Chemistry & food security

A context-based learning (CBL) resource

Student version

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Student introduction

'Chemistry and Food Security' is a group case study which will guide you through some of the applications of chemistry in the food industry. The problem will include an introduction to analytical and bioanalytical approaches to detecting food fraud as well as the use of new materials to assist in the detection and extraction of specific chemical species (eg contaminants) from food.

Emails and news stories

Throughout this problem you will be presented with a number of messages in the form of emails. These emails include important information on what you need to do for each part of the problem. Read them carefully and in your groups decide how best to respond.

You will also see a number of news stories relevant to the problem. These stories will provide some additional background information to the problem and will also contain some information that you will need to consider when preparing your solutions to the problem.

Learning outcomes and pre-session preparation

The resource includes a list of relevant intended learning outcomes from each session. This acts as a check list for what you should be able to do after tackling the part of the problem covered in that session. The assessments for each part of the problem is aligned to these lists so please make sure you demonstrate the competencies listed in your assessed work.

The pre-session preparation should guide your research before each session. It is worth remembering that the information presented in the problem is meant to be a starting point, you will need to do further research to fully prepare for each session.

Assessment

This resource makes use of a range of different types of assessment based on the general theme of science communication in the workplace. Communicating your understanding to a range of different audience types in a number of different ways is a very important skill to have. This resource aims to give you the opportunity to develop a range of communication skills and to make key decisions based on your scientific understanding of various concepts combined with an understanding of related political and business factors.

Facilitation

You will be guided through the problem solving process by a facilitator (or tutor). Although your facilitator can provide advice on problem solving strategies, the facilitator will not freely give information about the problem away. Your facilitator will help you by encouraging discussion amongst the group and (if needed) focussing this discussion.

The scenario

This module aims to provide you with a learning experience which familiarises you with a key area of industrial chemical research, food analysis. The problems place you in the role of an undergraduate chemist who is working on an industrial placement for a food analysis laboratory in Northchester, the capital city of the fictional nation of Northland (which you may assume is in the European Union and is very near to the UK). The food legislation of Northland parallels that of the UK – any differences in policy will be highlighted in the problem text. You will work as part of a team of placement students on a number of problems which are based on the science which underpins the quality assurance of food products and will give you some experience of how to communicate findings to a range of audiences.

Welcome email

> Dear Placement Students,
>
> I want to welcome you to your new role as undergraduate placement students at Northland Food Analysis Laboratories Ltd. During your time here you will be given the opportunity to apply a number of different approaches used to detect food fraud and isolate contaminants from food products.
>
> Best wishes,
> Sarah Robinson,
>
> Manager of Biochemical Analysis Laboratory
> Northland Food Analysis Laboratories Ltd

Table 1: Timetable for course

Week	Session	Topics	Assessment	Pre-session prep/feedback
1	0 (Optional – 60 mins)	Nucleic acids and DNA Amino acids Protein structure and function Wikis	Your group will produce a wiki based on the research performed for this part of the problem	Before session: Read the 'Session 0' summary which includes the ILOs and research the Discussion Questions The Introductory email from Dave Ball In session: Plan the research that needs to be done by the group. Create a plan of the wiki structure and get this checked by your facilitator After the session: Submit the final version of the wiki
2	1 (60 – 90 mins)	Background to food adulteration Introduction to protein and DNA analysis Liquid chromatography-mass spectrometry (LC-MS)	Use this session will to plan and prepare for the group presentations you will give in the next session	Before session: Read the 'Session 1' summary which includes the ILOs and research the Discussion Questions Read the Introductory email from Dave Ball In session: Audit your existing group knowledge related to the problem and identify research goals Plan their presentation – what points will you need to make? What additional research needs to be done? Who will do what? Will you practice the presentation? After the session: Complete your research and preparation for the presentation

Week	Session	Topics	Assessment	Pre-session prep/feedback
3	2 (90 – 120 mins)	Background to food adulteration Introduction to protein and DNA analysis Liquid chromatography-mass spectrometry (LC-MS)	This session will be used for the group presentations	Before session: Read the 'Session 2' summary which includes the ILOs. In session: Deliver your group presentation and reflect on your performance. Evaluate the presentations given by the other groups.
4	3 (90 – 120 mins)	Real-time PCR Analysis of results of DNA analysis experiments Data analysis and forming conclusions	Your group will prepare a short report including an analysis of the data provided by Dave Ball	Before session: Read the 'Session 3' summary which includes the ILOs and research the Discussion Questions The newspaper stories and the correspondence from Dave Ball (including the data) Download the template for the report In session: Audit your existing group knowledge related to the problem and identify research goals Analyse the data you have been provided with Before next session: Submit your short report on the data discussed in the session
5	4 (60 mins)	Introduction to the chemical analysis of drinks	Your group will develop an experimental investigation based on established protocols. You	Before session: Read Dave Ball's email about vodka analysis Read the 'Session 4' summary which includes the ILOs and research the Discussion Questions

