Chapter 8

About this chapter

The epidemiological findings from Chapter 7 were important to inform disease control activities in LBMs in Indonesia. This chapter builds on the findings from Chapter 7 by identifying a set of critical control points to reduce the risk of virus contamination in the LBM environment. Three sources of information were used in this chapter: (a) Chapter 7 findings, (b) Other published literature on avian influenza viruses in LBMs, (c) Flowchart decision tree for critical control point determination. The study found five points in the poultry workflow that qualify as critical control points.

My role in this study was to design the study methodology, collate the data, review the literature, identify the critical control points and write the manuscript. The study was published in Preventive Veterinary Medicine and has been reproduced in this chapter with permission from the publisher, Elsevier.
Critical control points for avian influenza A H5N1 in live bird markets in low resource settings

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ABSTRACT

Live bird markets can become contaminated with and become a source of transmission for avian influenza viruses including the highly pathogenic H5N1 strain. Many countries affected by the H5N1-virus have limited resources for programs in environmental health, sanitation and disease control in live bird markets. This study proposes five critical control points (CCPs) to reduce the risk of H5N1-virus contamination in markets in low resource settings. The CCPs were developed based on three surveys conducted in Indonesia: a cross-sectional survey in 119 markets, a knowledge, attitudes and practice survey in 3 markets and a microbiological survey in 83 markets. These surveys assessed poultry workflow, market infrastructure, hygiene and regulatory practices and microbiological contamination with the H5N1-virus. The five CCPs identified were (1) reducing risk of receiving infected birds into the market, (2) reducing the risk of virus spread between different bird flocks in holding cages, (3) reducing surface contamination by isolating slaughter processes from other poultry-related processes, (4) minimizing the potential for contamination during evisceration of carcasses and (5) reducing the risk of surface contamination in the sale zone of the market. To be relevant for low resource settings, the CCPs do not necessitate large infrastructure changes. The CCPs are suited for markets that slaughter poultry and have capacity for daily disposal and removal of solid waste from the market. However, it is envisaged that the CCPs can be adapted for the development of risk-based programs in various settings.

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1. Introduction

In many countries, food markets are an integral part of the community – providing foods that reflect the local culture and traditions of the people as well as serving as a commercial and social centre. Food markets that offer bird carcasses as well as live birds either for sale or for slaughter are collectively referred to as live bird markets (LBMs) (World Health Organization, 2006b).

LBMs provide major contact points between people and animals, creating optimal conditions for the zoonotic transfer and evolution of infectious disease pathogens. LBMs are known to amplify and disseminate the highly pathogenic avian influenza A H5N1 (AI H5N1) virus (Kung et al., 2007). Studies have shown that AI H5N1 can be found in birds as well as on work surfaces in LBMs (Desvaux et al., 2006; Santhia et al., 2009; Wang et al., 2006). There is also evidence that humans have been infected with AI H5N1 in LBMs (World Health Organization, 2006a; Zhou et al., 2009). AI H5N1 virus infection in humans is of public health concern; the zoonotic disease has a high case fatality rate, and the virus has pandemic potential if it mutates into...
a form that transmits rapidly between humans (Kandun et al., 2006; Webster et al., 2005).

Most guidance on AI H5N1 recommends controlling the disease “at source” – that is, in the birds (Food and Agriculture Organization, 2009). Controlling AI H5N1 virus in LBMs is critical to prevent the dissemination of the virus back into farms and backyard bird holdings which can occur through movement of live birds, infective poultry by-products and fomites (Santhia et al., 2009). However, complete elimination of the virus from LBMs is not realistic if the farms supplying the LBMs continue to have outbreaks of AI H5N1 (Mullaney, 2003). Therefore, the goal in LBMs in areas endemic for the virus is to reduce the risk of contamination that may lead to human infection and continued circulation of the virus in birds.

Risk-based programs relate hazards to public health outcomes (Simjee et al., 2007). Risk-based programs have been used to control avian influenza viruses in LBMs (Kung et al., 2003; Mullaney, 2003). LBMs implementing such programs have been in high resource settings where there is good public health regulation and pre-requisite programs (PRPs) for general hygiene. PRPs are practices and conditions needed prior to and during implementation of risk-based programs such as good management, training and equipment (World Health Organization, 1999). In addition to PRPs, risk-based programs usually involve critical control points (CCPs) for managing hazards. CCPs are steps at which control can be applied and are essential to reduce, prevent or eliminate a hazard to an acceptable level (Codex Committee on Food Hygiene, 1997).

In high resource setting, risk-based programs in LBMs involve cleaning and disinfection activities as well as periodic rest days, for which impact is monitored through microbial surveillance (Kung et al., 2003; Mullaney, 2003; Trock et al., 2008). Risk-based programs would be difficult to implement in many countries affected by AI H5N1 due to limitations in resources and capacity, especially the availability of PRPs and an environment operating to good standards of hygiene. In such settings, disease control may be feasible if CCPs are not dependent on good infrastructure and capacity for PRPs.

Taking into account the limited capacity for PRPs, limited disease surveillance activities and low levels of public health regulation, this study aimed to identify CCPs for H5N1-virus control in LBMs in low-resource settings. The study was conducted in Indonesia – a low resource country that has been heavily affected by AI H5N1 (World Health Organization, 2010; World Organization for Animal Health, 2010).

1.1. Setting

There are an estimated 13,000 LBMs across the 17,000 islands of Indonesia (Raharjo, 2010). Many LBMs in Indonesia offer a variety of birds for slaughter and sale, including broilers, layers, village chicken, Muscovy ducks and geese. Birds coming into LBMs may be sourced from a variety of farms or backyard holdings, and may have travelled hundreds of kilometers from neighboring districts or provinces.

The bird area of an LBM in Indonesia generally has five zones: (1) bird delivery zone where trucks unload live birds, (2) bird holding zone which comprises cages or pens to house live birds, (3) bird slaughter zone where birds are killed, defeathered, eviscerated and dressed, (4) bird sale zone with display tables, and lastly, (5) waste management zone where remnants such as innards and feathers are discarded. In some LBMs, bird zones are combined. For example, small markets may have two or three bird vendors, where each operates a self-sufficient stall. In these stalls, live birds are held in cages placed under the work table, birds are killed on the floor or on the work table, a hot water barrel and a defeathering machine are used to scald and defeather the carcass and the internal organs are removed on a work table. The final products – whole bird carcasses or pieces of meat – are then displayed at the front of the stall on display tables made either of ceramic tiles, steel or wood covered with a plastic sheet.

2. Materials and methods

Since CCP identification relies on thorough knowledge of the workflow, the product and the hazard itself, three surveys were conducted. The three surveys assessed poultry workflow, infrastructure, regulatory practices and LBM contamination with the H5N1 virus. The findings from the surveys were then used to quantitatively summarize and synthesize the existing capacity for PRPs. The findings from the surveys and synthesis of PRP capacity in LBMs formed the basis of CCP identification. This multi-step process was critical to reduce the subjectivity associated with CCP selection. Methods for the (a) three surveys, (b) synthesis of PRP capacity, and, (c) CCP identification, are described in more detail below. Approval for the study was obtained from the Health Research Ethics Committee at the Indonesian Ministry of Health as well as the Australian National University Human Research Ethics Committee.

2.1. Cross sectional survey

A cross-sectional survey was conducted in 119 LBMs to assess infrastructure and hygiene practices. The 119 LBMs were selected from 17 districts in four provinces in Indonesia: Jakarta, West Java, Banten and South Sulawesi. Methods for selecting the 31 LBMs in Jakarta, 41 in West Java and 11 in Banten province have been described previously (Indriani et al., 2010). In South Sulawesi, all 36 LBMs in the provincial capital Makassar were included. The survey was conducted using a structured questionnaire with 33 close-ended questions. The questions were divided in five sections: (a) seven questions about general conditions in the market, (b) five questions about market infrastructure, (c) nine questions about poultry in markets, (d) five questions about poultry processing, and (e) seven questions about cleaning and disinfection. The interviews were conducted in Bahasa Indonesia by three interviewer teams who received one-day training in survey administration and documentation. Data were entered and descriptive statistics were calculated in Microsoft Excel® (Microsoft Corp., Redmond, WA, USA).
2.2. Knowledge, attitude and practice survey

A survey on knowledge, attitudes and practices (KAP) was undertaken in three LBMs in South Sulawesi province to assess in detail the poultry workflow, hygiene practices, regulation and knowledge about AI H5N1. The KAP survey was conducted amongst three market managers and 37 bird vendors. For market managers, the survey had open-ended questions regarding the LBM management structure and staffing, market rules, utilities and hygiene practices, and relationships with government authorities such as the district veterinary and health offices. For the poultry vendors, the survey questions focused on documenting the poultry workflow steps, equipment used including personal protective equipment, knowledge and attitudes on avian influenza, and hygiene practices. The interviews were conducted in Bahasa Indonesia by three interviewers who received one-day training in survey administration and documentation. During the interviews, responses were paraphrased and repeated to the respondent to ensure accurate interpretation of answers. The qualitative data arising from the interviews with the market managers were analyzed by themes where one perspective was compared to responses in the same category. Descriptive statistics were calculated for responses from bird vendors in Microsoft Excel® (Microsoft Corp., Redmond, WA, USA).

