as revealed by simple logistic regression method and multiple logistic regression model adjusted for variables 1, 2, and 5

	Variables	***Simple logistic regression***			***Multiple logistic regression***		
		Odds ratio	***Confidence interval***	***P value***	***Odds ratio***	***Confidence interval***	***P value***
1.	Overcrowding of live birds kept in WMs before slaughter	2.127	1.020 - 4.434	0.04414	1.703	0.680 - 4.261	0.25541
2.	Use of unclean waste trays underneath the stacked cages and crates	3.333	1.394- 7.969	0.00678	1.981	0.685 - 5.729	0.20736
3.	Scalding practised before plucking feathers increase contamination*	4.582	0.497- 42.227	0.17920	-	-	-
4.	Improper evisceration practices lead to cross-contamination* (denoted by *E. coli* isolation)	1.244	0.267- 5.808	0.78085	-	-	-
5.	Lack of usage of disinfectant/ detergent to clean the WM premises	5.590	2.536- 12.324	0.00001	5.284	2.327 - 12.001	0.00007

**Variables 3 and 4 were excluded from the multiple logistic regression analysis*

RESULTS

Wet market characteristics

All 123 WM operations investigated in the present study are fixed site operations. Majority of the observed WM were operated either as small boutiques (n=103) or stalls in the community markets (n=11). However, nine WM operations were operated in households of the farmers. Slaughtering was generally carried out in the mornings. Depending on the consumer preference birds are processed as either skin less or skin intact meat. The observed infrastructure facilities of the WM were varied. Slaughtering and processing were done manually neither following the proper procedures nor having appropriate equipment. Observed processing steps at WM have shown in Figure 2.

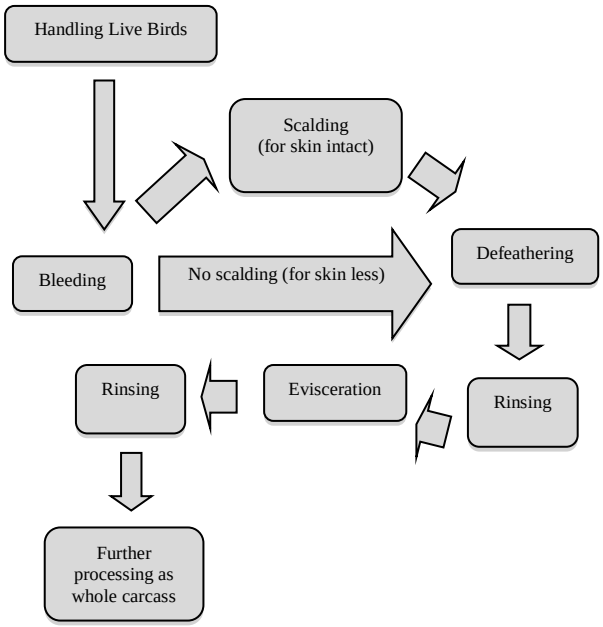

Figure 2: Steps involved in processing of poultry in the WM of Sri Lanka

In all the observed WM vendors, birds were kept either inside the premises or outside but next to the selling unit (81.87%) except for some household operations where poultry sheds were used to keep birds (8.13%). Of the 123 WM observed, 64.23% (79/123) used cages while 18.69% (23/123) used a small place (temporary enclosure) inside a shop and 8.94% (11/123) used plastic crates to keep the birds before being slaughtered. Types of birds kept, slaughtered and sold at WM were varied from place to place (Figure 3). Most of the WM operations (68.29%) handled broiler chicken only and slaughtering age of broiler chicken was between 30 to 50 days. About 24.39% of WM operations handled both broiler and culled layers while about 2.44% of the WM operations had multiple species (chicken, ducks, quails, turkey etc.). Among other WM studied, 2.44% of the WM sold broiler and village chicken while the mixed operation of broiler, culled layers and village chicken were sold in 1.63% of WM operations. Less than 1% of WM operations sold culled layers solely (Figure 3). Generally, the slaughtering age of culled layer birds was around 2 ½ years while the age of village chicken was varied. Live birds were received mainly from middlemen, occasionally from their own farms and other suppliers.

