Nanotechnology – the future in poultry production, from health to feed monitoring

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By 2050 food demand is expected to increase by 70% and meat production is projected to increase by 50% making agri-food industries and livestock – a key industry for future growth.
World Health Organization – 3 new diseases emerge each year and two of these three originate in livestock and 75% are zoonotic

To meet the current and emerging challenges of farmed animal disease surveillance, diagnostics and control - a paradigm shift is required in identifying how diseases are identified.

Shift is from shipping samples from farms to labs with rapid diagnosis on the farm itself.
Four Revolutions in Agriculture

First Revolution
Mechanization (Industrial Revolution) 18th Century

Second Revolution
Green Revolution (Scientific Advances in Crop and Livestock Breeding) 1943 – 1970s

Third Revolution
Genetic Engineering Since 1973

Fourth Revolution
Precision Agriculture & Livestock Farming
Animal Health – The Missing Link

Trends for Future

- From reactive to proactive, predictive and preventive
- Combination of in-vitro and in-vivo diagnostics
- Completion of diagnostics towards therapy and progress tracking

Improve Biosecurity protocols and enhance animal traceability and welfare

Tools and technologies - Enable Rapid, Real-time and On-farm monitoring of diseases and record keeping

Channel the profits to the producers and farmers
Avian Influenza

High Pathogenic – Not so common

Low Pathogenic – occurs frequently

Currently no pen-side testing available

Diagnosis involves sending swabs from the throat of live animals and fecal content and blood samples from the poultry to the laboratory for RT-PCR analysis

6 hours to 4 days to know the results

Culturing techniques vs RT-PCR techniques
Biosensor for Avian Flu Detection

Bird flu can be detected in minutes

Point of Care Diagnostics

Re-usable devices that use disposable disease specific biochips

Sampling droplet of milk or blood
Add coloured reagent solution
Wait 2 min for incubation & Insert in the reader
Diagnosis Complete

The Technology

<table>
<thead>
<tr>
<th>Sampling</th>
<th>Micro-liters of solution by capillary</th>
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</thead>
<tbody>
<tr>
<td>Analysis on the Go</td>
<td>Easy to use, simple colour solutions for chemical reaction</td>
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<tr>
<td>Processing in the Reader</td>
<td>Cartridge plugs into adapter jack of smartphone</td>
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<tr>
<td>Information Processing</td>
<td>Processor route signal to software application</td>
</tr>
<tr>
<td>Display Output</td>
<td>Diagnosis of disease, Quantification, numbers stored on device with date and time stamp</td>
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Electrochemical Biosensors for Avian Flu Diagnosis

Properties of Individual Nanostructures
- GO as an interface layer chemically bonded with HNPs
- Ag@[Ru(bpy)] 
- exhibit synergistic redox activity
- Chitosan modification show bio-affinity layer to anti-body coupling

Bare Au-PCB
- (i) Plasma treatment
- (ii) GO drop casting
- HNPs functionalization

HNPs-GO Electrode
- Bacterial cell monolayers

Electrochemical Measurement
- Typical current vs potential graph
Blood or Litter or Fecal sample or Oral swabs

60 Seconds

RESULTS

LED-induced Fluorescence
Microfluidic Chip
ITO Heater
Emission Filter
Phototransistor Array

3 - 10 minutes

BioNano Laboratory

ID: 09
Date: 20/12/2015
Time: 15:00:30
H5N1
H9N1

GRYPHSENS
BioNanoLab.ca
Wireless Activity Sensor Network to Predict Avian Influenza in Poultry Farms

Wireless node
- Size: $\phi 19 \times 6$ mm
- Weight: 1.2 g (without battery)
- Continuous operational period: > 2 weeks
- Communication distance: 20 m (without block)

![Image showing wireless sensor node components]

![Image showing wireless sensor node with plastic case and isolators]

![Diagram showing data graphs for body temperature and activity]

Wireless Activity Sensor Network to Predict Avian Influenza in Poultry Farms

(a) and (b) show the 1 hour average activity (blue line) and average of daytime activities (green line)

Examples of activities (blue dots) and body-temperatures (red line) data of chickens infected with CkMZ11. (a) and (b) are the cases that fever is not clearly shown and is clearly seen, respectively.
Hybrid Mobile Environmental and Population Density Management System
Mobile Radio Frequency Remote Control Switch

Image Transmission to Calculate Population Density for Real-time Monitoring from the Mobile Phone Apps
Nanotechnology Switch to Activate Event-Driven System for Chick Health Monitoring

Implementing the MEMS Device on the Wireless Sensor Node
Nanotechnology Switch to Activate Event-Driven System for Chick Health Monitoring

Successful Result of Activity Measurement of a Chicken During One Day

Nogami et al. (2014) DTIP

Photographs of a Fabricated PVDF Film Sensor Node
Results of Activity Measurement of a Chicken Using PVDF Film Device (Wireless Operation)

Nogami et al. (2014) DTIP

Source: Nishihara et al., (2013) IEEE Transactions in Biomedical Engineering

SMART Wearables for Poultry Health Monitoring

Process of Calculation of the Blood Flow in the Circuit Box of MEMS-LDF

Unaffected light $f$ Doppler shifted light $f + \Delta f$

Interfere

Photoelectric conversion

Fourier transform

$\omega P(\omega)$

Proportional to blood flow

$\langle \omega \rangle = \int_0^\infty \omega P(\omega) d\omega$
Blood flow and physical activity data transmitted from the MEMS-LDF and from the acceleration sensor attached to healthy chicken for five days.

Source: Nishihara et al., (2013) IEEE Transactions in Biomedical Engineering
Flock Talk - Broiler Vocalisation for Predicting Disease

Decoding Mass Poultry Vocal Sounds

✓ Hunger,
✓ Feeding,
✓ Post-oviposition,
✓ Fright,
✓ Heat stress,
✓ Healthy sounds,
✓ Lack of water,
✓ Rales Coryza and other Respiratory Distress, Catching & Handling,
✓ Beaking and many more

Screenshot of the Adobe® Audition™ software showing the spectrograms and the frequency analysis window relative to a specific vocalisation. In the main window the time–frequency vocalisation graph is shown, while the inset represents the frequency analysis. Source: Fontana et al., (2015) Computers and Electronics in Agriculture
Improving Public Health

- Decrease in spread of targeted disease,
- Overall reduction in antimicrobial usage
- Improved environmental footprint of animal production
- Improved food safety for consumers

Enhancement of Animal Welfare

- Practical tool for on-farm diagnostic applications
- Reduction of animal fluids (from millilitres to a droplet or microlitre of samples)
- Reduction in the trauma of diagnostic procedures
- Enable Veterinary health professionals to respond rapidly to animals with diseases
Nanotechnology – Implications in Poultry Sector

Silver Nanoparticles in Poultry Production

Direct Approach
- Nano in Vaccines
- Nanomaterials influenced feed

Indirect Approach
- Non Contact Applications
  - Antimicrobial Sprays
  - Chitosan Based Biosensors
    - Biocompatible Nanomaterials