2.3. Microbiological survey

Contamination with the H5N1 virus was assessed through a survey in 83 LBMs in three provinces in Indonesia. The methods for this survey have been described in a related study that focused on identifying risk factors for LBM contamination (Indriani et al., 2010). For the current study, the microbiological findings are assessed in context of CCP identification. In brief, the survey method involved swabbing up to 27 different environmental sites in 83 LBMs. The sites represented different poultry-related work activities; three sites related to the delivery of birds into LBMs, seven for holding birds in cages/pens, nine sites related to bird slaughter, six for sale and two sites for waste disposal. The samples collected from these sites were tested for AI H5N1 using real time reverse transcriptase polymerase chain reaction (rRT-PCR) (Indriani et al., 2010).

2.4. Capacity for PRP

A table was constructed with the 14 standard PRPs for food production as defined by the Codex Alimentarius Commission (Codex Committee on Food Hygiene, 1997). Definitions for each standard PRP were operationalized for the context of poultry workflow in LBMs. Based on the findings from the three surveys, LBM PRP capacity was summarized by qualitatively assessing existing capacity against the 14 standard PRPs.

2.5. CCP identification

The three surveys, general capacity for PRPs in LBMs and relevant scientific literature were used to identify CCPs. A diagram outlining poultry workflow in an LBM was constructed to identify potential CCPs. Confirmation exclusion of each potential CCP was guided by a logic reasoning approach as per the Codex decision tree for CCP determination (Codex Committee on Food Hygiene, 1997). Using the decision tree, a CCP denotes a step at which the hazard can be controlled using available measures and where it is necessary to achieve hazard control. For steps where the hazard exists but no control measure exist, then the process should be modified at one or more steps to include a control measure that ensures the ultimate safety of the product (Lu, 1970).

3. Results and discussion

3.1. Cross sectional survey

Most LBMs surveyed were open daily (n=117, 98.3%). Most LBMs (n=82, 68.9%) had pests such as scavenging cats, dogs, rats and insect infestation. For infrastructure, stalls in 13 (10.9%) LBMs had wooden work surfaces, 68 (57.1%) had ceramic surfaces and 38 (31.9%) had a combination. The majority (n=82, 68.9%) had water piped to each stall, but the others (n=37, 31.1%) had to source water using buckets from wells inside or outside the LBM. For waste management, the majority of LBMs (n=83, 69.7%) removed solid waste daily, whilst some removed waste less frequently than daily (n=29, 24.4%) and 7 (5.9%) LBMs had no solid waste management system. For liquid waste, the majority of LBMs had open drainage systems (n=73, 61.3%), 16 (13.4%) had covered drains and 29 (24.3%) LBMs had no liquid waste management system.

In terms of bird management, the majority of the LBMs surveyed (n=93, 78.2%) kept unsold birds in the LBM for more than one night. Additional bird flocks coming into the LBM on different days were mixed with flocks already inside the LBM (n=46, 38.7%). Some LBMs (n=30, 25.2%) mixed different species of birds in the same cages/pens. Vendors in six LBMs admitted to selling sick birds to consumers. For poultry processing, 20 (16.8%) LBMs surveyed did not slaughter birds in the LBM. Vendors in the majority of LBMs slaughtered birds in the individual stalls (n=68, 57.1%), 4 (3.4%) LBMs had a separate common slaughter and 27 (22.7%) LBMs had slaughtering in both stalls and a common area.

For cleaning, most LBMs cleaned their stalls and slaughter areas daily (n=116, 97.5%). However, only 72 LBMs (60.5%) used soap during cleaning. Based on visual inspection, vendors in only 25 (21%) LBMs had cleaning equipment like brushes, brooms and buckets. A minority of LBMs mandated that birds be removed before cleaning (n=44, 37%). At the time of the survey, 59 LBMs (49.6%) appeared clean defined as no visible waste, blood or remnants on tables or floors.

3.2. Knowledge, attitude and practice survey

Two LBMs in the KAP survey had 17 personnel and the third had 28 personnel. The KAP survey in 3 LBMs revealed a lack of food safety awareness amongst market managers and bird vendors. No training was provided for vendors in disease prevention and food safety practices. Use of
personal protective equipment was limited with only 11 (29.7%) workers wearing boots and 11 (29.7%) wearing aprons. Cages in each stall were overcrowded with birds and they were placed in close proximity to work surfaces. Study teams observed feathers and feces transfer from inside cages. None of the workers reported using soap or detergents when cleaning work surfaces and only 7 (18.9%) workers reported using soap to clean knives and defeathering equipment. The majority of vendors (n = 32, 86.5%) reported cleaning chopping boards several times per day and the others cleaned the boards once at the end of trade (n = 5, 13.5%). One-third (n = 11, 29.7%) of vendors did not know or gave incorrect symptoms of AI infection in birds, and only one wrapped birds that died naturally in the market before disposing of it in the waste disposal area.

LBMs did not have specific regulations for hygiene, zoning of activities or poultry workflow. Birds were allowed to be sold live in all LBMs. Due to limited budgets provided by local government, the LBMs could not guarantee water or electricity supply to vendors even though stall fees were paid by vendors. This resulted in vendors seeking private sources for electricity and water supply. For water, this included establishing private wells inside or near the LBM that were not monitored or tested routinely. None of the three LBM managers had standard procedures to deal with mass bird deaths. Further, they did not understand the regulatory and inspection roles of government agencies, nor the support that these authorities can provide to assist LBMs.

The majority (n = 26, 70.3%) of vendors and all LBM managers mentioned the need to improve infrastructure such as roofing, drainage, flooring and supply to utilities such as water and electricity. All managers also wanted training in healthy market concepts as well as business training to improve market income.

### 3.3. Microbiological survey

Thirty-nine out of the 83 LBMs had evidence of H5N1-virus contamination. Most LBMs had contamination in the sale (n = 30, 36.1%), slaughter (n = 29, 34.5%) and bird holding (n = 24, 28.9%) zones (Table 1). However, a few LBMs also had contamination in the delivery zone (n = 11, 13.2%) and waste disposal zone (n = 9, 10.8%). Surfaces in the slaughter zone, such as tables chopping boards and baskets, were found to be amongst the most contaminated (Table 1). In the sale area, display tables, weigh scales and chopping boards were most contaminated (Table 1).

### 3.4. Capacity for PRPs

Table 2 outlines the standard Codex PRPs (Codex Committee on Food Hygiene, 1997). In the context of LBMs, PRPs mandate a number of activities including cleaning and disinfection, monitoring systems, segregation of processes that have potential for cross-contamination and training of workers/managers in hygiene and sanitation. Based on the three surveys, many LBMs do not comply with the PRPs required for good hygiene (Table 2). Capacity for safe packaging (PRP 12) is deemed to be high and availability of durable and easy to clean equipment (PRP 4) is moderate. However, LBMs surveyed had low capacity for all other 12 PRPs including waste management, prevention of cross-contamination and maintenance, cleaning and sanitation.

### 3.5. CCP identification

Based on the LBMs surveyed, the poultry workflow is presented in Fig. 1. The workflow represents processes in LBMs that either slaughter birds at stalls or in a common slaughter location, and that, at minimum, have a waste management system that removes rubbish and remnants daily. Fig. 1 also presents the five CCPs identified in the study. The workflow and rationale for each CCP is described below. Mechanisms to manage CCPs in the context of LBMs in a low resource setting are suggested.