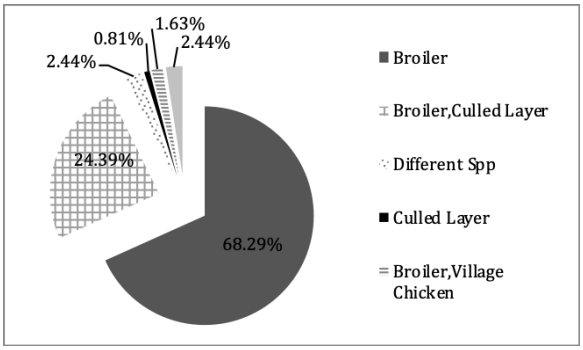

Figure 3: Percentage of type of birds kept, slaughtered and sold at the WMs in Sri Lanka

In all WM, birds were handled by hand and bleeding was done manually. Some WM operators (4.06%) practiced scalding before de-feathering as there were demands for skin intact meat, while others de-feathered the birds without scalding. For rinsing, water from different sources was used while none was chilled and operationally chlorinated. Majority of WM operators used tap water (47.97%), followed by well water (41.46%), tube well water (7.32%), both tap and well water (2.44%) and one used lagoon water for rinsing the de-feathered birds. Dressed birds were often displayed on shelves at ambient temperatures until they were sold. Unsold meat was kept in freezers overnight by some sellers (43.1%). Inadequate facilities for disposing of poultry slaughter waste such as blood, feathers and offal were overt. Solid waste disposal methods were varied in a majority of WM (63.42%), and solid waste was collected by respective local government authorities (pradeshiya sabhas, urban councils and municipal councils). Other methods of disposal included feeding pigs (21.14%), disposal in communal dumping sites (4.88%) and in pits (9.76%). One WM operator used solid waste for biogas production. Though

cleaning and disinfection of the sites were performed by 65.04% of the WM operators, improper evisceration was depicted by a high (94.31%, 116/123) prevalence of *E. coli* in tested meat samples.

Prevalence of *Salmonella* at WM in Sri Lanka

Wet market operation (selling unit) was considered positive when meat samples or contact surfaces (cutting boards or knives) or both that were tested positive for *Salmonella*. Thus, the overall *Salmonella* prevalence of WM operations in the study was 47.97 % (59/123, 95% CI: 39.02-56.92). Of the 59 *Salmonella* positive WM operations, 89.83% (53/59) were boutiques, followed by 5.08% (3/59) community markets and 5.08% (3/59) households respectively. The prevalence of *Salmonella* in poultry meat sold at WM operations was 30.89% (38/123, 95% CI: 22.61-39.17) while the prevalence of *Salmonella* in meat cutting boards and knives was 24.39% (30/123, 95% CI: 16.69.2-30.09) and 23.58% (29/123, 95% CI: 15.97-31.19) respectively. Wet market operations showed moderately positive correlations for *Salmonella* prevalence [meat samples (r =0.69), cutting boards (r=0.59) and knives (r =0.57)] whereas low positive correlations (r <0.5) were observed for *Salmonella* positive meat versus *Salmonella* positive cutting boards, *Salmonella* positive meat versus *Salmonella* positive knives and *Salmonella* positive cutting boards versus *Salmonella* positive knives respectively.

Associated risk practices for *Salmonella* contamination

Of the five independent variables tested using simple logistic regression analysis, only three variables were statistically significant ((p < 0.05) (Table 2)). Based on the odds ratio (Table 2) overcrowding of live birds kept in WM operations before slaughter has increased the prevalence of *Salmonella* in WM by about two folds (odds ratio=2.127) when compared to the WM which did not overcrowd the live birds while keeping before slaughter. Wet markets, which use unclean waste trays underneath stacked bird crates and cages, become positive for *Salmonella* 3.3 times more often than WM that did not use waste trays. Those who were not using disinfectant/ detergent to clean the WM premises had significantly (p=0.00001, Odds ratio=5.6) high *Salmonella* prevalence compared to the WM using disinfectant/ detergents.

