FOREWORD

The Nineteenth Annual Research Review describes the ongoing research programme in the School of Biosystems Engineering at University College Dublin from over 78 researchers (10 academic staff, 2 technicians, 11 postdoctoral researchers and 55 postgraduates). The research programme covers three focal areas: Food and Process Engineering; Bioresource Systems; and Bioenvironmental Engineering. Each area is divided into sub-areas as outlined in the Table of Contents which also includes the name of the research scholar (in bold); the research supervisor(s); the title of the research; the nature of the research programme; and the research sponsors. It also includes the noting of four awards for presentational excellence at the Nineteenth Annual Biosystems Engineering Research Seminar held in University College Dublin on Wednesday 12th March 2014.

The four Appendices in the Review provide:

- a listing of research projects in progress which were not included in the Review;
- profiles of Postdoctoral Research Scholars;
- a photographic record of postgraduate students; and
- a photographic record of the full-time staff who assisted in project supervision and administration.

The Editors gratefully acknowledge the dedicated work of the individual research scholars, their research supervisors and the financial support of research sponsors. Suggestions as to how future editions might be improved in presentation, style or content would be greatly appreciated. A copy of this book is available to download from the UCD Research Repository at: http://researchrepository.ucd.ie

ENDA CUMMINS and TOM CURRAN 20th May 2014

* MEngSc1, MSc1, MAgrSc1 = Research Masters (Mode 1)
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Classification of *Listeria innocua* and *Escherichia coli* Using Near-Infrared Spectroscopy and Chemometrics

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Abstract

Classification of *Escherichia coli* and *Listeria innocua* using transreflectance near infrared (NIR) spectroscopy together with chemometric methods was investigated in this study. NIR spectra were recorded from a series of dilutions of bacterial suspensions in phosphate buffered saline. Calibration models were developed by using partial least squares discriminant analysis (PLS-DA). Besides the full wavelength calibration models, competitive adaptive reweighted sampling (CARS) was employed for the first time to select some important wavelengths so that simplified models could be achieved for classification of different bacterial species. All the samples were correctly classified using only three wavelengths (1884, 1886 and 1890 nm) during classification of *E. coli* and *L. Innocua* samples at species level. This study showed that NIRS could be a potential tool for bacteria classification.

Introduction

To understand microbial ecology and enhance food safety surveillance, detection and classification of bacteria at species or strain levels are essential. Many bacteria are food sanitation indicators or some can be directly responsible for foodborne illnesses outbreaks (Giraffa and Neviani 2001). For instance, the situation of faecal contamination of food or water is usually indicated by the number of *Escherichia coli* (Kornacki and Johnson 2001) while *Listeria monocytogenes* as one of the main pathogenic strains is widely found in many foods. Traditional approaches for bacterial detection, identification and numeration are usually time-consuming and laborious and they are unsuitable for fast and routine assays due to their great complexity and high costs. Therefore, the development of simple, rapid and accurate methods is desired.

Near infrared spectroscopy (NIRS) is powerful a non-destructive method that has been widely applied in many fields. Regarding microbial applications, NIRS has been successfully used for bacterial classification in isolated systems as well as bacterial load determination. For example, Rodriguez-Saona et al. (2001) applied NIR together with principal component analysis (PCA) for classification of bacteria at species/strain level where *E. coli* spp., *Bacillus* spp., *Pseudomonas* sp. and *Listeria* sp. were included. However, PCA is a descriptive and not a modelling method. Alexandrakis et al. (2008) collected NIR spectra of bacterial suspensions in maximum recovery diluents without applying sample filtration and cell drying. Classification models were developed based on NIR transreflectance spectra and chemometric methods including principal component analysis, partial least squares discriminant analysis (PLS-DA) and soft independent modelling of class analogy (SIMCA). In this study, four different bacterial species (*E. coli* spp., *Bacillus* spp., *Pseudomonas* sp. and *Listeria* sp.) were successfully identified and three *Pseudomonas* strains were well classified in the wavelength range of 700 to 900 nm. In another study, by applying discriminant factor analysis on PCA-compressed spectral data, Siripatrawan et al. (2010) succeeded in classifying two *E. coli* strains. The objective of this study was to establish both full-wavelength and simplified calibration models to discriminate *Escherichia. coli* from *Listeria. innocua* samples.
Materials and methods