Birds come into an LBM from a variety of sources. There is no documentation of bird sources nor is there routine health inspection of birds entering the LBM. However, as a number of studies have shown, birds can enter an LBM infected with AI H5N1 virus (Santhia et al., 2009; Webster, 2004). Some species such as chicken will become symptomatic generally within two days of infection and the majority of the flock will die, but other species such as ducks and geese may remain asymptomatic (Nguyen et al., 2005). Since chicken is the most common species sold in LBMs, there is an opportunity to reduce the number of infected birds entering the LBM by excluding sick incoming

![Fig. 1. Critical control points for avian influenza A H5N1 in the workflow of live bird markets.](image_url)
Table 1
Environmental contamination with avian influenza A H5N1 virus in 83 live bird markets.

<table>
<thead>
<tr>
<th>No.</th>
<th>Poultry zone</th>
<th>Environmental site</th>
<th>RT-PCR positive LBM(<em>\text{s}) LBM(</em>\text{s}) tested (%)</th>
<th>LBM(_\text{s}) +ve for zone, N=83 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Delivery</td>
<td>Inside cages on truck</td>
<td>6/45 (13.3)</td>
<td>11 (13.2)</td>
</tr>
<tr>
<td>2</td>
<td>Delivery</td>
<td>Floor in delivery area</td>
<td>6/49 (12.2)</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Delivery</td>
<td>Water run-off in delivery area</td>
<td>4/38 (10.5)</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Holding</td>
<td>Poultry cage floors</td>
<td>6/79 (7.6)</td>
<td>24 (28.9)</td>
</tr>
<tr>
<td>5</td>
<td>Holding</td>
<td>Holding area floor</td>
<td>8/80 (10)</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Holding</td>
<td>Water run-off</td>
<td>11/72 (15.3)</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Holding</td>
<td>Poultry feeding bottle water</td>
<td>8/67 (11.8)</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Holding</td>
<td>Poultry feeding basket food</td>
<td>6/72 (8.3)</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Holding</td>
<td>Handles to poultry cages</td>
<td>9/79 (11.7)</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Holding</td>
<td>Inside of waste bins</td>
<td>10/59 (16.7)</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Slaughter</td>
<td>Knife handles used for slaughtering</td>
<td>8/75 (10.7)</td>
<td>29 (34.9)</td>
</tr>
<tr>
<td>12</td>
<td>Slaughter</td>
<td>Basket holding dying chickens</td>
<td>8/71 (11.3)</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Slaughter</td>
<td>Floor in slaughter area</td>
<td>10/77 (13)</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Slaughter</td>
<td>Chopping or slaughtering board</td>
<td>14/71 (19.7)</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Slaughter</td>
<td>Processing table after de-feathering</td>
<td>15/70 (20)</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Slaughter</td>
<td>Baskets holding poultry meat</td>
<td>14/70 (20)</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Slaughter</td>
<td>Drain path</td>
<td>12/75 (16)</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Slaughter</td>
<td>Tap handles in slaughter area</td>
<td>7/65 (10.7)</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>Slaughter</td>
<td>Waste bin</td>
<td>13/71 (18.3)</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>Sale</td>
<td>Chopping boards</td>
<td>15/80 (18.8)</td>
<td>30 (36.1)</td>
</tr>
<tr>
<td>21</td>
<td>Sale</td>
<td>Weigh scales</td>
<td>12/57 (21.1)</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>Sale</td>
<td>Knife handles</td>
<td>12/78 (15.4)</td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>Sale</td>
<td>Waste bins</td>
<td>10/90 (16.7)</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>Sale</td>
<td>Wet cloths for cleaning surfaces</td>
<td>14/78 (17.9)</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>Sale</td>
<td>Tables for poultry display</td>
<td>19/80 (23.8)</td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>Waste disposal</td>
<td>Area waste disposal bin</td>
<td>15/78 (19.2)</td>
<td>9 (10.8)</td>
</tr>
<tr>
<td>27</td>
<td>Waste disposal</td>
<td>Wet cleaning mops</td>
<td>8/66 (12.1)</td>
<td></td>
</tr>
</tbody>
</table>

flocks of chickens. Hence, CCP 1 is at receipt of birds into the LBM, where vendors must reject sick flocks of chicken. One mechanism would be for vendors to inspect and check flocks for signs of AI H5N1 infection using a clinical case definition. This involves searching for symptoms such as reduced bird movement, discharge from the mouth, eyes or cloaca, bluish comb or reduced movement of head. If the inspection suggests there is illness amongst the flock, vendors must reject the flock and inform the LBM manager so that district agriculture authorities can initiate outbreak control measures.

Once flocks of birds come into the LBM holding zone, there is an opportunity for the virus to spread between birds held in cages or pens. This is CCP 2. Flock separation is needed to reduce virus spread within the LBM especially for LBMs that keep birds for a number of days or sell live birds to consumers. Specifically, vendors must separate flocks coming into the LBM from different sources. This may require adding panels between stacked cages to prevent bird contact, increasing the number of feeding bottles and having a daily cleaning regimen to remove dirt and excreta from cages before the next flock of incoming birds.

The next step in the workflow is to kill and bleed the birds. During this process, birds flap around which can generate droplets carrying viral particles. Since large droplets settle within one meter of the source (World Health Organization, 2007), it is important to keep consumers and other birds at a safe distance from the slaughter process. Therefore, CCP 3 is to isolate the slaughter step. Slaughtering should be conducted at least two meters away from the bird holding and sale zones. If distancing is not possible due to the layout or size of the LBM, another option is to install an easy-to-clean physical barrier such as plastic that prevents splashing.

After the birds are killed and the blood drained, the vendors scald the carcass in hot water to pluck the feathers. Dipping the carcass in water reduces the dust expelled when the feathers are plucked. This is practiced routinely as part of the workflow and inherently minimizes the risk of environmental contamination (World Health Organization, 2004). Therefore, it is not considered a CCP. The plucked feathers are then gathered by the vendor and are disposed off at the end of the trading day along with remnants arising from the slaughter process.

Vendors break the bird neck and eviscerate the carcass. Evisceration is a critical step in the slaughter process because it may rupture the bird’s internal organs and result in spillage of fecal material, viruses and bacteria onto the meat and on environmental surfaces. From the microbiological survey, surfaces associated with slaughter such as work tables and chopping boards were amongst the most contaminated. Thus, reducing contamination in the evisceration step is CCP 4. Mechanisms to address this CCP are to provide technical training in appropriate slaughtering techniques to slaughterers and supplying them with simple but appropriate evisceration tools. Another mechanism is through regular cleaning of surfaces using detergents after the evisceration process. Previous studies have shown that simple soap products, detergents and alkali destroy H5N1-infectivity within 5 min at 0.1%, 0.2% and 0.3% dilution (Stahid et al., 2009).

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### Table 2

Capacity for prerequisite programs in live bird markets surveyed in Indonesia.

<table>
<thead>
<tr>
<th>Standard PRPs</th>
<th>Standard PRPs in context of LBMs</th>
<th>Current PRP capacity in LBMs</th>
<th>PRP capacity examples in LBMs surveyed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Management and supervision</td>
<td>• Local health and agriculture authorities and market managers trained in hygiene principles and have monitoring plans</td>
<td>Low</td>
<td>• No training provided to managers in hygiene</td>
</tr>
<tr>
<td>2. Facilities</td>
<td>• Zoning to prevent cross-contamination</td>
<td>Low</td>
<td>• Roles of different local agencies unclear</td>
</tr>
<tr>
<td>3. Supplier control</td>
<td>• Only healthy birds enter LBMs</td>
<td>Low</td>
<td>• 64.9% LBMs are not zoned</td>
</tr>
<tr>
<td>4. Equipment</td>
<td>• Mechanism to trace back bird origin</td>
<td>Moderate</td>
<td>• 57.1% LBMs have easy-to-clean work surfaces</td>
</tr>
<tr>
<td>5. Maintenance, cleaning and sanitation</td>
<td>• Surfaces and equipment need to be easy-to-clean with detergents</td>
<td>Low</td>
<td>• No documentation of source of incoming birds in LBMs</td>
</tr>
<tr>
<td>6. Pest control</td>
<td>• All zones clean to prevent pest infestations</td>
<td>Low</td>
<td>• 68.9% LBMs had evidence of pest infestation</td>
</tr>
<tr>
<td>7. Waste management</td>
<td>• Drainage for liquid waste such as bird blood and wastewater</td>
<td>Low</td>
<td>• 24.4% LBMs had no drainage system for liquid waste</td>
</tr>
<tr>
<td>8. Personal hygiene and health status</td>
<td>• Bird workers excluded if sick</td>
<td>Low</td>
<td>• 30.3% LBMs did not remove solid waste daily</td>
</tr>
<tr>
<td>9. Visitors</td>
<td>• Prevent consumer access to slaughter zone or handling raw meat</td>
<td>Low</td>
<td>• Limited pay-by-use toilets</td>
</tr>
<tr>
<td>10. Receiving, storage and shipping</td>
<td>• Live birds held in appropriate caging</td>
<td>Low</td>
<td>• No soap for hand-hygiene</td>
</tr>
<tr>
<td>11. Cross-contamination</td>
<td>• Separation of slaughter zone from other bird zones</td>
<td>Low</td>
<td>• No protocols for exclusion of sick staff</td>
</tr>
<tr>
<td>12. Packaging</td>
<td>• Clean plastic bags for meat</td>
<td>High</td>
<td>• Customers can handle meat and live birds in selection process</td>
</tr>
<tr>
<td>13. Staff training</td>
<td>• Staff trained in general hygiene, food safety and sanitary slaughter techniques</td>
<td>Low</td>
<td>• 75.5% LBMs use difficult-to-clean cages</td>
</tr>
<tr>
<td>14. Traceability and recall</td>
<td>• Trace back possible if sick birds detected.</td>
<td>Low</td>
<td>• 40% LBMs keep birds in LBMs during cleaning</td>
</tr>
</tbody>
</table>