Week	Session	Topics	Assessment	Pre-session prep/feedback
			should define which variables you will test.	In session:. Describe the approach you intend to use to your facilitator Before next session: Read the feedback on your plan from your facilitator
6	5 (60 mins & 4 – 8 hours of lab time)	The adulteration of coffee products Experimental approaches used to detect food fraud in coffee production	Your group will a prepare laboratory plan which will be checked before lab sessions After the lab sessions, you will submit a full report of their investigation	Before session: Read Dave Ball's email Read the 'Session 5' summary which includes the ILOs and research the Discussion Questions In session:. Describe your chosen approach to your facilitator After the session Submit your lab plans to your facilitator and read through the feedback before the lab session
7	6 (60 – 90 mins)	Introduction to molecularly imprinted polymers Applications of molecularly imprinted polymers	You will prepare a group 'elevator pitch' based on your research on the detection and extraction of contaminants and toxins in food products	Before session: Read Dave Ball's email Read the 'Session 6' summary which includes the ILOs In session: Describe your elevator pitch to your facilitator After the session Reflect on the feedback received on your pitch and finish preparation of your pitch ahead of the next session

Week	Session	Topics	Assessment	Pre-session prep/feedback
8	7 (15 mins per group)	Introduction to molecularly imprinted polymers Applications of molecularly imprinted polymers	This session will be used for the group elevator pitch presentations	Before session: Practice your pitch in front of an audience before the next session Read the 'Session 7' summary which includes the ILOs After the session Reflect on the feedback you receive from your presentation

Unit 1: Investigation of food fraud in meat products

Session 0 (60 minutes)

Pre-session preparation
Students should be prepared to discuss the following topics in this session:

- The structure and function of proteins and nucleic acids.

Intended learning outcomes

SCIENTIFIC

By the end of this part of the problem students should be able to:

- Describe how proteins are formed from amino acids and how the functionality of the constituent amino acids affect the properties of proteins
- Describe the structure and role of nucleic acids

TRANSFERABLE

By the end of this part of the problem students should be able to:

- Reflect on elements of previous learning and apply them to a new context
- Work as part of a small team to develop an understanding of key scientific concepts
- Design wiki pages to communicate group findings

Resources and arrangements
- This session will work best if students have access to computer facilities (eg tablet devices, laptops or PCs) with internet access which will allow them to conduct research as they tackle the problem.

Discussion questions
Nucleic acids and DNA

- What is a helix? What is a double helix?
- What makes up the backbone of DNA?
- How are the two strands of DNA connected together?
- What are base pairs and how are they connected to the rest of the DNA molecule?
- What are the differences between DNA and RNA?
- How long are typical strands of DNA?
- What are the functions of nucleic acids in cells?
- What happens to nucleic acids after they are eaten?
- Why aren't nucleic acids or nucleotides essential in the diet?

Amino acids and protein structure and function

- What happens to protein when we eat it?
- Why do we need protein in the diet?
- What are typical functions of proteins in the body?
- What chemical bonds are present in proteins?
- What are the four levels of protein structure and their significance?
- What is an essential amino acid?
- What is the relationship between amino acids and proteins?
- What factors influence the final structure of a protein?

Wikis

- What is a wiki? Give at least two common examples of wikis you may have used.
- How does a wiki differ from a normal web page?

Deliverable
By the next session you will need to submit the following:

- Your group wiki on amino acids and DNA

Session 1 (60 – 90 minutes)

Pre-session preparation
Students should be prepared to discuss the following topics in this session:

- Food adulteration (both accidental and intentional), qualitative and quantitative testing and analytical and bioanalytical techniques used to detect food adulteration including DNA analysis by Polymerase Chain Reaction (PCR), protein analysis by Enzyme-linked Immunosorbent Assay (ELISA) and trace chemical analysis liquid chromatography-mass spectrometry (LC-MS).