Bacterial strains

*Listeria innocua* strains (*n* = 4) were collected from Teagasc Food Research Centre (Ashtown, Dublin). Two of the *Listeria innocua* strains were in-house collections where *L. innocua* 5030266 was originally from tomato salad and *L. innocua* 165T48A from raw minced beef. They were both identified in Ashtown. The remaining two strains, i.e., *L. innocua* NCTC11288 and *L. innocua* DSM20649 were isolated from brains of cows and were purchased reference strains. All three *E. coli* strains were obtained from Food Safety Laboratory, University College Dublin. *E. coli* BL21, *E. coli* DH5α and *E. coli* K12 were all from reference collections.

Ceramic beads in glycerol (Technical Service Consultants, UK) were used to store bacterial strains (-80 °C) prior to use. A single bead of each strain was streaked individually onto tryptone soya agar (TSA; Oxoid UK) and cultured at 37 °C for 22 ± 2 h. One colony of each strain was removed from the plate and transferred into a tube containing 25 ml tryptone soya broth (TSB; Oxoid, UK) and incubated at 37 °C for 18 ± 2 h. Tubes were centrifuged at 2,683 xg for 10 min at 4 °C and the supernatant discarded. The obtained pellet was then re-suspended in 25 ml sterile phosphate buffered saline (PBS, Oxoid, UK) and centrifugation repeated. The resulting pellet was finally re-suspended in 10 ml PBS leading to a solution with bacterial concentration of approximately 9.0 log10 CFU ml⁻¹. Serial dilutions in 9 ml PBS of each culture were then carried out. Aliquots from appropriate PBS tubes were plated onto TSA to estimate the cell numbers in the original solution and all of the dilution tubes. The tubes were then stored at 4 °C prior to spectroscopic analysis.

Spectral acquisition

A scanning monochromator (NIRsystems 6500 spectrometer; Foss NIRSystems, Silver Spring, MD, USA) in transflectance mode over the 400 – 2498 nm wavelength range at 2 nm intervals was utilized for spectral acquisition. Before spectral collection, bacterial samples were removed from the refrigerator and set for 30 min to reach room temperature. A camlock cell was utilized to enable good control of sample thickness (0.1 mm). During each scanning, 0.1 ml of bacterial suspension was placed to the camlock cell aseptically and the gold-coated backing plate was carefully inserted to avoid bubble creation. Each sample was scanned in duplicate and the second scan was obtained by rotating the camlock ca. 180°; the average of the two scans was calculated and utilized for further data processing. All the samples were scanned in random order in terms of species, concentration and scanning date so that any possible systematic effects from temperature variations could be eliminated or alleviated. WinISI II software (v1.04a; Infrasoft International, Port Matilda, MD) was used to control the whole procedure of spectral acquisition.

Model calibration

A total of 196 spectra were obtained and the entire data set were partitioned into calibration and prediction sets manually. Specifically, one sample was randomly-selected out of the three independent spectra collected for each bacterial strain and it was included in the prediction set with the remaining two in the calibration set. Consequently, 133 and 63 samples were used for calibration and prediction respectively. Partial least squares discriminant analysis (PLS-DA) is a linear classification method and it was applied in this study. To evaluate model performance, the overall correct classification rate (OCCR) was calculated. To establish simplified calibration models, competitive adaptive reweighted sampling (CARS) was utilized. It is a new variable selection method based on partial least squares regression and the principle of Darwin’s Theory of Evolution (Li et al. 2009).
Results and discussion

NIR spectra

Figure 1 shows the spectra of all bacterial suspensions for the two bacterial species. As can be seen, little difference is observed in spectral responses although different bacterial species and strains with large cell concentration range (0 – 9 log<sub>10</sub> CFU ml<sup>-1</sup>) were involved. The spectra are dominated by two large absorption peaks at around 1450 and 1960 nm and these two bands can be attributed to second and first overtone respectively of the O-H stretching mode of water (Alexandrakis et al. 2008, Büning-Pfaue 2003). This is reasonable because the samples were composed of 0.9% saline solution and bacterial cells. Another peak between 400 and 500 nm may have arisen from the colour of the gold-coated backing plate used in the camlock cell. Two sensors were used in the NIR system and this resulted in the discontinuity in the spectra around 1100 nm but of no significance.