According to Codex.  
Findings quoting percentages are from the survey conducted in 119 LBMs. All other findings are based on the KAP survey in three LBMs.

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After evisceration, the carcass is washed in water and cut into pieces. This may be followed with a second wash in water. These three steps are not considered CCPs as they usually take place at the same location as evisceration. Therefore, by applying the controls in the evisceration step (CCP 4), especially regular cleaning of surfaces, then contamination will be reduced.

The meat is then displayed on tables for sale. Since the microbiological survey showed that the sale zone was frequently contaminated with H5N1-virus, CCP 5 is to reduce contamination at the sale point. Previous studies have shown that cleaning is effective at eliminating influenza viruses from environmental surfaces in LBMs (Bulaga et al., 2003; Trock et al., 2008). Therefore, CCP 5 can be managed through daily cleaning with detergents of these surfaces. All remnants and visible dirt must be removed and disposed off in the waste disposal zone to reduce the potential for environmental contamination.

### 4. Conclusions

Control of AI H5N1 in LBMs is critical as part of the strategy to control the disease in birds and to reduce the risk of human infection. Risk-based programs focus on preven-
tation rather than inspection, take a bottom-up approach that acknowledge the variability in context and process, and are generally simple to implement (Herrera, 2004). This is the first study to consider H5N1 risk management in LBMs in low resource settings by proposing control points based on the scientific data presented. Five CCPs were proposed in this study based on three surveys that assessed infrastructure, hygiene practices, poultry workflow and H5N1-virus contamination in LBMs in Indonesia. The CCPs identified are relevant for LBMs that slaughter birds and that, at minimum, remove rubbish/solid waste daily.

The three surveys revealed limited infrastructure, hygiene and regulatory practices in LBMs. The findings were aligned with previous work that explored high risk practices in LBMs (World Health Organization, 2006b). Vendors and LBM managers had limited food safety knowledge and information about avian influenza. Further, the microbiological survey showed alarming frequency of contamination in some of the LBM work surfaces surveyed, including areas accessible to consumers such as sale tables and weigh scales. This increases the risk of infection and spread of virus through fomites. Despite these challenges, the KAP survey showed a general willingness amongst vendors and LBM managers to enhance conditions in the markets.

Based on the synthesis of PRP capacity, some PRPs may potentially be attainable in the context of the low-resource LBMs surveyed. Two examples are staff training and management and supervision, where the existing human resources and organizational structure overseeing LBMs has the potential to be utilized for enhanced application of disease control principles. Each LBM has a manager with a number of deputies and cleaning staff. These human resources can eventually be trained and mobilized to manage disease risk. Further, most district agriculture authorities have part-time representatives in LBMs for meat inspection and revenue collection. These staff may be mobilized to provide training in hygiene, slaughtering techniques and safe work practices.

Since each LBM has its unique characteristics for which control activities will need to be specifically tailored, a full risk-based program for the control of H5N1-virus was not proposed in this study. However, it is expected that the CCPs identified and the mechanisms suggested for the control of each CCP are adaptable to various types of LBMs, especially those that slaughter live birds and those with limited zoning of poultry workflow. Further, LBMs in Indonesia are similar to LBMs in many other low-resource countries with limited infrastructure, facility maintenance and public health regulation (World Health Organization, 2006b). Therefore, the CCPs identified in this study may be applicable to other countries with minor modification. This should make the task of developing a comprehensive risk-based control program relatively easy for market, veterinary and public health authorities in different settings.

The CCPs identified in this study do not only address the safety of the final product (meat), but also the risks associated with the entire poultry workflow which can place humans and other birds at risk of AI H5N1 infection. This is an atypical approach. Traditionally, CCPs address processes that contaminate the final product whilst PRPs address risk associated with the process (Bas et al., 2007). However, since PRPs in the LBMs surveyed were found to be sub-optimal, the risks associated with the entire poultry workflow had to be addressed through CCPs. This was considered critical for LBMs in low resource settings since enhancement of PRP capacity will likely involve expensive infrastructure changes such as piping water, supplying electricity and upgrading physical infrastructure such as tabletops, floors and roofing.

The main limitation of this study is that the CCPs identified were not validated. However, this can be seen as a next step in a few trial LBMs, where it will necessitate microbiological surveillance to determine if a reduction in AI H5N1 contamination was achieved. Even though the objective of this study was to aid in the control of AI H5N1 in LBMs, it is anticipated that the recommendations could also assist in the control of other pathogens, such as Salmonella and Campylobacter, which are associated with bird slaughter (McCrea et al., 2006). Such benefits should be explored in the validation of the CCPs, as they may appeal to national decision-makers as an opportunity for integrated disease control activities.

Acknowledgements

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References


Chapter 9

Paper 6: Application of a healthy food markets guide to two Indonesian markets to reduce transmission of “avian flu.”
About this chapter

The previous two chapters provided some of the epidemiological information needed to establish and operationalize disease control programs for AI H5N1 in LBMs in low resource settings such as Indonesia. This chapter describes a non-experimental field intervention trial where disease control measures were implemented to determine the practical aspects of implementation and to learn lessons for future application. Such research is needed in developing countries to highlight that international guidance can be implemented in low resource settings. The control measures were selected based on the WHO recommendations for developing healthy LBMs but also arise from the findings of the previous studies in this PhD, including recommendations for daily solid waste removal, zoning poultry workflow to reduce cross contamination and instituting daily cleaning routines.

The study described in this chapter found that disease control measures could be established for each of the WHO-recommended control measures. The participatory approach to operationalising the control measures involving LBM managers and vendors was well received by these stakeholders.

This study is of international importance as it is the first to demonstrate that AI H5N1 control measures can be instigated in LBMs in low resource settings in virus endemic countries. The study provides a proof-of-concept for future trials, including experimental designs and application in different settings.

My role in this study was to provide technical input into the interventions applied in the two trial LBMs, to determine the outcome measures and to collect the data to assess implementation and to identify lessons learnt. I wrote the manuscript and coordinated all co-author inputs pre-submission. The study was submitted to the Bulletin of the World Health Organization and was published in April 2012.
Application of a healthy food markets guide to two Indonesian markets to reduce transmission of “avian flu”

Gina Samaan,a Ferra Hendrawati,b Trevor Taylor,c Tangguh Pitona,b Dini Marmansari,b Ratna Rahman,b Kamalini Lokugea & Paul M Kellya

Problem  The World Health Organization (WHO) developed a guideline with 10 control measures to reduce transmission of A(H5N1) avian influenza virus in markets in low-resource settings. The practical aspects of guide implementation have never been described.

Approach  WHO’s guideline was implemented in two Indonesian markets in the city of Makassar to try to reduce transmission of the A(H5N1) virus. The guideline was operationalized using a participatory approach to introduce a combination of infrastructural and behavioural changes.

Local setting  Avian influenza is endemic in birds in Makassar. Two of the city’s 22 dilapidated, poorly-run bird markets were chosen for the study. Before the intervention, neither market was following any of WHO’s 10 recommended control measures except for batch processing.

Relevant changes  Market stakeholders’ knowledge about the avian influenza A(H5N1) virus improved after the interventions. WHO guideline recommendations for visual inspection, cleaning and poultry-holding practices, as well as infrastructural requirements for zoning and for water supply and utilities, began to conform to the WHO guideline. Low-maintenance solutions such as installation of wastewater treatment systems and economic incentives such as composting were well received and appropriate for the low-resource setting.

