Rapid Diagnostic Approaches for Ensuring Food Security

Training Workshop on Risk Identification and Screening Technologies of Agro-food
Shanghai Academy of Agriculture Science
Shanghai
China
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www.qub.ac.uk/igfs
New Global Research Institute

Queen's University Belfast

Institute for Global Food Security
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- 35 – 40 PIs
- 60 – 80 PDRAs
- 100 – 120 PhDs
- ~15 embedded support staff
- A critical mass of 200 – 250 researchers

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<th>Rank</th>
<th>Institution</th>
<th>Agriculture, Veterinary and Food science</th>
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<td>SRUC (joint submission with Edinburgh)</td>
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Having the credibility to link with recognised centres of excellence and thought leaders wherever they are located.
State of the Art Facilities

Food Analysis (Wet chemistry LAB): Sample preparation for food, feed and environmental sample analysis

ASSET LAB: Highly innovative rapid diagnostics including biosensor (SPR, acoustic wave, microarrays, lateral flow, flow cytometry, electrochemistry) and spectroscopic (IR and RAMAN) technologies

Advanced ASSET LAB: Suites of HPLCs, UPLC coupled to mass spectrometers including QTof, Xevo-TQ, Xevo-TQS, PDA, REIMS, Isotope ratio, ICP-MS for chemical analysis

Mammalian cell culture Facility for in vitro toxicological assessments using high content screening analysis

Pathogen LABs: Category 2 and Category 3 Pathogen labs

Animal facility for in vivo toxicological assessment
The World Food Summit of 1996 defined food security as “when all people at all times have access to sufficient, safe, nutritious food to maintain a healthy and active life”.

The driver for IGFS research is to support national and international efforts to provide sufficient, safe, authentic and nutritious food.
Map of Global Food System
Global Food Safety System

Global Food System is highly complex involving many factors and disciplines
  Politics and governance
  Science
  Environmental
  Technology
  Security
  Economics
  Societal

Supply versus demand
  Faster food production faster testing required for release to market

Impact of contamination at any point in the supply chain can affect all factors

Food contaminant testing is mainly only performed if legislatively required and if methods are available
Food Safety Testing

Under the current EU Food Hygiene legislation Producing safe food is the responsibility of Food Business Operators (FBOs)

The safety of food may be checked throughout the food supply chain at Hazard Analysis and Critical Control Points (HACCPs) such as

- Source of raw materials (pre and post harvest)
- Production site
- Processing sites
- End product testing

These checks may be performed as
- Routine by the larger companies through in-house testing
- Through legislated regulatory monitoring of certain products

The equipment normally employed are sophisticated instruments such as
- Mass spectrometry
- Molecular detection platforms such as PCR
1. Functional Assays
   a. Animal assays
   b. Cell based
   c. Receptor based
   d. Enzyme based
   e. Fluorescence based

   - Level of contaminant measured is relative to the biological effect of the sample
   - May detect new toxic analogues
   - Contaminant identification is not unequivocal
   - Technology transfer of methods is difficult

2. Biochemical Assays
   a. ELISA
   b. Lateral flow devices
   c. Biosensor

   - Binder assay
   - Toxicity may not correlate with cross-reactivity
   - Sample preparation and data analysis is fast
   - Screening tools for HACCP management and rapid response

Methods applied to food analysis
Methods applied to food analysis

3. Spectroscopic methods
   a. Near IR
   b. Mid IR
   c. RAMAN
   d. SERS

   ➢ Fingerprinting techniques
   ➢ Non-destructive methods little to no sample prep
   ➢ Require chemometric models of known samples
   ➢ Sensitivity is questionable

4. Analytical methods
   a. HPLC
   b. LC-MS
   c. GC-MS
   d. ICP-MS

   ➢ Contaminants can only be identified and quantified for available analytical standards
   ➢ Toxicity equivalent factors must be applied
   ➢ Sample clean-up is extensive with oxidation steps being required in cases
   ➢ Data analysis is laborious
   ➢ LC-MS is unequivocal for identification