![Figure 1. The original spectral profiles of all samples](image)

Full wavelength classification models

Using the spectra in the visible-SWNIR and NIR ranges, PLS-DA models were established. For the visible-SWNIR range, four latent variables were utilized and the model yielded an overall correct classification rate of 97.74% and 96.83% for calibration and prediction sample sets respectively. By further checking out model performance, three samples were found to be mis-classified in the calibration set, where two *E. coli* samples was determined as *L. innocua* and one *L. innocua* sample identified as *E. coli*. Efforts were devoted to find out whether there would be connections between wrong classifications with certain levels of bacterial cell concentration in the analysed suspension. It was expected that samples with low bacterial concentration would be the most potential source for wrong classifications simply because there were less chemical information about bacteria in these samples. However, by checking mis-classifications during calibration and prediction performance, no such clear connection was found. Consequently, it appeared that classification of the two specific bacterial species was not directly related to bacterial concentration. When it comes to the NIR range, perfect classification (OCCR = 100%) was achieved for both calibration and prediction and the optimal NIR model utilized eight latent variables.

Simplified models

Though very good results were obtained using full wavelength models either in the visible-SWNIR or NIR wavelength range, it can be advantageous to use only a few variables for accurate, simplified and potentially more robust classifications. By applying CARS, two wavelengths (454 and 456 nm) were selected in the visible range and three wavelengths (1884, 1886 and 1890 nm) in the NIR range.
PLSDA models were then developed using these 5 wavelengths and OCCRs for calibration and prediction of 98.50% and 96.83% as well as 100% and 100% for the visible and NIR regions respectively were achieved. It is encouraging to find that by using such simple models (only two or three wavelengths involved for modelling), equally good (for the NIR model) or even better (for the visible model) classification performance was eventually obtained. Such simplification of models enables the use of only one simple sensor to cover either of the narrow spectral ranges to achieve excellent classification performance rather than using hundreds of wavelengths and therefore more complex and slow sensors. As a result of using the simplified models, both accuracy and speed were assured.

Conclusions

Near-infrared spectroscopy was successfully employed to classify E. coli and L. innocua samples in isolated systems. Competitive adaptive reweighted sampling is a useful tool for selecting important variables and such selection could lead to even better model performance and the simple model structure is favoured for development of simple detecting systems for classification of E. coli and L. innocua.

Acknowledgements

This study was supported by UCD-CSC Scholarship Scheme awarded to Mr. Yao-Ze Feng.

References


HYPERSPECTRAL IMAGING FOR INSPECTING ENTEROBACTERIACEAE COUNTS IN SALMON FILLETS DURING COLD STORAGE

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Abstract

Enterobacteriaceae counts (EBC) is often used as a useful indicator for food safety evaluation. This work was conducted to investigate the potential of near-infrared (NIR) hyperspectral imaging (900–1700 nm) for rapid and non-destructive determination of EBC distribution in farmed salmon fillets during cold storage. Hyperspectral images were acquired at different storage times for all salmon samples and their spectral features were extracted. Partial least-squares regression (PLSR) algorithm was used to correlate the spectral data with the reference EBC values measured standard pour plate method. Important wavelengths were then selected based on the correlation coefficients (RC) of PLSR model, leading to seven individual wavelengths of 921, 931, 1145, 1252, 1366, 1628 and 1658 nm. With the seven wavelengths, an optimised model named RC-PLSR was established, resulting in a correlation coefficient of prediction ($R_p$) of 0.940 and root mean square error of prediction (RMSEP) of 0.507. The overall results indicated that NIR hyperspectral imaging technique combined with PLSR analysis could be used for inspecting EBC of salmon fillets during the period of cold storage.