Lessons learnt  Combining infrastructural changes with behaviour change interventions was critical to guideline implementation. Despite initial resistance to behaviour change, the participatory approach involving monthly consultations and educational sessions facilitated the adoption of safe food-handling practices and sanitation. Market authorities assumed important leadership roles during the interventions and this helped shift attitudes towards regulation and market maintenance needs. This shift may enhance the sustainability of the interventions.

Abstract in العربية, 中文, Français, Русский and Español at the end of each article.

Introduction

Live bird markets have been implicated in the circulation of avian influenza A(H5N1) virus1 and are a potential source of viral transmission among humans and animals.3,5 In 2006 the World Health Organization (WHO) developed a guideline – A guide to healthy food markets – to reduce contamination with and transmission of A(H5N1) virus in live bird markets.1 The guideline lists 10 control measures for the poultry area of markets, the main aims of which are to improve the environment and ensure safe food-handling practices. The 10 control measures involve education and awareness of how avian influenza is transmitted; monitoring of conditions and food-handling practices; visual inspection of fowl to look for signs of infection; use of personal protective equipment (masks, gloves, disposable aprons, rubber boots, etc.); market zoning to prevent public access to potentially contaminated areas; use of potable water for cleaning and hand-washing; appropriate cage design and holding practices; appropriate cleaning practices; properly designed utilities, such as drainage systems, and batch processing. This study reports on the lessons learnt from implementing the guideline in two live bird markets in Makassar, Indonesia, a low-resource country with areas where avian influenza A(H5N1) virus infection is endemic in fowl.

Problem and local setting

The site of the study was the city of Makassar (population 1.6 million), where 80,000 birds are slaughtered daily and where avian influenza A(H5N1) virus infection is endemic in birds.7 Makassar has 22 live bird markets under the purview of the municipal market authority. All of them have dilapidated infrastructure, no health services and an inadequate operational environment. Two markets were selected for this study based on the management teams’ readiness to undergo the interventions. Market A had 186 kiosks, 17 management and sanitation staff, and 5 poultry kiosks that received and slaughtered a daily total of 500 birds; Market B had 247 kiosks, 17 management and sanitation staff, and 13 poultry kiosks that received and slaughtered a daily total of 2700 birds.

Before the intervention, an assessment was conducted to determine the extent to which WHO’s 10 control measures were being practised.8 The assessment showed that only one of the measures – batch processing – was being followed as recommended in the WHO guideline, which calls for separating poultry batches, cleaning between batches and at the end of the trading day, and having the capacity to trace back poultry through the use of regular suppliers. The other nine control measures were not met. For example, each poultry kiosk held, slaughtered and sold birds without separate zoning for these different processes; drainage, bins, electricity and water supplies were limited; work surfaces, cages and floors were hard to clean; and no regulated inspection or sanitation programmes were in place.

Approach

A municipal-level taskforce was established. It was composed of the finance and operations staff of the municipal market authority, general managers and sanitation teams of the live bird market, and members of the nongovernmental organization (NGO), CHF International, that was funded to implement the

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project to improve the two markets according to the WHO guideline. The task-force oversaw the change process and monitored the interventions monthly.

Interventions promoting infrastructural and behavioural changes were introduced over an 18-month period (January 2008–June 2009). The interventions were specifically aimed at achieving compliance with the nine recommended measures not being practiced at the markets (batch processing was excluded since it was already being practiced). A participatory approach involving market managers, sanitation teams and poultry vendors was applied to put the measures into operation. Under this approach, problems were posed and potential solutions discussed at monthly consultation meetings held at the markets until acceptable options emerged.

Interventions that required construction or introduction of new goods were designed to ensure sustainability, low ongoing costs and easy maintenance. Education sessions lasting two hours were held monthly to improve market managers’, sanitation teams’ and poultry vendors’ knowledge and practices in the area of sanitation and food handling. These 18 sessions were held at canteens near the markets and addressed waste management, food safety, recognition of signs of infection with avian influenza A(H5N1) virus and notification of affected fowl. The staff of CHF International developed key messages based on the WHO guideline and provided the training. Information was discussed and monitoring protocols and logs were developed during these 18 sessions.

Progress in implementing the intervention was evaluated through a post-intervention inspection, interviews with market managers, sanitation teams and poultry vendor surveys. These activities were conducted by a two-person team composed of one external evaluator (GS) experienced in avian influenza control in live bird markets and one NGO officer responsible for overseeing guideline implementation at both markets. GS developed the necessary evaluation tools based on the WHO guideline and provided one day of training to the NGO officer on questionnaire administration and data collection and recording.

An unannounced one-day inspection was conducted at each market by the team one month after the intervention. The team used a checklist to confirm that the necessary goods had been installed and that the protocols and logs developed were in use. Interviews with market managers and sanitation teams were conducted using semi-structured questionnaires developed with guidance from WHO and field tested locally. The questions explored the presence of any roadblocks to guideline implementation and the adequacy of the change process and the interventions. Answers to each question were summarized and differences in perspectives identified.

Changes in vendor knowledge, attitudes and behaviour before and after the intervention were measured using a field-tested, structured survey instrument containing 38 close-ended questions. The survey was conducted verbally in the local dialect. The NGO officer conducted the pre- and post-intervention surveys among 34 and 29 poultry vendors, respectively (Table 1). These numbers represent all vendors present in the market on the days the interviews were conducted. Changes in vendors’ knowledge, attitudes and behaviours before and after the intervention were analysed using $\chi^2$ or Fisher’s exact tests, as required.

Ethics approval for the study was obtained from the Health Research Ethics Committee at the Indonesian Ministry of Health and from the Australian National University Human Research Ethics Committee.

**Findings**

**Education and awareness**

Poultry vendors’ knowledge and attitudes surrounding avian influenza A(H5N1) virus transmission improved after the intervention. Six vendors from both markets continued to slaughter sick chickens and to sell sick or dead chickens (Table 1). They stated that they sold these chickens as feed for fish farms, but no follow-up was conducted to verify this information.

**Monitoring**

With the aid of municipal agriculture officers, both markets developed disease-
monitoring protocols. These protocols provided for simple visual inspection of incoming birds, a cost-free intervention. Monitoring logs were filled daily by market managers in both markets and kept in the communal poultry holding zone.

**Visual inspection**

Posters and protocols for poultry inspection and disease notification were developed and placed in a visible location in the poultry area of each market. More poultry vendors could correctly identify signs of avian influenza A(H5N1) virus infection in birds after the intervention than before it ($P = 0.09$) (Table 1).

**Personal protective equipment**

Poultry vendors rejected face masks and goggles because they made them feel too hot when worn during poultry slaughter. However, the use of plastic aprons increased after the intervention ($P = 0.001$).

**Market zoning**

The poultry area was completely reconstructed within a four-month period in both markets. The new structures adhered to zoning and unidirectional workflow, as per the WHO guideline (Fig. 1). Of the 29 poultry vendors surveyed after the intervention, 25 (86%) expressed satisfaction with the changes. The remaining vendors indicated that they had fewer buyers because the area where poultry is sold to the public had been isolated. Eleven vendors (38%) mentioned a dip in sales after the interventions, but seven of these vendors (64%) still felt satisfied with the changes.

**Water**

In both markets, existing water wells were closed and city water was piped to the poultry areas. Toilets with handwashing facilities were installed, with easy access for all workers and customers.

**Cleaning**

Market sanitation teams were provided with high-pressure hoses. Easy to clean stainless-steel work surfaces were installed. Cleaning logs were filled daily by the market sanitation teams. Cleaning practices by poultry vendors improved after the intervention (Table 1).

**Utilities**

The poultry areas were provided with electricity, and an anaerobic wastewater treatment system that decreases organic matter was installed in them. Composting bins and rubbish bins with lids were provided and placed in visible locations, and drains were covered and sloped. One vendor who was unhappy with the intervention claimed that drainage was slow. On verification, market managers suggested that this vendor was unhappy with his corner location in the sale area as he felt that it was isolated. No other vendor complained about the drainage.