According to the multiple logistic regression analysis, only variable 5 (lack of usage of disinfectant/ detergent to clean the premises) was statistically significant (p = 0.00007). The odds of WM operations becoming *Salmonella* positive were 1.7 times more when overcrowding of live birds kept in WM before slaughter was adjusted for unclean waste trays and lack of usage of disinfectant/ detergent. Use of unclean waste trays underneath the stacked cages and crates increased contamination with *Salmonella* by about two folds when adjusted for overcrowding and lack of usage of disinfectant/ detergent. The odds of WMs become positive for *Salmonella* were five folds higher when WMs did not use disinfectant/ detergent to clean their premises compared to regular use of disinfectant/ detergents.

DISCUSSION

The growth of the Sri Lankan meat industry is determined by consumer perception (Alahakoon *et al*., 2016). Consumers' willingness to purchase meat depends on the parameters such as economic, cultural, religious, social, personal and marketing factors (Dietz *et al.,* 1995). Our study showed 68.29% of broiler chicken was handled by wet markets and this might be due to local demand for warm or freshly slaughtered meat. Contrary to other Asian countries (Cardona *et al*., 2009), sales of native chickens and other species were very much less (2.44%) in Sri Lanka. In the local context, chicken sold with skin intact was lower and scalding was not a common operation in traditional slaughtering.

All WM sites are operated in permanent locations in urban to semi-urban townships in Sri Lanka. Three types of WM operations could be observed, and the majority were operated as isolated small boutiques (n=103) while a few stalls in community markets and farmhouses were operated as WM vendors. In community markets, WM stalls were often located with the other unprocessed meat (beef, mutton and pork) stalls however often separated from the retail poultry shops that sold processed meat. As reported in other countries, onsite slaughtering was practised in each WM studied. Live birds were kept on site either within the premises or outside (close to the WM premises) (81.87%) under minimum inputs until slaughtering. It was evident that the live animals often come into direct contact with the WM workers and buyers, posing potential health risks. This direct contact could be a potential source of contamination with *Salmonella*, *E. coli*, *Campylobacter* and Avian

influenza as reported in wet markets of other counties (Cadrona *et al*., 2009; Huat *et al*., 2010; Webster, 2004; Yang *et al*., 2011). Control and prevention of carcasses being contaminated by such pathogens was a big challenge, especially in small-scale operations like the WM operations investigated in the present study.

Slaughtering was generally carried out in the mornings in contrast to WM in other countries where slaughtering was done throughout the business hours. Morning slaughtering could be considered as a better practice compared to traditional slaughtering done during the hot season which has been reported to have a significantly increased incidence of bacterial flora on poultry carcasses (Cohen *et al.,* 2007). Furthermore, Upadhyaya *et al*. (2012) have found a high number of *Salmonella* positive shops in the evenings. It may be due to the continuous accumulation of waste products at the WM. Depending on the consumer preference, live birds were processed manually as either skinless or skin intact (4.06%) by the WM workers or butchers. WM operators used scalding before manually plucking feathers, when skin intact meat was preferred by the consumers. The quality and temperature of the scalding water were critical in determining the final degree of carcass contamination (da Silva, 2007) and reuse of the same water for scalding carcass was evident in the WM sites studied. Cross-contamination could occur especially during scalding, defeathering, head pulling, evisceration and chilling in wet market operations (Fries, 2002) while poor hygienic practices among poultry meat handlers have been found to be facilitating the spread of *Salmonella* in WM (Gaungoo and Jeewon, 2013). Washing carcasses before and after evisceration may contribute to the dissemination of bacteria on and among carcasses. The evisceration process generally resulted in a significant increase in microbial faecal contamination (Yashoda *et al*., 2001) and a high prevalence of *E. coli* (94.31%) in the tested meat samples depicted the degree of faecal contamination in local WM operations during evisceration. Chilling of carcasses was not practised in any of the WM observed though quick chilling at 4 to 10° C was the best way of preventing bacterial growth (da Silva, 2007).