Introduction

Enterobacteriaceae as a large group of spoilage microbes mainly contains Escherichia coli, Shigella, Salmonella and Yersinia. They can transform carbohydrate (sugar) into acids and gas during the process of fermentation (Feng et al., 2012). The output of the transformation could cause serious health problems to consumers. In food products, Enterobacteriaceae counts (EBC) is often used as a useful indicator for food safety evaluation (Tosukhowong et al., 2011). Routine techniques for detecting EBC mainly include standard pour plate method (Botsoglou et al., 2010), enzyme-linked immunosorbent assay (ELISA) (Dwivedi & Jaykus, 2011), polymerase chain reaction (PCR) assay (Liu et al., 2013) and PCR-ELISA method (Kuo et al., 2010). Although these techniques are useful and effective, they are still time-consuming, labor-intensive, tedious, destructive, inefficient and thus not suitable for a rapid and real-time inspection.

Hyperspectral imaging emerged as an advanced non-destructive technique provides detailed spectral and spatial information simultaneously, which can be analysed for characterization of target samples in a more objective and reliable way (He et al., 2013a). In recent years, many applications on the use of hyperspectral imaging for quality control and inspection have been reported in various agri-food products, such as red meat (Wu et al., 2012), fruits and vegetables (Rajkumar et al., 2012) and cereals (Shahin et al., 2014). As for fish products, some chemical and physical attributes such as tenderness (He et al., 2014a), colour (Wu et al., 2012), moisture (He et al., 2013b), drip loss and pH (He et al., 2014b) have been investigated using hyperspectral imaging. However, few reports have been found on the hyperspectral imaging for EBC evaluation of salmon fillets. Therefore, the main objective of this study was to explore the potential of hyperspectral imaging for rapid determination of EBC in farmed salmon fillets during cold storage. The spatial EBC distribution of different storage times was finally visualised.

Materials and Methods

Fillets preparation and sampling
Thirty fresh farmed salmon fillets were supplied by local supermarkets in Dublin, Ireland. The fillets were vacuum-packed and then transported to laboratory of (FRCFT), UCD, Ireland.
Sampling was conducted by cutting each fillet into cubes with size of 3 cm × 3 cm × 1 cm. The 94 samples were then re-packed using cling film, labelled and stored at 4 °C.

**Hyperspectral imaging system**

The hyperspectral imaging system used for image acquisition can be found in the study of He et al. (2013b). Due to the low signal-to-noise ratio within the ranges of 897–900 nm and 1700–1753 nm, only the wavelength range of 900–1700 nm was used for further data analysis.

**Images acquisition and calibration**

At each test day, about 15 samples were scanned by the hyperspectral imaging system. Hyperspectral images of samples were acquired at different storage times. Image calibration was then performed by using the following formula:

$$C_i = \frac{R_i - D_i}{W_i - D_i}$$  \hspace{1cm} (1)

where $C$ is calibrated image, $R$ is raw image, $W$ is white reference image, $D$ is dark reference image and $i$ is the pixel index, i.e. $i=1, 2, 3 \ldots, n$ and $n$ is the total number of pixels.

**EBC measurement**

After image acquisition and calibration, the samples were immediately used to measure their reference EBC values by using the Violet Red Bile Glucose (VRBG) agar. The VRGB agar was then incubated at 37 °C and enumerated after 24 h. The final EBC colonies were recorded as colony-forming units (CFU) and the results are listed in Table 1.

| Table 1. Statistical results of EBC measured by the VRGB agar colony-counting method |
|-----------------------------------------|---------|---------|------|---------|
| Number of samples | Maximum | Minimum | Range | Mean ± SD |
| Calibration set | 71 | 6.940 | 2.477 | 4.463 | 5.148 ± 1.530 |
| Prediction set | 23 | 6.892 | 2.672 | 4.220 | 5.127 ± 1.519 |

SD: Standard deviation

**Data analysis and EBC distribution**

Average spectra of each cubed sample were extracted from the same position within its corresponding hyperspectral image using the Region of Interests Function (ROI) of ENVI v4.6 software. Partial least-squares regression (PLSR) was used to establish the quantitative relationship between the extracted spectral data and the reference EBC values measured by the above method. Then, a colour map was created to exhibit the EBC distribution.