**Conclusion**

Behavioural change was critical to the adoption of hygienic practices and the implementation of the WHO guideline. Since people tend to resist changes in their work routines,9,10 we achieved success in this respect by applying the participatory approach consisting of regular consultations, educational sessions and by making infrastructural changes that facilitated and provided an incentive for behaviour change.11

Market managers and the municipal market authority assumed important leadership roles in overseeing adoption of the guideline. All stakeholders recognized the need to regulate market sanitation practices and utilities to maintain consumer interest and sustain live bird markets as points of municipal revenue. This resulted in a commitment by the municipal market authority to use funds already allocated by the local government to provide maintenance and uninterrupted supplies of electricity and water, without additional cost to vendors in the two markets. We believe this commitment will ensure the intervention’s sustainability. It may also provide impetus for the municipal market authority to roll out the intervention in Makassar’s other 20 live bird markets over the next 5 years using municipal funds.
An anaerobic wastewater treatment system and composting reduce the risk of contamination with the A(H5N1) virus and are cheap and easy to maintain. Composting also enables sanitation staff to supplement their income by turning poultry waste into a marketable commodity. Such economic incentives increase compliance with interventions, especially in low-resource settings.

The intervention did not result in any increase in kiosk fees, since it was funded through CHF International. Although cost-sharing would have been favourable, initial buy-in from authorities and vendors was limited by the fact that WHO's guideline had never before been applied in Indonesia. Therefore, this experience was treated as a proof-of-concept. Future applications of the guideline in Indonesia should explore other funding models (e.g. public–private co-contributions).

The fact that the two bird markets were chosen because their management teams showed readiness to implement the interventions may have increased the likelihood of success. However, the intervention should yield similar results in other low-resource settings, since the workflow in markets is generic. Furthermore, managers of other live bird markets may be motivated by the lessons learnt from this experience (Box 1).

Since the WHO guideline prioritizes certain interventions more than others, managers of markets with limited resources may choose to implement the interventions having higher priority.

Acknowledgements
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Competing interests: None declared.

Box 1. Summary of main lessons learnt

- The interventions outlined in the World Health Organization’s guide to healthy food markets can be implemented in low-resource settings endemic for avian influenza A(H5N1) virus.
- To implement the interventions and maximize potential for sustainability, various stakeholders had to be involved in the change process, including the government market authority, market managers, sanitation teams and poultry vendors.
- Regular consultation and education sessions, as well as infrastructural changes with financial incentives, facilitated behaviour change and the adoption of hygienic practices by market stakeholders.
Application d’un guide des marchés d’alimentation saine à deux marchés indonésiens afin de réduire la transmission de la «grippe aviaire»

Problème L’Organisation mondiale de la Santé (OMS) a conçu un guide avec 10 mesures de contrôle permettant de réduire la transmission du virus de la grippe aviaire A(H5N1) sur les marchés à faibles ressources. Les aspects pratiques de l’application du guide n’ont jamais été décrits.

Approche Le guide de l’OMS a été appliqué à deux marchés indonésiens dans la ville de Makassar afin de tenter de réduire la transmission du virus A(H5N1). Le guide a été utilisé à l’aide d’une approche participative pour présenter une combinaison de changements infrastructurels et comportementaux.

Environnement local La grippe aviaire est endémique chez les oiseaux à Makassar. Deux des 22 marchés à oiseaux délabrés et pauvres de la ville ont été choisis pour l’étude. Avant l’intervention, aucun des deux marchés ne suivait les 10 mesures de contrôle recommandées par l’OMS, à l’exception du traitement des lots.

Changements significatifs Les connaissances des parties prenantes des marchés sur le virus de la grippe aviaire A(H5N1) se sont amplifiées après les interventions. Les recommandations du guide de l’OMS en matière d’inspection visuelle, de nettoyage et de pratiques de conservation de la volaille, ainsi que les exigences infrastructurels pour le zonage et pour les équipements et l’alimentation en eau ont commencé à être conformes au guide de l’OMS. Des solutions nécessitant peu de maintenance, comme l’installation de systèmes de traitement des eaux usées, ainsi que des incitations économiques comme le compostage ont été bien accueillies et s’adaptaient parfaitement au système à faibles ressources.

Leçons tirées Combiner les changements infrastructurels aux interventions de changements des comportements était essentiel à l’application du guide. Malgré une première résistance au changement comportemental, l’approche participative impliquant des consultations mensuelles et des sessions de formation ont facilité l’adoption d’une hygiène publique et de pratiques de gestion d’une alimentation saine. Les autorités des marchés ont joué un rôle de leader important lors des interventions, ce qui a aidé à modifier les attitudes envers la réglementation et les besoins en maintenance des marchés. Ce changement peut améliorer la durabilité des interventions.

Résumé

Application d’un guide des marchés d’alimentation saine à deux marchés indonésiens afin de réduire la transmission de la «grippe aviaire»

Problème L’Organisation mondiale de la Santé (OMS) a conçu un guide avec 10 mesures de contrôle permettant de réduire la transmission du virus de la grippe aviaire A(H5N1) sur les marchés à faibles ressources. Les aspects pratiques de l’application du guide n’ont jamais été décrits.

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Resumé

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Resumen

Aplicación de la guía para mercados de alimentos saludables en dos mercados indonesios con el fin de reducir la transmisión de la «gripe aviar»

Situación La Organización Mundial de la Salud (OMS) desarrolló una guía con 10 medidas de control para reducir la transmisión del virus de la gripe aviar A (HSN1) en mercados en entornos con escasez de recursos. Nunca se describieron los aspectos prácticos de la aplicación de dicha guía.

Enfoque La guía de la OMS se aplicó en dos mercados indonesios de la ciudad de Makassar con el fin de intentar reducir la transmisión del virus A (HSN1). La guía se hizo más funcional a través un enfoque participativo para introducir una combinación de cambios tanto en las infraestructuras como en los comportamientos.

Marco regional La gripe aviar es endémica en las aves de Makassar. Para este estudio se eligieron dos de los 22 mercados de aves deteriorados y mal gestionados de la ciudad. Antes de la intervención, ninguno de los dos mercados seguía ninguna de las 10 medidas de control recomendadas por la OMS, exceptuando la de procesamiento en lotes.

Cambios importantes Tras la intervención, se observó una mejora considerable de los conocimientos de los participantes en el mercado sobre el virus de la gripe aviar A (HSN1). Empezaron a aplicarse las recomendaciones de la guía de la OMS en cuanto a inspección visual, limpieza y prácticas de explotación avícola. Del mismo modo, los requisitos infraestructurales de distribución en zonas, suministro de agua y servicios públicos empezaron a adherirse a la guía de la OMS. Las soluciones de bajo mantenimiento como la instalación de sistemas de tratamiento de aguas residuales y los incentivos económicos como el del compostaje fueron bien recibidos y adecuados para este entorno con escasez de recursos.

Lecciones aprendidas La combinación de intervenciones para realizar cambios en las infraestructuras y en el comportamiento resultó fundamental en la puesta en práctica de la guía. A pesar de la resistencia inicial a los cambios de comportamiento, el enfoque participativo con consultas mensuales y sesiones educativas facilitó la adopción de unas prácticas seguras de manipulación de alimentos y de saneamiento. Las autoridades competentes asumieron un importante rol de liderazgo durante las intervenciones, lo que ayudó a cambiar actitudes respecto a las necesidades de regulación y de mantenimiento de los mercados. Este cambio podría potenciar la sostenibilidad de las intervenciones.

Referencias

Chapter 10

Discussion and Conclusions
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The H5N1 virus is of international public health concern as it has the potential to trigger a pandemic if it acquires the capacity for efficient transmission between people (1). The current virus has caused the death of millions of birds and economic loss for farmers, and it has a high case fatality rate in humans. Despite these concerns and although many countries have been affected by outbreaks of the virus, gaps remain in the knowledge about the epidemiology of human infection and effective disease control measures. This is especially the case for low-resource countries such as Indonesia which are considered likely sites for pandemic emergence due to limitations in disease control, surveillance and public health management (1-3). Therefore, research is much needed to better inform and operationalize public health action.

This thesis presented six studies conducted in Indonesia that addressed two key aims:

(a) To examine the epidemiology of human AI H5N1 infection, and
(b) To inform disease control measures in LBMs in low resource settings.

Both aims address gaps in the literature and have important policy and future research implications.

The first aim was addressed by the three studies presented in Chapters 4-6. These studies added new information to the body of knowledge on human AI H5N1 infection. Chapter 4 found that an interplay of genetic susceptibility, age and types of exposure impact the risk of infection and clustering of cases. Chapter 5 was the first globally to quantify household attack rates, disease intervals and reproduction numbers for a large number of outbreaks. Chapter 6 was the first globally to report on contaminated fertilizer as a potential source of human AI H5N1 exposure.