ANALYTICAL METHODS TRADITIONAL CONFIRMATORY METHODS
Criteria for a Screening Test

Food is produced on an ever-increasing scale
Screening interventions are designed to identify contaminants in a commodity early, thus enabling earlier intervention and management to prevent risk to human health

- Rapid
- Reliable
- Low cost
- Low false positives
- No false negatives
- Safe

2.2. SCREENING METHODS

Only those analytical techniques, for which it can be demonstrated in a documented traceable manner that they are validated and have a false compliant rate of < 5 % (β-error) at the level of interest shall be used for screening purposes in conformity with Directive 96/23/EC. In the case of a suspected non-compliant result, this result shall be confirmed by a confirmatory method.
Screening Tests for Food Analysis

Animal Based

- Toxins in food
- Botulism
- Marine toxins

Cell Based

- Antibiotics residues in milk

Receptor Based

- Dioxins in feed & food

Antibody Based

- Chemical contaminants in foods

Screening tests that require special facilities for use
Antibodies specific for a desired antigen can be conjugated with a fluorescent label, or colour-forming enzyme & are used as a "probe" for detection.

Well known applications of this include lateral flow tests eg pregnancy tests, ELISA and immunohistochemical staining of microscope slides.

The speed, accuracy & simplicity of such tests has led to the development of rapid techniques for the diagnosis of disease, microbes & chemical contaminants in food.
Emerging Issues - Pyrrolizidine Alkaloids

With pre-coated antibody plates
Analysis time = 45mins
Emerging Issues - Pyrrolizidine Alkaloids

Illustration of the detection capability of the multiplex ELISA for jacobine, lycopsamine, heliotrine and senecionine in honey matrix over the three days at 3 levels 0 μg/kg (■), 25 μg/kg (○) and 50 μg/kg (▲).
Day 1: Analysis 1 to 7; Day 2: Analysis 8 to 14; Day 3: Analysis 15 to 21.
Multiplexing technology – Antibiotic Residues

Nitrofurans and chloramphenicol

Advantages
Cost-effective
Simple to use – ELISA
Offers 5 tests in one
Multiplexing technology – Mycotoxins

Fumonisins

T2

Zearalenone
A biosensor is an analytical device incorporating a biological or biologically derived sensing element either intimately associated with or integrated within a physicochemical transducer. The usual aim is to produce a digital electronic signal which is proportional to the concentration of a specific analyte or group of analytes.

Bio to nanosensor
Bio to nanosensors

Why nanosensors?
Smaller and faster
Require less power to run
Greater sensitivity
Better specificity
Cost-effective
Remote use
Simple to use

SPR Biosensor
Invented by Liedberg, Nylander, Lunström (1983)

High Tech
MS analysis

Multi mycotoxin methods
Multi pesticide methods
Untargeted analysis
Fingerprint profiling
Semi-portable multiplexing technology

Antibodies attach to fluorescent nanoparticles to detect chemicals or foodborne pathogens.

Particles can have a different core that identifies a specific assay in a multiplex system.

The label attached to the antibody determines the level of binding in a similar way to the ELISA.
Semi-portable multiplexing technology

Toximet Technology

Good Correlation with LC-MS for aflatoxin

Mycotoxin analysis - Aflatoxins

Evaluation of an alternative spectroscopic approach for aflatoxin analysis: Comparative analysis of food and feed samples with UPLC–MS/MS

Katrina Campbell¹, Ana L. Ferreira Cavalcante², Pamela Galvin-King², Michalina Opatowska-Stachowicka³ (Dr.), Catherine Brabant³ (Dr.), Isabelle Metayer³, Didier Montoul³ (Dr.), Simon A. Haughey³ (Dr.), Christopher T. Elliott³ (Prof.)

Show more
On site or end product testing
Lateral Flow Technology

Lateral flow immunoassays point-of-contact tests are simple to use, provide rapid results with minimum amount of sample preparation.