**Results and discussion**

**Calibration based on full wavelength**

Based on the full spectral range of 900-1700 nm, a PLSR model was developed and its ability of EBC prediction is shown in Table 2. As shown in Table 2, the PLSR exhibited a good performance with high regression coefficients ($R$) and low root mean square error (RMSE). Moreover, the absolute difference of RMSE in calibration (RMSEC) and prediction (RMSEP) was 0.096 which indicated a good robustness of the PLSR model.

| Table 2. Results of EBC calibration and prediction of samples by using full wavelengths and selected important wavelengths, respectively |
|-------------------------------------------------|---------|---------|---------|---------|---------|---------|---------|
| Model | Number of wavelength | Number of latent factors | Calibration set | Prediction set | |
|       |                    |                      | $R_C$ | RMSEC | $R_P$ | RMSEP | RPD |
| PLSR  | 239                | 9                     | 0.959 | 0.433 | 0.935 | 0.529 | 2.813 |
| RC-PLSR | 7              | 5                     | 0.950 | 0.472 | 0.940 | 0.507 | 2.967 |
Calibration based on important wavelengths

Using the regression coefficients (RC) of PLSR model, seven individual wavelengths at 921, 931, 1145, 1252, 1366, 1628 and 1658 nm were selected as important wavelengths (Figure 1). Based on the seven important wavelengths, an optimised model named RC-PLSR was built and its result is shown in Table 2. Although the number of wavelengths was reduced from 239 to 7, the performance of the RC-PLSR model was similar to the PLSR model. Moreover, the $|\text{RMSEC} - \text{RMSEP}|$ value in RC-PLSR model was 0.035, 64% less than that in PLSR model, which indicated that the RC-PLSR model had better robustness than the PLSR model. Besides, the RPD value of 2.967 in RC-PLSR model was close to that (2.813) of PLSR model, which showed the similar abilities of the two models in predicting EBC of salmon samples. In general, the use of RC for important wavelength selection was helpful to improve the prediction accuracy and robustness of PLSR model.

![Figure 1. Important wavelengths selected by regression coefficients (RC) of PLSR model](image)

EBC distribution

EBC visualisation was realized by transferring RC-PLSR model to each pixel of hyperspectral images, resulting in colour maps for understanding the spatial variation of EBC values from sample to sample and even spot to spot in the same sample. Figure 2 shows some examples of EBC distribution with different EBC values. In the maps, a linear colour scale on the right side of samples was assigned from blue to red to indicate the EBC values in the salmon samples from low to high. The colour scale was used to exhibit the spoilage process of salmon samples, with blue, green and red colour represented the low, middle and high spoilage degree of EBC, respectively.

![Figure 2. EBC distribution map of some tested samples with different EBC value.](image)

Conclusions

Hyperspectral imaging in the spectral range of 900-1700 nm was proven suitable for EBC prediction in salmon fillets. Out of 239 wavelengths, only seven important wavelengths were selected by using regression coefficients of PLSR model. The developed PLSR model and RC-PLSR model based on full range spectra and spectra at important wavelengths, respectively, had similar good performance in predicting EBC. The whole results showed that NIR hyperspectral imaging has a potential and could be used as a rapid and non-destructive technique for EBC evaluation in salmon fillets.
Acknowledgements

The authors would like to acknowledge the financial support provided by the Irish Research Council for Science, Engineering and Technology under the Government of Ireland Postdoctoral Fellowship scheme.

References


IDENTIFICATION OF MINCED LAMB MEAT ADULTERATION USING NIR HYPERSPECTRAL IMAGING

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Abstract
The potential of NIR hyperspectral imaging for identification and prediction of heart/liver adulteration content (2-56%) in minced lamb meat was evaluated within the spectral range from 950 to 1600 nm. Relative reflectance of mean spectra decreased with increasing adulteration level at 950-1040 and 1200-1300 nm domains. Regression coefficients of PLS was employed for optimal waveband selection. The coefficient of determination for prediction ($R^2_p$) was found to be 0.940 and 0.939 with root mean square error (RMSEP) of 3.959% and 3.973% for heat and liver adulteration, respectively, illustrating the feasibility of NIR hyperspectral imaging for rapid and non-destructive detection of meat adulteration.