The second aim was addressed by four studies presented in Chapters 7-9. These studies filled gaps in knowledge about LBM environmental contamination with the AI H5N1 virus and risk factors for this contamination (Chapter 7). The studies also highlighted the potential to control AI H5N1 viruses through the application of interventions designed specifically for low resource settings (Chapters 8 and 9), where they built on existing WHO guidelines and trialled the recommended interventions. This aspect of
the thesis was novel as the studies were the first globally to highlight the practical potential for AI H5N1 virus control in LBMs low resource settings.

The key conclusions arising from the various studies in this thesis are presented below. These are discussed in the wider context of AI H5N1 epidemiology and disease control, as well as the recommendations for policy and research.

**Human AI H5N1 infection**

Understanding the epidemiological characteristics of human H5N1 infection improves capacity to predict and respond to outbreaks (4). This thesis carefully assessed the epidemiology associated with cluster outbreaks. Clusters represent 36% of all cases detected in Indonesia between June 2005 and July 2009. Clusters are critical to the overall epidemiology of H5N1 since they can be an early warning signal for changes in virus behaviour. This is important to assess the virus’ capacity for transmission between people and its pandemic potential. Overall, the thesis added evidence that the dynamics and risk factors for human AI H5N1 infection vary depending on the setting (1). A number of key conclusions were drawn regarding the risk factors for infection, clustering and transmission dynamics. These are discussed below.

**Genetic susceptibility to AI H5N1 infection**

The role of host genetics in AI H5N1 and other infectious diseases is increasingly being explored (5). The studies reported in Chapters 4 and 5 added evidence that there may be genetic predisposition to infection. Chapter 4 quantified the risk of infection for different genealogical relations to index cases, and found that first degree relatives, especially siblings, were at highest risk of infection. This does not imply that human-to-human transmission occurred in these outbreaks since common point source exposures could not be ruled out. However, it does suggest that there is a host genetic effect on susceptibility to infection from any source.

There is a need to acknowledge the potential for both bias and confounding in these findings. Since the findings relate to surveillance outbreak investigation data, there may
be case ascertainment bias, where cases in one household were more likely to be
detected by the health system than cases from different households. As noted in
previous studies (5, 6), this bias is likely to be occurring to some degree. However, in
Indonesia, both family and other exposed populations such as neighbours, co-workers,
students and healthcare workers were laboratory-tested for H5N1 infection during
outbreak investigations. Despite casting a wide net to detect additional outbreak-
associated cases, no additional cases were identified amongst non-blood relatives in any
of the 139 outbreaks reported. This effect was also observed in other countries (4).
Thus, bias alone does not seem to fully explain familial clustering.

Another potential explanation for these findings is confounding. Since family members
share food, activities and the household, it is feasible that they share the high-risk
exposures for infection. However, this also does not seem to offer a full explanation for
the observed clustering amongst blood-related household members. For example, if
household members share high-risk exposures, why were no clusters of genetically-
unrelated spouses detected? The explanation that household members share high-risk
exposures can be disputed. As presented in Chapter 4, not all cases had high risk
exposures. Further, there is likely to be an ecological fallacy since many individuals
with high risk exposures such as slaughtering infected birds did not develop infection.
Thus, high-risk exposures alone do not seem to offer a full explanation for human
infection with the current AI H5N1 virus.

Future studies including genome-wide linkage studies in affected families may be
informative and further our collective understanding on the role of host genetics in AI
H5N1.

**Transmission dynamics for AI H5N1 outbreaks**

Elucidating outbreak transmission dynamics is essential to enable pandemic risk
assessment and to prompt rapid response to a virus capable of sustained human-to-
human transmission (1, 7). The study reported in Chapter 5 was the first globally to
quantify the transmission dynamics for a large number of AI H5N1 outbreaks (n=80).
The findings demonstrated the value of using detailed household epidemiological data
to determine reproduction numbers, disease intervals and attack rates within households.

In the Indonesian dataset, one outbreak was considered an outlier based on its large size; eight cases compared to four or less cases in all other 138 outbreaks. To show the impact of the outlier on the transmission parameters, results were presented and compared for both (a) the outlier included, and (b) the outlier excluded (8). The findings were also compared with the previous Yang et al study (9) that assessed the transmission parameters for the outlier cluster alone, and helped place those findings in the larger context of all Indonesia outbreaks. The analyses found that most evidence for human to human transmission of the H5N1 virus came from this outlier cluster. This underscored the importance of checking for and handling outliers in the analysis process since they have the potential to skew findings and conclusions made (8). Specifically, the secondary attack rate and human transmission reproduction number found in Chapter 5 were much lower compared to the Yang et al study (9) that assessed these parameters for the outlier cluster.

One limitation of the study reported in Chapter 5 was that the number of secondary cases was small (n=35). This limited the type of models that could be used to explore transmission dynamics and it limited the parameters that could be quantified. Future studies utilizing global or cross-country datasets should be conducted to enable quantification of other parameters. Future research should also explore whether reproduction numbers changed over time to determine whether there have been any increases or decreases in transmission (10). This is necessary due to the virus’ pandemic potential.

**Exposures to AI H5N1 virus**

Based on the analysis of the public health surveillance data in Chapters 4-6, a major conclusion of this thesis was that most human AI H5N1 cases were due to exposure to sick poultry or contaminated environments such as households, neighbourhoods or LBMs. Very few cases were likely due to human-to-human transmission of the virus. However, it is important to note that there is likely to be an under-reporting of cases
both in Indonesia and in other countries, and that the range and types of exposures may differ in reported cases from unreported cases. This case ascertainment bias may potentially limit knowledge of risk factor and epidemiological characteristics of the virus. Thus, prospective cohort studies in outbreak areas and studies that extensively assess potential exposures such as that reported in Chapter 6 are required to address this limitation. Chapter 6 involved extensive laboratory testing of samples collected from various environmental sites and from contacts to explore potential exposures and the magnitude of the outbreak. The study found that contaminated garden fertilizer may be a possible source for human AI virus infection but that the outbreak was limited to two cases.

According to a systematic review published in 2011 on H5N1 exposures for human infection, the relative risk of different exposures remains unknown (11). In that review, exposures were categorized into two groups as summarized in Table 10.1 below. In this thesis, exposures were categorized into three groups that represent hypothesized differences in risk (Table 10.1). An important difference was in the direct exposure group. In the thesis, direct exposure denoted all direct contact and handling of birds as per the systematic review, but the category also included cases that had sick/dead birds in the household. This was done to denote the likely higher risk of exposure in one’s home compared to other settings such as the neighbourhood or LBM.
Table 10.1: Categories of exposures for human AI H5N1 infection

<table>
<thead>
<tr>
<th>Category</th>
<th>Systematic Review, 2011</th>
<th>Thesis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Category 1</td>
<td>Bird (direct contact)</td>
<td>Direct</td>
</tr>
<tr>
<td></td>
<td>• Food preparation (e.g. chopping carcass, defeathering)</td>
<td>• Handled sick/dead birds</td>
</tr>
<tr>
<td></td>
<td>• Bird care (e.g. feeding)</td>
<td>• Handled bird products (e.g. restaurant worker)</td>
</tr>
<tr>
<td></td>
<td>• Bird slaughter (e.g. culling)</td>
<td>• Sick/dead birds in home</td>
</tr>
<tr>
<td>Category 2</td>
<td>Other (no direct contact)</td>
<td>Indirect</td>
</tr>
<tr>
<td></td>
<td>• Environmental contamination (e.g. home, village, LBM)</td>
<td>• Bird deaths in neighbourhood</td>
</tr>
<tr>
<td></td>
<td>• Fomites (e.g. farm vehicle)</td>
<td>• LBM visit</td>
</tr>
<tr>
<td></td>
<td>• Intermediate host (e.g. cat)</td>
<td>• Healthy birds in neighbourhood</td>
</tr>
<tr>
<td>Category 3</td>
<td>-</td>
<td>Other</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Inconclusive but exposed to prior case</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Inconclusive despite investigation</td>
</tr>
</tbody>
</table>

The findings from Chapter 4 supported this approach to exposure categorization, where direct exposure to sources of virus was more likely to result in case clustering. This suggests that the relative risk of exposures classified as direct is higher than exposures classified as indirect. This hypothesis warrants further investigation and can lead to quantification of the relative risks for the different exposure categories. It can also help determine what constitutes meaningful exposure and the denominators for estimating the risk of infection in outbreaks (1).