The benefits of immunochromatographic tests include:

1. User-friendly format.
2. Very short time to get test result.
3. Long-term stability over a wide range of climates.
4. Relatively inexpensive to make.

These features make strip tests ideal for applications, such as:
• home testing,
• rapid point of care testing
• testing in the field for various environmental and agricultural analytes.

In addition, they provide reliable testing that might not otherwise be available to developing countries.
Lateral Flow Technology

Development and Validation of a Lateral Flow Device for the Detection of Nicarbazin Contamination in Poultry Feeds

KATRINA CAMPBELL,1,2 TERENCE FODEY,1 JONATHAN FLINT,3 CHRISTOPHER DANKS,3 MARTIN DANAHER,4 MICHAEL O'KEEFFE,4 D. GLENN KENNEDY,4 AND CHRISTOPHER ELLIOTT1

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J. Agric. Food Chem. 2007, 55, 2497−2503 2487

Development and validation of the first high performance-lateral flow immunoassay (HP-LFIA) for the rapid screening of domoic acid from shellfish extracts

Waqqas Javaid1,*,2,3,4,5 Julia Mansey1,5, Katrina Campbell1,5, Mark Hopper2,5, Karrie Melville2,5, Stephen Holmes2,5 Jennifer Rice2,5, Christopher Elliott1

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On site end product testing - ASP, DSP, PSP
Multiplex approaches for emerging concerns

Tropane Alkaloid
- atropine
- scopolamine
CTRL

Ergot Alkaloid
- ergocristine
- ergotamine
CTRL

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Rapid Multiplex Portable Diagnostics

Aim to produce a lower cost platform offering
- Low cost analysis
- Simplicity in use
- Highly specific single target analysis
- Multiplexing – multiple target analysis
- Bespoke sensitivity
- Robust – high performance
- Field deployable

Suitable for source to product testing

Scientific know how

- Molecular level – DNA / RNA for pathogen and speciation testing
- Protein Level – Allergen testing eg milk, nuts, eggs, seafood
- Residual level – Low molecular weight toxins / antibiotics / contaminants
Nanotechnology in Portable Diagnostics

- Printing receptors on WG chip
- Assembling the WG chip into a cartridge
- Applying sample and labelling reagents
- Obtaining the results
- Measurement
Simplicity in Use

Important to implement simple testing regimes to allow FBOs to perform testing

Offer a simple device requiring minimal sample preparation through either simple fluid application (blood, milk, juice) or dissolution of solid foods in buffering reagents

Depending on the complexity required

Qualitative – YES/NO Answer
Quantitative – Provide a concentration
Antigen Coated Competitive ELISA

**Toxin protein conjugate (TPC)**

- No toxin in sample
  - Antibody binds to TPC
  - Labelled antibody binds to antibody
  - High response

- Toxin in sample
  - Antibody binds to toxin
  - Wash step removes antibody
  - Low response
Marine and fresh water toxin assay

a: Domoic acid

b: Okadaic acid
c: Saxitoxin
d: Cylinderspermopsin
e: Microcystins
Assay for Antibiotics in milk

Multiplex Test for detecting antibiotics at MRL values
Organophosphorus Pesticides

- parathion
- dichlofenthion
- triazophos
- phoxim
- coumaphos
Spectroscopic techniques

“fingerprinting” technique giving unique spectra
Little or no sample preparation
Ideal technique for use with adulteration of food eg fats and oils
Multivariate techniques can be used to extrapolate the desired chemical information

Image → Detector → Processor → Data → Answer

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Summary for Rapid methods

- Speed – higher throughput
- Simplicity in use
- Minimal sample preparation
- Relatively low cost
- Multiplexing
- Portability
- Remote sensing
- Requirements of regulators or industry
- End product testing for release systems
Looking for new approaches to investigate
Known and unknown food safety concerns
Thank You for Listening

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