Intended learning outcomes

SCIENTIFIC

By the end of this part of the problem students should be able to:

- Recognise that food adulteration (intentional and accidental) has been an issue throughout time
- Discuss the legal measures that have been put in place to help combat food adulteration
- Describe the scientific basis of the techniques used to detect meat adulteration and the relative merits of these techniques to specific cases
- Evaluate the potential risk to human health from contaminants in adulterated meat supplies

TRANSFERABLE

By the end of this part of the problem students should be able to:

- Work in a team to research a range of analytical methods used in food analysis
- Perform literature searches on an active area of research in order to gain a greater understanding of how fundamental scientific concepts are applied to current research
- Work in groups to produce written summaries of scientific research suitable for a range of different audiences and present the key findings in a short talk

Resources and arrangements

- This session will work best if students have access to computer facilities (eg tablet devices, laptops or PCs) with internet access which will allow them to conduct research as they tackle the problem.

Discussion questions
Background to food adulteration (food fraud)

- What is meant by food adulteration? Why might food be adulterated?
- What legislation exists to protect consumers from food adulteration?
- Safety checks can be carried out throughout the food supply chain. What are the four key components of this supply chain?
- Qualitative tests can be used to identify whether a given contaminant is present or not in a product. Quantitative tests can be used to determine the amount of a contaminant in a sample. Why is qualitative testing still used if the level of detail given in the results is lower than that obtained from quantitative testing?
- As a group, identify the key stakeholders in cases of food-fraud and briefly discuss the interests of each of these stakeholders.

Introduction to DNA and protein analysis

- DNA analysis by polymerase chain reaction (PCR) is one of the most commonly used approaches for detecting food fraud. As a group discuss how PCR works and consider how it may be applied to food fraud cases. Highlight any potential difficulties of using this approach.
- Analysis of cases of potential meat fraud may also make use of protein analysis by Enzyme-linked immunosorbent assay (ELISA). As a group discuss how ELISA works and consider how it may be applied to food fraud cases.
- Compare and contrast the use of ELISA and PCR in these kinds of analyses and consider the relative advantages of the different approaches.
- Briefly discuss any other techniques that may be used in the analysis of meat fraud and consider the relative merits of these approaches.

Liquid chromatography-mass spectrometry (LC-MS)

- LC-MS can be used to help detect (and quantify) phenylbutazone present in samples of meat. Briefly describe the operating principle of LC-MS.
- What is the chemical structure of phenylbutazone?
- What are the primary uses of phenylbutazone?
- What measures are put in place to prevent meat from horses exposed to phenylbutazone from entering the human food chain in the EU?
- What are the risks posed to human health by phenylbutazone?

Deliverable
By the next session each group needs to have prepared the following:

- The group presentation which you will deliver (you should also be prepared to answer questions on your research)
- The one page executive summary of your group research

Session 2 (90 – 120 minutes)

Pre-session preparation
Students should be prepared to discuss the following topics in this session:

- Your chosen approach (from session 1) so that you can participate in a short group presentation on this topic and answer questions from your peers.
- The other analytical approaches discussed in the last session so you can ask your peers questions about their presentations.

Intended learning outcomes

SCIENTIFIC

By the end of this part of the problem students should be able to:

- Describe the scientific background of an analytical approach used to investigate food fraud and evaluate the relative strengths and weaknesses of this approach in the context of the other available approaches.

TRANSFERABLE

By the end of this part of the problem students should be able to:

- Verbally communicate scientific ideas to an audience of peers and to respond to a range of questions on the ideas presented
- Formulate appropriate questions based on a concept presented by a group of peers

Deliverable

- In this session you will deliver your group presentation

Session 3 (90 – 120 minutes)

Pre-session preparation
Students should be prepared to discuss the following topics in this session:

- Food adulteration (both accidental and intentional), qualitative and quantitative testing and analytical and bioanalytical techniques used to detect food adulteration (including DNA analysis by Polymerase Chain Reaction (PCR) and protein analysis by Enzyme-linked Immunosorbent Assay (ELISA)).

Intended learning outcomes

SCIENTIFIC

By the end of this part of the problem students should be able to:

- Consider the applicability of real time PCR in the analysis of meat products and identify the difficulties in using the data generated by this approach to generate a solution to the problem
- Use data generated by other types of analysis to help inform your conclusions
- Analyse a set of data in order to generate conclusions relevant to the context of a specified problem

TRANSFERABLE

By the end of this part of the problem students should be able to:

- Perform literature searches on an active area of research in order to gain a greater understanding of fundamental scientific concepts are applied to current research
- Communicate findings from a scientific study in the form of a written report which addresses the requirements of supervisors and government agencies

Resources and arrangements

- This session will work best if students have access to computer facilities (eg tablet devices, laptops or PCs) with internet access which will allow them to conduct research as they tackle the problem.

Discussion questions
Real-time PCR

- What are the key differences between real-time PCR and the standard PCR approach? What are the advantages of real-time PCR in food analysis?
- How is the concentration of target DNA quantified by real-time PCR?