**Effect of age on AI H5N1 infection**

This thesis found that young people (5-30 years) were at greater risk of infection (Chapters 4 and 5). This supports findings from other countries (4). Reasons for this age-related risk were not explored but may be a result of (a) socio-cultural practices for bird-rearing, (b) heightened immunological susceptibility to infection or (c) hygiene and
sanitary behaviours. These warrant further investigation as they may help in the design of age-relevant risk communication messages.

**Control of AI H5N1 in live bird markets**

Chapters 4-6 highlighted that the majority of human AI H5N1 infection result from zoonotic transmission of the virus. These findings reiterate the importance of controlling the virus in birds and at the human-animal interface to minimize the risk of human infection (12). Since LBMs have been shown to be a source of human infection and can propagate outbreaks in birds, they are an important site for intervention (13-19).

Even though LBMs are commonplace in both high and low resource countries, much of what is known about the control of avian influenza viruses in LBMs comes from high resource countries such as the United States (18, 20-22). Prior to this thesis, published studies on LBMs from low resource countries such as Indonesia, China, Viet Nam and Egypt reported virological surveillance findings and presented case reports for human infections with LBM exposure (19, 23-27). This thesis was the first to explore implementation of disease control measures in LBMs in a low resource setting. Three major conclusions arise from the studies conducted in this thesis.

**Potential for AI H5N1 virus control in LBMs in low resource settings.**

The identification of CCPs (Chapter 8) and the field intervention trial (Chapter 9) added evidence and tools that controls for AI H5N1 virus can be applied in LBMs in low resource settings. Even though the virus cannot be eliminated from the LBM environment as long as outbreaks occur in farms supplying birds (12), the thesis showed that control measures can be tailored and applied in LBMs in Indonesia.

The field intervention trial was the first globally to demonstrate that comprehensive control measures can be practically implemented in LBMs in a low resource setting. Recognizing that there are many ways in which contamination can occur, a holistic approach was applied combining both infrastructure and behaviour change interventions. This holistic approach, operationalised in a participatory manner, was
Discussion and Conclusions

aligned with the WHO guideline applied in the trial as well as the CCPs identified in Chapter 8. As can be seen in Figure 10.1, the interventions were multi-faceted reflecting the connection between the various disciplines in pathogen control. This approach is commonly used to address food safety issues in both high and low resource countries, where hazard control is predicated on various interventions including water quality assurance, improvement in workflow and better management of live animals (28).

Figure 10.1: Interrelationship between various disciplines in control of AI H5N1 virus in LBMs

There were two main limitations to the field intervention trial that impact the conclusions made in this thesis. First, the trial was not conducted using an experimental research design which would have offered more robust evidence. There may have been selection bias since LBMs were selected based on market manager willingness to participate. Thus, these LBMs might have had a greater likelihood of a successful outcome. Further, since the study was limited to two LBMs, the findings are not necessarily representative of all LBMs. Recognizing these potential biases, it was not possible to apply an experimental design as it was outside the financial scope of this PhD, but it is recommended as a future research step.

Second, the trial did not assess the impact of the control measures on AI H5N1 virus contamination in the LBMs. The study reported in Chapter 9 focused solely on the practical application of the interventions to identify lessons learnt for future application.
Thus, future research is needed to assess the direct impact of interventions on virus presence in LBMs.

**Cross-benefits of interventions for AI H5N1 in LBMs.**

Interventions for AI H5N1 virus in LBMs have the potential to control other pathogens. As discussed in Chapter 8, the H5N1 control measures may yield benefit for foodborne pathogens such as *Salmonella* and *Campylobacter*. Previous research published on avian influenza control in LBMs did not consider cross-cutting benefits of the interventions. Since most intervention research was conducted in high resource countries where control for other pathogens may already exist, it is possible that the linkages did not warrant investigation. However, for low resource countries where food safety, regulation capacity and infrastructure are less developed (12), demonstrating the cross-cutting benefits of interventions in LBMs may play an important role in advocating for change. As countries like Indonesia develop, they move towards targeted interventions for specific hazards and gain greater capacity for disease surveillance, risk assessment and regulatory practice (28). Thus, studies that show interventions can carry cross-cutting benefits for public health provide stronger rationale for government investment.

**AI H5N1 surveillance in LBMs**

A recent systematic review on exposure pathways at the human-animal interface found gaps in knowledge on potential routes of AI H5N1 virus transmission from contaminated environments to humans (11). The Chapter 7 findings add to this body of knowledge by identifying environmental sites that can be contaminated in LBMs.

Chapter 7 showed that AI H5N1 virus can be found throughout LBMs especially in the slaughter and sale zones. The sites and risk factors for contamination support findings from previous research (29-31). Widespread contamination in LBMs raises two key issues. First, it emphasizes the need for disease control to minimize the risk to human health for both workers and consumers in LBMs.
Second, the findings should be explored to determine sites most efficient for virus surveillance programs. Previous research conducted in Hong Kong suggests poultry feeding water as a potential surveillance site (31). However, this thesis found sites more commonly contaminated including tables for meat display, weigh scales and carcass processing tables. Further, since publication of the study reported in Chapter 7, the MOA in Indonesia has used the five most commonly contaminated sites in the routine surveillance conducted in LBMs in the wider-Jakarta region (personal communication). The surveillance at these sites continues to yield high rates of positivity of up to 60% of samples tested. Thus, the development of an international standard protocol for avian influenza virus surveillance in LBMs based on such findings would be beneficial for authorities monitoring virus prevalence and for researchers monitoring virus evolution.

**Recommendations for policy**

The findings from the various studies in the thesis are directly relevant to policy and policy implementation. The findings about the epidemiology of human AI H5N1 infection inform future outbreak investigations and warrant updates in Indonesia’s curricula for training rapid response teams for AI H5N1 outbreaks. The findings can also be used to revise the outbreak investigation protocols to include the collection of more detailed data on household contacts and microbiological investigations of possible environmental sources of infection.

For LBMs, the studies reported in this thesis warrant updates to the MOH’s guidelines for improving the health of food markets. The guideline can reflect the various findings for prioritizing LBMs for intervention, types of intervention and the process of change. These should be disseminated to district level officials who have the mandate and direct responsibility for LBMs.

**Recommendations for future research**

Reflecting back at the various studies undertaken in this thesis, I would have liked to explore a number of topics both more broadly and in greater detail. For example, for my
studies on the epidemiology of human AI H5N1 infection, I would have also liked to evaluate the MOH surveillance system for human AI H5N1 infections. The studies in Chapters 4 and 5 showed that information on household contacts of cases was only available for 80 of the total 139 outbreaks. Reasons for the missing data could have been explored and remedied.

However, due to both time and financial limitations, such endeavours were not feasible. Nevertheless, all the studies reported in this thesis were shared with stakeholders at the MOH and MOA. This may help authorities identify and follow up future research priorities pertaining to the human disease epidemiology and control of the AI H5N1 virus in LBMs.

In this chapter, I have highlighted specific areas for future research in the area of AI H5N1 infection in humans and in disease control efforts in LBMs. These specific research needs are summarized below:

1. Role of host genetics in AI H5N1 infection – to better understand the mechanisms for infection and risk groups for the zoonotic infection.
2. Transmission dynamics – exploration of the global dataset to enable quantification of various parameters and comparison between countries.
3. AI H5N1 exposures to infection – to assess the relative risk of various exposures and establish denominators for estimating risk for infection during outbreaks to better support contact tracing and additional case detection efforts.
4. Age – to explore the reasons for age-related risk and determine their impact on disease control programs including risk communication messaging.
5. LBM intervention trials – conduct trials to assess impact of interventions on AI H5N1 virus control in LBMs as well as cross-benefits for other pathogens such as foodborne pathogens associated with bird slaughter.
6. AI H5N1 surveillance in LBMs – further exploration of environmental sites efficient for routine surveillance programs, and the development of a standard protocol for virological surveillance in LBMs.
Outcomes and conclusions

This thesis explored host-pathogen interaction, disease dynamics and distribution, and risk factors for pathogen spread and human infection. The thesis applied a variety of research methods and emphasized operational and implementation research. The thesis added evidence and tools that support the development and implementation of disease control programs for AI H5N1 virus in Indonesia and potentially other virus-endemic countries. Collectively, the findings and conclusions made will help public and veterinary health authorities in addressing the current risk posed by AI H5N1 and in the early detection of a virus with the capacity for human transmission.

References