In the present study, most of the WM received live birds through middleman and occasionally from their own farms and other suppliers. This supply chain ensured the availability of live animals at WM throughout the year with a possibility of carryover of animals from one day to the next and perhaps for weeks in some WM vendors. In most cases, wet markets received birds with faeces and dust picked up from litter and from other birds during transit (Prakash *et al*., 2005) and the same phenomenon could be observed in the present study. Frequent introduction of new animals provides optimum conditions for the amplification and perpetration of disease agents such as *Salmonella* thus increasing the risk of contamination. The presence of a range of species was typical in wet markets (Fournié *et al*., 2012; Kirunda *et al*., 2014) however a few WMs operations in Sri Lanka had multiple species confined in the same cage and sold together under unhygienic conditions. As in any other live poultry market, the most commonly sold type of poultry was broiler (68.29%), followed by culled layer, village chicken, and other species such as quails and ducks. The biosecurity level of WMs was minimal and poor practices were commonly observed in our study, including birds keeping indoors until slaughter, caging birds in excess capacity, unsafe transport, continuous re-usage of dirty cages, having unclean waste trays, keeping multiple species of animals, unhygienic slaughtering, soiled feathers with faecal droppings of birds, prolonged usage of water in unclean vessels and unavailability of freezing facilities. Solid waste was collected by respective local government authorities in the majority of WM operations (63.42%) and not handled by the WM operators even though the most practical and effective methods of disposal of poultry slaughter waste were burial and incineration in poor resource areas (Nicholson *et al*., 2005). However, malpractices such as feeding pigs (21.14%) with WM solid waste without proper treatment and disposing in common dumping lands (4.88%) could lead to the spread of diseases including salmonellosis in the areas concerned.

Overall observed *Salmonella* prevalence of WM in the present study was 47.97 % (59/123, 95% CI: 39.02-56.92). It was lower than the *Salmonella* prevalence reported in China (54.4%) where good hygienic processing methods and hazard analysis critical control point systems for *Salmonella* control were not in place (Yang *et al*., 2011). The lower prevalence reported in similar studies in Vietnam (46.2%), Nepal (Ta *et al*., 2012), Chennai region in India (2.6%) (Murugadas *et al*., 2015) and in Colombia (30%) (Donado-Godoy *et al*., 2012) may be attributed to implementation of good hygienic processing methods and *Salmonella* control systems. Of

the *Salmonella* positive WM operations, majority (89.83%) were isolated boutiques, which are found in different urban and semi urban townships. In contrast, the WM stalls in community markets where public health inspectors/ Veterinarians often intervene had a low *Salmonella* prevalence. Therefore, the high incidence of *Salmonella* in isolated boutiques could be due to minimal intervention and monitoring of Public Health Inspectors and Veterinarians. In the present study, the prevalence of *Salmonella* in poultry meat sold at WM was 30.89% while that in meat cutting boards and knives were 24.39% and 23.58% respectively, indicating improper and ineffective cleaning and disinfection practices. *Salmonella* contamination rate of 36.0% on chopping boards and 33.0% on knives had been reported in a study carried out in a pork processing plant in Thailand (Sangaunkait, 2005). Similarly, Upadhyaya *et al*. (2012) also found that chopping boards (55.0%) and knives (30.0%) were more often contaminated with *Salmonella*. Hanging the birds was the best way of preventing cross-contamination of clean carcasses since cross-contamination can occur on the working table. As carcasses were not sealed in bags in WM, further contamination cannot be minimized (da Silva, 2007).