- PCR analysis frequently makes use of mitochondrial DNA. What is mitochondrial DNA and why it is frequently used as the basis of this type of analysis?
- How is DNA extracted from meat samples for real time PCR analysis?
- Why is quantification of a PCR result difficult when mitochondrial DNA is used?
- What is meant by the term Limit of Detection (LOD)?

Analysis of results

- How can the real time PCR data be converted into quantities of equine DNA? How reliable will the quantification be?
- What is the significance of the higher than normal detected levels of trace metal ions present in the last two samples?

Deliverable

- A report on the results of this analysis using the template provided by Dave Ball.

Unit 2: Investigating adulteration of drinks

Session 4 (60 minutes)

Pre-session preparation
Students should be prepared to discuss the following topics in this session:

- The contamination of alcoholic drinks, spectroscopic and chromatographic techniques.

Intended learning outcomes

SCIENTIFIC

By the end of this part of the problem students should be able to:

- Evaluate a range of experimental approaches used to analyse alcoholic drinks and choose a suitable approach for a given problem.

TRANSFERABLE

By the end of this part of the problem students should be able to:

- Write a brief experimental plan which outlines how to run an analytical investigation and provides details on the anticipated results.
- Plan a simple experimental investigation based on established protocols

Resources and arrangements

- This session will work best if students have access to computer facilities (eg tablet devices, laptops or PCs) with internet access which will allow them to conduct research as they tackle the problem.

Discussion questions

- Why is the adulteration of alcoholic spirits a problem? What types of adulterants are commonly used?
- Who are the major stakeholders in cases of adulteration of alcoholic spirits?
- Research and discuss the experimental approaches commonly used to detect adulteration of spirits. Discuss the difficulties associated with some of these methods.
- What simple experimental approaches could be used to identify the presence of methanol in vodka?

Deliverable
Before the next session you need to prepare:

- A short plan (maximum one page) that outlines an experimental approach that could be used to identify adulterated samples of vodka. This should include a step-by-step set of instructions on how to run the experiment, a list of reagents, an equipment list and some comments on the expected results

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Session 5 + lab sessions (60 minutes planning session and 8 – 12 hours laboratory investigation)

Pre-session preparation
Students should be prepared to discuss the following topics in this session:

- Adulteration of coffee and the development of an experimental plan to analyse samples of coffee and distinguish between Arabica and Robusta beans.

Intended learning outcomes

SCIENTIFIC

By the end of this part of the problem students should be able to:

- Consider the methods commonly used to distinguish between Arabica and Robusta coffee beans
- Develop an experimental plan to create a simple method to distinguish between Arabica and Robusta coffee beans.
- Perform a laboratory investigation to measure the quantities of caffeine extracted from ground Arabica and Robusta coffee beans and to analyse the products using a range of different analytical approaches.

TRANSFERABLE

By the end of this part of the problem students should be able to:

- Work in a team to develop an experimental approach based on an open ended problem
- Research a range of experimental approaches and decide which approaches provide potential solutions to a given problem.
- Consider the information required by third-parties from this investigation (eg supervisors, other analysts, government agencies, etc.)
- Closely coordinate a laboratory investigation with a group of collaborators.

Resources and arrangements

- The planning session will work best if students have access to computer facilities (eg tablet devices, laptops or PCs) with internet access which will allow them to conduct research as they tackle the problem.
- The laboratory session will have to be run in a suitable chemistry laboratory. Students will need to prepare the appropriate COSHH/risk assessment statements for their investigations.

Discussion questions

- Identify the potential stakeholders in this problem (i.e. coffee adulteration) and briefly describe the nature of their interests.
- Describe some of the approaches that have been developed to detect this type of adulteration.
- There has been some success in DNA analysis of coffee beans. Briefly explain why DNA analysis is of limited applicability to roasted coffee beans.

Deliverable
Before conducting the laboratory investigation you will need to submit the following:

- A plan for your laboratory investigation which must be approved by your tutor/facilitator.

After conducting this investigation, you will need to submit the following:

- A report outlining your laboratory investigation including a summary of your key findings (use the template you have been given).

Unit 3: Detection and extraction of toxins in food products

Session 6 (60 – 90 minutes)

Pre-session preparation
Students should be prepared to discuss the following topics in this session:

- The use of Molecularly Imprinted Polymers (MIPs) in the extraction and detection of specific chemical components (such as contaminants) in food products, the nature of different types of food contamination, potential applications of substances extracted from food products and the viability/profitability of adopting a new approach/technology into an existing business.

