Modeling Avian Influenza Immunity Distribution Profile Through the Poultry Production Network in Egypt: A Decision Tool for Zoonotic Influenza Management

M. Peyre 1, M. Choisy 2, H. Sobby 3, W.H. Kilany 3,4, A. Tripodi 5, G. Dauphin 6, M. Saad 7, F. Roger 1, J. Lubroth 8, and Y. Jobre 3
1 Cirad AGIRs, France; 2 IRD MIVEGEC, France & OUCRU, Vietnam; 3 FAO ECTAD, Egypt; 4 RLOP, Cairo, Egypt; 5 FAO Rome, Italy; 6 GOVs, Egypt

ABSTRACT
Vaccination against avian influenza (AI) is currently applied worldwide with inactivated vaccines. Since November 2012, a novel recombinant rHVT-AIS (Hemagglutinin of turkeys as vector) vaccine has been commercialized and applied to day-old chicks (DOC) in some industrial hatcheries in Egypt (Kilany, 2014; Kilany, 2012). The objectives of this study were to assess the cost-effectiveness of AI DOC vaccination in hatcheries and the feasibility of implementing AI DOC vaccination in the different production sectors in Egypt.

A model of the Egyptian poultry production network was combined with a model on flock immunity to simulate the distribution profile of AI immunity according to different vaccination scenarios (including DOC vaccination or not). The model estimated the levels of vaccine coverage for each node of the network and vaccination scenario and positive sero-conversion levels and the duration of sero-protection.

The model predicted that targeting DOC AI vaccination in industrial and large size hatcheries would increase immunity levels in the overall poultry population in Egypt and especially in small commercial poultry farms (from <30% to >60%). This strategy was shown to be more efficient than the current strategy using inactivated vaccines. Improving HPAI control in the commercial poultry sector in Egypt would have a positive impact effect to improve disease control.

This innovative approach to the outcome of AI immunity predictive model supports the design of a more efficient HPAI disease control plan in Egypt. This model may be replicated in other AIV endemic countries that wish to better manage infections or emerging disease threats.

STUDY OBJECTIVES
We combined network analysis of poultry production systems with an immunity model to study the distribution profile of avian influenza immunity in flocks through the commercial poultry production network in Egypt.

The specific objectives were:
1. To model the movement of DOC within the poultry value chain of Egypt
2. To estimate vaccine coverage and sero-conversion levels according to different vaccination scenarios including DOC vaccination.

DATA COLLECTION
Network data were collected using Social Network Analysis method.

Analysis of network connectivity using the cut point analysis was performed to assess the structure of the network and to identify nodes which have a key role in distribution of DOC through the network. Network connectivity and structural equivalence analyses were used to identify the different DOC vaccination hubs to be tested in the study.

RESULTS
The model demonstrated a statistically significant increase of vaccination coverage (>40%–>55%) within the total population in hatchery vaccination was implemented in integrated and large farms (Fig. 2A). By only vaccinating integrated DOC (Se. 2), vaccine coverage in large and medium sized farms would reach 80%.

The model predicted that targeting DOC AI vaccination in industrial and large size hatcheries (Se. 4) would increase immunity levels in the overall poultry population in Egypt and especially in small commercial poultry farms (from <30% to <60%) (Fig. 2B) (Bouma, 2009).

Spatial analysis of AI immunity distribution demonstrated that under Sc. 4 the immune level density (both in terms of coverage and sero-protection) would increase above the threshold levels in the most at risk Governorates (Fig. 3).

DOC vaccination would be cost-effective either as prime-boost strategy with one boost of inactivated vaccine or as single dose vaccination both for long cycle and broiler birds whatever the current inactivated vaccination protocol in place (Table 2).

Table 1. VACCINATION SCENARIOS

<table>
<thead>
<tr>
<th>DOC source</th>
<th>Integrated hatcheries</th>
<th>Non-integrated hatcheries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Integration (sector 1)</td>
<td>Large farms (sector 2)</td>
<td>Medium farms (sector 2)</td>
</tr>
<tr>
<td>Scenario 1</td>
<td>hatchery</td>
<td>hatchery</td>
</tr>
<tr>
<td>Scenario 2</td>
<td>hatchery</td>
<td>hatchery</td>
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<tr>
<td>Scenario 3</td>
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</tr>
<tr>
<td>Scenario 4</td>
<td>hatchery</td>
<td>hatchery</td>
</tr>
</tbody>
</table>

Spatial Analysis: vaccine coverage

Figure 3. Spatial analysis of immunity distribution profiles was performed to account for spatial clustering of the different poultry production types (e.g. GP population is concentrated in 3 Governorates: 86% of the breeders are located in 1 Governorates); 70% of the layers in 5 Governorates; 60% of the broilers and the total poultry population is concentrated in 4 Governorates).

Table 2. Cost-Effectiveness Analysis

<table>
<thead>
<tr>
<th>Bird Type</th>
<th>Vaccine</th>
<th>No. Doses</th>
<th>Protection (%)</th>
<th>Vaccination cost (€/1000)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breeders</td>
<td>Inactivated</td>
<td>3-5</td>
<td>60-95%</td>
<td>84-140</td>
</tr>
<tr>
<td>Broilers</td>
<td>Inactivated</td>
<td>1</td>
<td>10-35%</td>
<td>20</td>
</tr>
<tr>
<td>Broilers</td>
<td>Vector</td>
<td>1</td>
<td>50-80%</td>
<td>31.5</td>
</tr>
</tbody>
</table>

Figure 2A. Evolution of the vaccine coverage rate per poultry production type, according to the different vaccination scenarios. Under baseline scenario (vaccine vaccination only), only the GP breeders and integrated broilers have a sufficient level of coverage (>40%).

Figure 2B. Evolution of the passive sero-conversion rate per poultry production type, according to the different vaccination scenarios. Under baseline strategy (vaccine vaccination only), only the GP breeders have a sufficient level of sero-protection (>40%).

CONCLUSIONS and PERSPECTIVES
This study demonstrated the interest of combining network analysis and immunity modelling to assess the efficacy of AI vaccination scenarios in Egypt.

The model predicted that targeting DOC AI vaccination in integrated and large hatcheries would increase immunity levels in the overall poultry population in Egypt, and especially in small commercial poultry farms, up to sufficient levels to improve HPAI disease control in Egypt.

This strategy was shown to be more efficient than the current strategy using inactivated vaccines. This approach would have only marginal impact on immunity levels in Sector 4 poultry household. However, improving HPAI control in commercial poultry sector in Egypt could have positive spillover effect on the epidemiological situation of the disease in the household sector (Sector 4).

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REFERENCES