Introduction
Meat products are of great importance in our daily meals by providing protein for helping body movement and metabolism. However, adulterations of meat products mixed with other cheaper substances (such as animal offal, flour and gelatin) were frequently reported (Wu et al. 2013, Morsy and Sun 2013) and thus pose a great concern to consumers. During the last few decades, great endeavour has been made to find some solutions for the detection of meat adulteration, including enzyme-linked immunosorbent assay (ELISA) (Macedo-Silva et al. 2000), polymerase chain reaction (PCR) (Karabasanavar et al. 2011) and nanobioprobe techniques (Ali et al. 2012). Though specific identification performance for adulterated meat was achieved by the above-mentioned approaches, disadvantages of high-cost in biochemical consumptions and destructive detecting procedure hinders the large-scale application in industry. Getting benefits from the fast development of sensing techniques, spectroscopic methods for non-destructive detection have been proposed and found extensive applications in quality inspection and safety control of agro-food products. For the detection of adulterated meat, spectroscopic analysis in UV, visible, near-infrared and mid-infrared region has been employed (Zhao et al. 2014, Alamprese et al. 2013). To compensate the deficiency of single-spot measurement of spectrometer, imaging technique is incorporated to generate a novel system called hyperspectral imaging. The combination of sufficient special information and abundant spectral signature from one targeted sample impels hyperspectral imaging to be a useful tool in food studies. Previous investigations of hyperspectral imaging on meat products mainly concentrated on detecting the physical properties (Barbin et al. 2013b), chemical compositions (Barbin et al. 2013a), and contaminations (Wu and Sun 2013). The objective of this paper is to utilize NIR hyperspectral imaging coupling with PLS analysis for predicting the adulteration percentage of minced lamb meat.

Materials and Methods
Sample preparation
The minced lamb meat (containing about 28% of fat) was purchased from a local supermarket, lamb heart and liver were supplied by a local grocery. Firstly, lamb heart and liver were cut into small pieces and then fully minced. Secondly, the minced lamb was weighed and evenly mixed with minced heart or liver at a certain proportion to guarantee that the adulteration percentage ranged from 2% to 56% with around 2% increment. Thirdly, the mixture was placed on a round metal lid for image acquisition. A total number of 18 samples for each adulteration experiment were prepared in the study.
**Imaging acquisition**

The line-scanned hyperspectral imaging system in the reflectance mode was used in the experiment, and the main components are shown in Fig. 1. The imaging unit was composed of a 12-bit CCD camera, a high performance spectrograph (ImSpector N17E, Specim, Spectral Imaging Ltd., Oulu, Finland) along with a standard C-mount optical lens (Xeva 992, Xenics Infrared Solution, Leuven, Belgium). Samples were placed on the translation stage with two 500-W halogen lamps for illumination, and hyperspectral images from both the front and back side of each sample were acquired for analysis. As the sample was moving in the scanning direction, spectral data of each line was recorded and transformed to computer. The whole acquisition procedure was operated by the computer coupled with corresponding software.

![Figure 1. Components of a line-scan hyperspectral imaging system](image)

**Image processing and data analysis**

After image acquisition, reflectance calibration was firstly performed on the obtained hyperspectral images of adulterated minced lamb using white/dark reference, as described by Kamruzzaman et al. (2013). Three different rectangular regions of interest (ROIs) (each ROI contains approximate 600 pixels) were extracted from the front or back images and the corresponding spectra were averaged to obtain a mean spectrum. Thus, there are 108 mean spectra in total for heart/liver adulteration experiment, among them 72 samples involving the whole adulteration percentage range were selected as the calibration set and the rest 36 samples were used as prediction set. Partial least squared (PLS) regression was applied on the full-wavelength range (950-1600 nm) for calibration, leave-one-out cross-validation (LOOCV) and prediction. To reduce data redundancy and speed up analysis, the most pertinent five wavebands were selected based on the regression coefficient of PLS model. Finally, PLS models on the selected wavebands were developed to evaluate the prediction performance of adulterated minced lamb meat using coefficient of determination ($R^2$) and root mean square error (RMSE), where $R^2_c$, $R^2_{cv}$, $R^2_p$, and RMSEC, RMSECV, RMSEP represent the coefficient of determination and the root mean square error for calibration model, cross-validation model and prediction model, respectively.