Intended learning outcomes

SCIENTIFIC

By the end of this part of the problem students should be able to:

- Describe what a Molecularly Imprinted Polymer (MIP) is and give some details of how a MIP is synthesised
- Recognise the importance of molecular imprinting approaches in creating MIPs and be aware of approaches used to overcome the challenges of synthesising a suitable MIP for a given target
- Describe the uses of Molecularly Imprinted Polymers (MIPs) in the detection, analysis and extraction of molecules (including contaminants) from food products
- Discuss a range of food contamination issues faced by the food industry and suggest potential solutions to these problems
- Compare the use of MIPs in food contamination analysis with other approaches

TRANSFERABLE

By the end of this part of the problem students should be able to:

- Give a concise group oral presentation on a new scientific approach to a real-world problem which effectively presents the science in the context of the requirements of a profit making business
- Research a range of new scientific approaches by reviewing the peer reviewed literature
- Recognise how the requirements of a for-profit business will influence the viability of various research approaches in an industrial setting

Resources and arrangements

- This session will work best if students have access to computer facilities (eg tablet devices, laptops or PCs) with internet access which will allow them to conduct research as they tackle the problem.

Discussion questions
Background

- Briefly discuss the meaning of the term Molecularly Imprinted Polymer (MIP).
- Before the development of Molecularly Imprinted Polymers (MIPs), what methods were used to detect and/or extract contaminants from food? What are the disadvantages of these approaches?
- The use of biometric sensor approaches have shown much promise for the extraction and analysis of contaminants. Briefly explain what is meant by the term biometric in this context.
- Briefly explain why MIPs appear to be very good potential sensors for detection of food contamination.
- Briefly describe the approaches used to create a MIP designed for a specific target.
- What approaches are used to design a monomer that will be complementary to the specified target?

Applications of MIPs

- What are hepatotoxins? Why might they be present in drinking water?
- Why is the molecule methidathion sometimes detected in olive oil?
- There are a number of existing successful methods for detection of organophosphorus pesticides in olive oils (such as GC-MS). What are the associated disadvantages with existing approaches?
- What advantages does MIP based extraction of methidathion have over existing approaches?
- Why are researchers interested in extracting kukoamine A from potato peels?
- Evaluate the advantages of each of the three approaches you have researched and decide which approach would best suit the aims of the business.

Deliverable
By the next session you need to:

- Research one of the specified approaches and prepare a 5 minute pitch on that approach. Be prepared to answer questions on your chosen approach. Remember to pitch your approach at a suitable level for the audience (i.e. the senior management of a for-profit scientific analysis company).

Session 7 (c.a. 15 minutes per group)

Pre-session preparation
Students should be prepared to discuss the following topics in this session:

- Your chosen extraction (researched since session 6) so that you deliver an elevator pitch to a team of managers.
- The scientific, ethical and business impact of your decision

Intended learning outcomes

SCIENTIFIC

By the end of this part of the problem students should be able to:

- Describe the scientific background of an extraction technique based on the use of Molecularly Imprinted Polymers (MIPs).
- Compare a range of different extraction techniques and rationalise a decision for choosing a given approach.

TRANSFERABLE

By the end of this part of the problem students should be able to:

- Verbally communicate scientific ideas to an audience of senior scientists and to respond to a range of questions on the ideas presented

Deliverable

- In this session you will deliver your 'elevator pitch'.

Appendix 1: Pre-session preparation sheets

Pre-session 0 preparation

Email

Dear Placement Students,

It's a pleasure to welcome you to Northland Food Analysis Laboratories. I will be supervising all of our placement students this year. During this placement I want you to work in close cooperation with our permanent staff and the other placement students. You will be involved in the investigation of cases of potential food fraud. Due to client confidentiality, I cannot tell you any more about the project at this stage.

In order to prepare you for this project, I would like you to review what you know about proteins and DNA by creating a small wiki on the staff intranet which provides a scientific background on these important concepts. You can decide on the structure and number of pages in the wiki but you should ensure that the wiki provides enough background to teach someone in year one of a chemistry degree (who hasn't done A-level biology) about proteins and DNA.

Best wishes,
Dave Ball,

Senior analyst,
Northland Food Analysis Laboratories Ltd.