In this study, we evaluated five independent variables as potential risk factors for a high prevalence of *Salmonella* in WM. Of the five, three (overcrowding of live birds, use of unclean waste trays and lack of usage of disinfectant/ detergent) were statistically significant (p>0.05) in simple logistic regression analysis and one was statistically significant when adjusted for other variables in the multiple logistic regression model. Lack of usage of disinfectant/ detergent to clean the WM premises was the most significant risk factor found in both regression analyses. The odds of WM operations becoming positive for *Salmonella* were five folds higher when WM operators did not use disinfectant/ detergent to clean their premises than the WM practising regular use of disinfectant/ detergents with and without adjusted for other independent variables tested. Previous studies have shown that daily cleaning and disinfection were effective at reducing infections such as *Salmonella*, *Campylobacter* and Avian Influenza at live bird markets (Marin *et al*., 2001; Rejab *et al*., 2012; Trock *et al*., 2008). Overcrowding of live birds kept in WM before slaughtering has increased the prevalence of *Salmonella* in WM by about two folds (odds ratio=2.127) compared to the WM without overcrowding before slaughter. As WM operators did not provide adequate space, live birds were often kept in dirty overcrowded cages and crates, which may or may not have cleaner waste trays/ floors. Birds in WM operations may harbour *Salmonella* in their faeces but may not show any symptoms of disease (Higgins *et al.*, 1982; Rigby and Petit, 1980, 1981) and serve as a source of potential contamination to uninfected birds. The faecal droppings of any contaminated birds can infect the other birds as well as contaminate the cages and crates. Cages used without waste trays can lead to contamination of the birds as well as the floor (WHO, 2006). Conversely, unclean floors and waste trays could provide ideal niches for the maintenance of pathogens in WM operations thus increasing the risk of cross-contamination with potential zoonoses. Our risk factor analysis confirmed that the use of unclean waste trays underneath the stacked cages and crates increases contamination with *Salmonella* by about two folds when adjusted for overcrowding and lack of usage of disinfectant/ detergent. Implementation of biosecurity measures and husbandry practices to prevent the introduction, replication and spread of infectious agents, has often been recommended to reduce the risk of infection or disease in poultry operations (Fox, 2012; Madec *et al.*, 2010). These findings would be important to the public health, food safety, and animal health personnel to design policies and strategies to reduce *Salmonella* contamination and to improve the quality standards of poultry wet market in Sri Lanka.

CONCLUSION

Even though semi-automated broiler chicken meat dominates the meat industry in Sri Lanka, consumer perceptions for warm, fresh meat sustain the wet markets in the country. The observed characteristics of the WM in Sri Lanka were generally consistent with those operated in other Asian countries even though there were some subtle deviations. General characteristics seen in majority of the WM operations (65% to 100%) included, keeping live birds onsite in overcrowded dirty cages, onsite slaughtering, practice of manual slaughtering and processing, unavailability of proper facilities and equipment for slaughtering and processing, selling of skin intact meat of broiler chicken, regular supply of live birds by middlemen, keeping meat/ dressed birds at ambient temperatures until being sold, lack of freezing facility, improper evisceration practices leading to cross-contamination with gut content, improper disposal of solid waste materials and

insufficient poultry diversity. Overall *Salmonella* prevalence of WM in Sri Lanka was moderate (47.97 %) while that in poultry meat sold at WM was low (30.89%). The prevalence of *Salmonella* in meat contact surfaces (cutting boards and knives) was low (<25%) as well. WM operations showed moderately positive correlations for *Salmonella* prevalent meat samples (r =0.69), cutting boards (r=0.59) and knives (r =0.57). We identified that not using disinfectant/ detergent to clean the premises as the most significant risk practice for *Salmonella* contamination in the wet markets of Sri Lanka. The other risk practices include overcrowding of live birds kept in WM before slaughter and the use of unclean waste trays underneath stacked bird crates.

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