**Results and Discussion**

**Spectral features of liver and heart adulteration**

The mean relative reflectance spectra representing different liver or heart adulteration levels in the minced lamb meat are shown in Fig. 2. Significant differences in relative reflectance were found in the spectral range of 950-1040 nm and 1200-1300 nm for both liver and heart adulteration. Meanwhile, the reflectance values at these two spectral regions decreased with increasing adulteration percentage, indicating a close relationship between the adulteration content and the reflectance spectra. The strong
peaks at around 1085 and 1265 nm could be associated with the 2nd overtone stretching of N-H due to protein (Phil Williams 1987).

Figure 2. The mean NIR spectra of different adulteration percentage extracted from ROI in hyperspectral images: (a) liver adulteration, (b) heart adulteration.

**Wavelength selection**
With a spectral resolution of 3.34 nm in the hyperspectral imaging system used in this work, 196 continuous wavebands in the region of 950-1600 nm were obtained, offering adequate information for analysis on one hand while descending the analytical capability on the other hand. Therefore, there is a need to select some feature wavelengths to simplify the modelling process, which is particularly important in practical applications. PLS is a simple yet powerful linear-regression means and widely used in multivariate data analysis. Based on the regression coefficient of PLS at a full-wavelength range, the pertinent wavebands carrying the most discriminate information for adulteration were ultimately selected. For heart adulteration the selected wavebands were 951, 1011, 1141, 1265 and 1602 nm, whereas for liver adulteration the selected wavebands located at 951, 1078, 1151, 1415 and 1592 nm in the study.

**Model performance comparison**
Table 1 displays the results of calibration models, cross-validation models and the prediction performance for heart and liver adulteration. In the full wavelength range, minced lamb meat with different adulteration level could be identified with the accuracy of $R^2_p \geq 0.940$ and RMSEP $< 3.959\%$. For heart adulteration, the same prediction performance was achieved by using five selected wavebands, demonstrating that the selected wavebands were capable to represent the full wavebands for the evaluation of heart adulteration. Compared to liver adulteration, though the value of $R^2_p$ in selected-wavelength range was smaller than that in full-wavelength range, redundant spectral data was reduced to a small number of wavebands at a similar prediction level.

<table>
<thead>
<tr>
<th>Adulterant</th>
<th>Model based on</th>
<th>$R^2_c$</th>
<th>RMSEC (%)</th>
<th>$R^2_{cv}$</th>
<th>RMSECV (%)</th>
<th>$R^2_p$</th>
<th>RMSEP (%)</th>
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</thead>
<tbody>
<tr>
<td>Heart</td>
<td>Full-wavelength</td>
<td>0.942</td>
<td>3.912</td>
<td>0.915</td>
<td>4.778</td>
<td>0.940</td>
<td>3.959</td>
</tr>
<tr>
<td>Heart</td>
<td>Selected-wavelength</td>
<td>0.942</td>
<td>3.916</td>
<td>0.934</td>
<td>4.236</td>
<td>0.940</td>
<td>3.959</td>
</tr>
<tr>
<td>Liver</td>
<td>Full-wavelength</td>
<td>0.942</td>
<td>4.005</td>
<td>0.928</td>
<td>4.516</td>
<td>0.943</td>
<td>3.857</td>
</tr>
<tr>
<td>Liver</td>
<td>Selected-wavelength</td>
<td>0.954</td>
<td>3.556</td>
<td>0.946</td>
<td>3.884</td>
<td>0.939</td>
<td>3.973</td>
</tr>
</tbody>
</table>
Conclusions
The current study showed that NIR hyperspectral imaging coupled with PLS analysis was suitable for predicting heart/liver adulteration in minced lamb meat. According to the regression coefficients derived in PLS model, five feature wavebands were selected to reduce data redundancy without reducing prediction performance.

Acknowledgements
The authors would like to acknowledge the University College Dublin (UCD) and Chinese Scholarship Council (CSC) for supporting the PhD study. Fund from Irish Government Department of Agriculture, Fisheries and Food (DAFF) for this work is also greatly appreciated.