Pre-session 1 preparation

Food fraud fear in Northland stores
Northland Guardian

Northland retailers have been left shocked by news that one of the main producers and distributors of processed meat products in Western Europe has been supplying beef products which may contain significant amounts of horse meat. The contaminated products were detected in products that MP Limited has produced and distributed for sale in an international chain of supermarkets which has branches in France, Belgium and Spain. The same company is one of the major suppliers of meat products to restaurants and supermarkets throughout Northland. The Northland government has demanded an investigation into a range of products to ascertain the extent of any possible fraudulent products which have reached Northland supermarkets. The news has caused concern amongst Northland's consumers and religious leaders…

Email

Dear Placement Students,

I'm sorry to cut short your induction to the company but we urgently need your help. The Northland government has awarded us a contract to investigate the recent food fraud case which has been in the news. As we are currently very busy undertaking the investigation, we need you to bring yourselves up to speed by researching the key components of food fraud investigations. Our investigation is based on three main forms of analysis:

The detection (and potential quantification) of equine (horse) DNA in meat products intended for human consumption

The detection of equine (horse) protein in meat products intended for human consumption

The detection of phenylbutazone (a veterinary drug not suitable for use in humans) in meat products intended for human consumption by liquid chromatography – mass spectrometry (LC-MS)

In the groups you have been assigned to, we would like you to choose one of these approaches to research (you may want to base this decision on your university studies) and to prepare a ten minute group presentation which you will deliver to all of the other placement students working at the company. You also need to prepare a one (A4) page executive summary on your chosen techniques that placement students can refer to. Please include some labelled diagrams and remember to describe these processes in the context of a food fraud investigation. Please be prepared to ask the other groups questions about their presentations as you will need to apply what you learn about all of these techniques very soon.

I have included some details of some useful articles that will help you start your research below.

Best wishes,
Dave Ball,

Senior analyst,
Northland Food Analysis Laboratories Ltd.

Suggested resources

- Ballin, N. Z., Vogensen, F. K., Karlsson, A. H., "Species Determination – Can we detect and quantify meat adulteration?", Meat Science, 2009, 83, 165–174.
- ABC News (Video), "Food Fraud? Watchdog Group Raises Concerns", 2013, http://bit.ly/24UCGoL (accessed 22/04/2015)
- BBC News (Video), "Horsemeat Scandal: Inside Lab Testing Products", 2013, http://bbc.in/1Rb6c5H (accessed 09/04/2015).
- Birch, H., "The Food Detectives", Chemistry World, 2009, 6, 10, 58–62.
- Edith, I. N., Ochubiojo, E. M., "Food Quality Control: History, Present and Future", chapter in "Scientific Health and Social Aspects of the Food Industry" edited by Caldez, B., 2012, Intech
- Hsieh, Y-H. P. and Ofori, J. A., "Detection of Horse Meat Contamination in Raw and Heat-Processed Meat Products", J. Agric. Food Chem., 2014, 62, 12536–12544.
- Perks, B., "Fighting Food Fraud with Science", Chemistry World, 2014, 48–52
- Walker, M.J, Burns, M., Burns, D., T. "Horse Meat in Beef Products-Species Substitution 2013", Journal of the Association of Public Analysts, 2013, 41, 67–106.

Pre-session 3 preparation

Adulterated meat could be harmful to your health warns minister
Northland Guardian

Northland minister for health Jeff Gayle has warned that meat products contaminated with horse meat may contain a veterinary drug known as phenylbutazone (or 'bute'). The drug is routinely used as a pain killer in horses but is excluded from the human food chain in Northland. Phenylbutazone is known to cause a number of disorders in humans including potentially fatal liver damage. Mr Gayle stated that there is no evidence to indicate that phenylbutazone has entered the human food chain but ongoing tests will attempt to ascertain whether the drug has been present in meat products sold in Northland.

Contaminated meat may contain lethal chemicals
Northchester Gazette

There are fears that a recent outbreak of illness in Northchester may be related to the possible contamination of meat products that have been sold throughout Northland. It is possible that meat products which may contain alarming amounts of horse DNA may also be contaminated by a range of drugs which are not suitable for entry into the human food chain. An anonymous source from the medical profession told the Gazette that there have been a number of severe cases of illness in Northland which may be consistent with symptoms of poisoning by the illegal drug phenylbutazone (known to vets as 'bute').

Email

Dear Placement Students,

I'm afraid the food fraud situation has escalated as you will have probably already seen in the news. There is now concern that contaminated meat products may have introduced drugs that are not fit for human consumption into the human food chain. I have attached some data from our ongoing analysis. I have asked everyone to take a look at this data and to write an analysis of the results as I believe everyone will bring something different to this analysis.

Please use the attached template to help you write a short report on the results. Essentially we need to know the following:

What concentrations of contaminant (in ng/µl) are present in these samples according to the results? What are the w/w percentages of equine DNA relative to total DNA content?

What are the limitations of these results? What conclusions can we draw in terms of what we report back to the government of Northland?

> Can we use these results to state whether any of these products constitute cases of gross adulteration?
>
> Is there a realistic risk to the population of Northland from phenylbutazone contamination of consumer food products?
>
> Northland's food legislation defines gross adulteration as being characterised by 1% (weight of contaminant/weight of total meat in product) or more of the meat content of the food product being horse meat.
>
> Best wishes,
> Dave Ball
>
> Senior analyst
> Northland Food Analysis Laboratories Ltd

Data

Table 2: DNA analysis data

Sample	Total DNA concentration (ng / μl)	Phenylbutazone (LC-MS)	Cq value	Comments
NCFL01	74.12	Negative	N/A	SmartSaver frozen lasagne (Sample 1)
NCFL02	72.22	Negative	13.007	SmartSaver frozen lasagne (Sample 2)
NCFB01	65.12	Negative	N/A	Fast Burger quarter pounder (Sample 1)
NCFB02	64.08	Negative	N/A	Fast Burger quarter pounder (Sample 2)
NCBS01	68.51	Negative	N/A	SmartSaver beef sausage (Sample 2)
NCBS02	70.03	Negative	N/A	SmartSaver beef sausage (Sample 2)
NCAB01*	71.12	Negative	13.759	Northchester army barracks canned meat reserve (Sample 1)
NCAB02*	73.25	Positive	13.858	Northchester army barracks canned meat reserve (sample 2)

The real-time PCR instrument used in this experiment has a limit of detection (LOD) of 0.1%.

The analysis was run for mitochondrial horse DNA.

Results were obtained by adding a fluorescent probe to the DNA mix. The cycle number (Cq) that a threshold value of fluorescence was detected has been recorded.

*Note – samples NCAB01 and NCAB02 also showed higher than normal levels of some trace metal species including tin and lead.

Real-time PCR calibration data

Table 3: PCR calibration data

Cq value	Equine DNA concentration (ng / µl)
10	0.0664
15	1.0476
20	37.4111
25	900.6582

Pre-session 4 preparation

Email

Dear Placement Students,

We have been contacted by Northchester University who would like us to investigate a case of suspected drink fraud. In the last seven days a group of students have suffered prolonged spells of severe illness. The students have experienced symptoms including severe headaches, blurred vision, dizzy spells and vomiting over a two day period since they became ill. The University's internal investigation appears to trace this back to the Northland Union of Students' 'Double Vision' event (a night where double measures of spirits are sold at the price of single measures) which took place last Tuesday.

Interviews with the affected students suggest that the possible cause was vodka sold at the 'Double Vision' night. We need to investigate samples of vodka collected from the university to establish the nature of the problem. This should be a relatively simple investigation so I thought it would be good experience for you to plan a suitable experiment to measure this which will be run in parallel with our normal investigation. Please design an experimental investigation which you would be able to run using the standard equipment in our laboratory (eg HPLC, UV-Visible absorption spectrometer, infrared spectrometer, etc.) and write a one page plan which outlines how to run the investigation, what equipment and reagents are needed and what the anticipated results would be.

Best wishes,
Dave Ball

Senior analyst
Northland Food Analysis Laboratories Ltd.

Suggested resources

- Barbosa-García, O., Ramos-Ortíz, G., Maldonado, J. L., Pichardo-Molina, J. L., Meneses-Nava, M. A., Landgrave, J. E. A., Cervantes-Martínez. "UV–vis absorption spectroscopy and multivariate analysis as a method to discriminate tequila", J., Spectrochim. Acta A, 2007, 66, 129.
- BBC News (Video), "Czechs Ban Spirits After Bootleg Alcohol Poisoning", 2012, http://bbc.in/1Rb6c5H (Accessed 09/04/2015)
- MacKenzie, W. M.; Aylott, R. I. "Analytical strategies to confirm Scotch whisky authenticity. Part II: Mobile brand authentication", Analyst. 2004,129 (7) :607–12

Email

Dear Placement Students,

The detection of coffee adulteration is a significant challenge. Adulteration of coffee beans affects farmers, processors and suppliers worldwide. Coffee production is dominated by two species of beans: "Arabica" and "Robusta". Arabica is associated with better quality products and is therefore sold at a higher price. "Green", unroasted coffee may be adulterated by producers with the addition of husks and Robusta beans.

We use a range of approaches to detect substitution of Arabica beans by Robusta beans including NMR and PCR but we would like to develop a relatively simple technique which can be used by our partner laboratories around the world which may not have access to the same level of analytical equipment that we have.

I would like you to plan a laboratory investigation into methods that could be used to distinguish between Arabica and Robusta and then to conduct the investigation. You might want to start by attempting a simple caffeine extraction using organic solvents and then determining the quantity of caffeine extracted per unit mass of bean.

I'm not sure what form this investigation will take but I have included a few experimental parameters that you may wish to investigate:

What are the best conditions for the extraction: which solvent works best? Are acidic or basic conditions better?

What approaches can be used to measure caffeine levels after the extraction? Can UV-Vis be used? (maybe you could measure the absorption of some standards to produce a calibration plot?).

Can sublimation be used to help establish caffeine levels?

We need to investigate whether these approaches are reproducible.

You should coordinate your efforts with the other groups in order to broaden the scope of your investigation. The end product should be a group report on your investigation which includes a summary of your key findings and a recommendation of whether the investigated approach should be adopted.

Best wishes,
Dave Ball

Senior analyst
Northland Food Analysis Laboratories Ltd.

Suggested resources

- Domingues, D. S., Pauli, E. D., de Abreu, J. E., Massura, F.W., Cristiano, V., Santos. M. J., Nixdorf, S. L., "Detection of roasted and ground coffee adulteration by HPLC and by amperometric and by post-column derivatization UV-Vis detection", Food Chem. 2014 Mar 1;146:353–62.
- Royal Society of Chemistry (Video), "High Performance Liquid Chromatography HPLC", 2008, http://bit.ly/225pyOS (accessed 22/04/2015)

Pre-session 6 preparation

Email

Dear Placement Students,

The detection and extraction of chemical compounds (such as toxins and other contaminants) in food products is a hugely significant area of research for the food industry. Food imported from outside the EU can be particularly prone to toxic mould contamination resulting in the presence of unwanted toxins such as aflatoxins and mycotoxins harmful to humans and animals due to changes in climatic conditions and lack of adequate quality control with improper harvesting and storage practices. The use of insecticides and pesticides (methidathion in olive oil) is also of particular concern. Hence there is a constant need for new methods of extraction and detection of toxins and contaminants in food.

We are investigating the feasibility of adopting one new approach for extracting components from food products that we can offer to our customers. We would like you to research the following new methods and then, as a group, decide which approach is likely to be most beneficial to the company (in terms of viability, potential impact on food science/health and potential profits) and to prepare a five minute 'elevator' pitch on your chosen proposal. This pitch will be given to a panel of senior managers and will be followed by 5–10 minutes of questions.

I have given you details of some relevant journal articles that will help your research.

The areas that we are primarily interested in are:

The use of Molecularly Imprinted Polymers (MIPs) to extract and quantify hepatotoxins from samples of drinking water

Weller, M. G., "Immunoassays and Biosensors for the Detection of Cyanobacterial Toxins in Water", Sensors, 2013, 13, 15085–15112.

The use of MIPs in the extraction of kukoamine A from waste potato peels

Piletska, E. V., Burns, R., Terry, L. A., Piletsky, S. A., "Application of a molecularly imprinted polymer for the extraction of kukoamine A from potato peels", Journal of Agricultural and Food Chemistry, 2012, 60 (1), 95–99.

The use of MIPs in the extraction and analysis of pollutants in olive oil (eg methidathion)

Bakas, I., Oujji, N. B., Moczko, E., Istamboulie, G., Piletsky, S., Piletska, E., Ait-Ichou, I., Ait-Addi, E., Noguer, T., Rouillon, R., "Molecular imprinting solid phase extraction for selective detection of methidathion in olive oil", Analytica Chimica Acta, 2012, 734, 99–105.

General papers:

Cheong, W.J.; Yang, S.H.; Ali, F., "Molecular imprinted polymers for separation science: A review of reviews". J. Sep. Sci. 2013, 36, 609–628.

Karim, K., Breton, B., Rouillon, R., Piletska, E. V., Guerreiro, A., Chianella, I., Piletsky, S. A., "How to find effective functional monomers for effective molecularly imprinted polymers?", Advanced Drug Delivery Reviews, 2005, 57 (12), 1795–1808.

Best wishes,
Dave Ball

Senior analyst
Northland Food Analysis Laboratories Ltd

Appendix 2: Report templates

Investigation of methods to detect adulteration of coffee

Northland Food Analysis Laboratories Ltd
Northchester
Northland

Date (Month, Year)

Referencing and acknowledgements

Executive summary

Maximum one page, Arial, 12pt text

Report

Maximum 4 pages, Arial 12 point text, divided into the following sections.

Background

Methods

This section should include a brief discussion justifying why each method was used and how data was generated from these approaches.

Analysis of results

This section may include charts and tables. You may also discuss limitations of results here.

Conclusions

- Bullet point list.

Recommendations for actions based on results

Recommendations for future work

Analysis of meat products for presence of equine DNA

Northland Food Analysis Laboratories Ltd
Northchester
Northland

Date (Month, Year)

Referencing and acknowledgements

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