References
AN ASSESSMENT OF RT-qPCR ACCURACY IN MONITORING INFECTION NOROVIRUS IN OYSTER FARMS

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Abstract

Wastewater contamination causes Norovirus (NoV) to accumulate in commercial shellfish, which is monitored using RT-qPCR. RT-qPCR does not distinguish infectious copies from non-infectious, so it is not ideal for risk assessment. Additionally, sites being sampled are assumed to be spatially homogenous, but this has not been shown. To test homogeneity, and the standard sample size of ten, a single site was intensively sampled during the 2013-2014 winter period. Analysis of results is ongoing. Also during the winter season, in three additional sites, the ratio of infectious to non-infectious virus copies detected with RT-qPCR was modelled using an FRNA bacteriophage surrogate. Analysis of results is ongoing.

Introduction

The accumulation of norovirus (NoV) in commercial oysters is a significant food safety risk. NoV infections in humans are the most common cause of acute gastroenteritis in Europe and the United States, and can result in severe vomiting and diarrhoea (Hall et al., 2013). Infectious copies are shed in faeces and are dispersed to the environment in sewage effluent (Wang and Deng, 2012). Oysters feed through constant filtration of seawater, so although wastewater NoV may be diluted in the environment, it will concentrate in the oyster flesh (Lees, 2000). This accumulation can persist for several weeks. The majority of commercial oysters are consumed raw, or lightly cooked, which means even low exposure to pathogens is a risk to the consumer. In the past, monitoring wastewater contamination with bacterial indicator organisms has virtually eliminated gastroenteritis caused by bacterial sources (Rippey, 1994). Viruses persist and accumulate in much greater degrees than bacteria, and strongly resist purification, so bacterial indicators are poor predictors of viral contamination (DePaola et al., 2010; Flannery et al., 2009; Lees, 2000).

In Europe, a PCR based method for monitoring shellfish NoV concentrations has been established, and is moving forward to legislation (Anonymous, 2013). However, the extent to which this method can reflect the actual risk of consumer infection is, in crucial ways, unclear. RT-qPCR does not readily distinguish between infectious and non-infectious copies of a virus, which can lead to overestimation of NoV concentrations (Hamza et al., 2011; Pecson et al., 2011). Different disinfection treatments of wastewater before release will alter the ratio of active copies to those deactivated (Nuanualsuwan et al., 2002; Rodriguez et al., 2009). Additionally, the persistence of virus accumulation in oyster flesh could, over time, lead to significant variances in the pattern of virus distribution across a large geographical site. The standard sampling methodology relies on an assumption of spatial homogeneity, which has not yet been proven valid in this case.

This project aims to investigate and improve the ability of a NoV monitoring method to accurately reflect the real risks of consumer illness. The method will be tested in two key respects: the validity of its sampling assumptions, and the reliability of RT-qPCR in assessing infectious NoV concentrations.

The objective of this study is to investigate the ability of a NoV RT-qPCR monitoring method to accurately predict the true risk of consumer illness.

Materials and Methods

To draw valid conclusions from a sample of a population, it must be unbiased and large enough to account for population variance. Practicalities of time and cost are also a factor. In the current method, a site manager delivers to a laboratory a sample of ten oysters. The contaminated flesh is dissected
and homogenised, and NoV per gram is measured with RT-qPCR. This result is used to characterise the risk level of the entire site (Anonymous, 2013). Here, a case study will be run on a single site, which will be sampled intensively, at both a peak and a low during the NoV season. Results will be used to test assumptions of homogeneity and assess the current sample size.

There are currently no methods available to assess NoV infectivity, short of human inoculation. F-specific RNA (FRNA) bacteriophages are also found in wastewater, and have been proposed as a surrogate for NoV, owing to similarities in structure and behaviour (Dore et al., 2000; Havelaar et al., 1993). Infectious numbers can be detected with a traditional plaque assay, after which specific species can be genotyped. This project compares the ratio of infectious to non-infectious copies of the human-associated FRNA bacteriophage species GA, and examines how much RT-qPCR overestimates concentrations. NoV concentrations will also be tested.

**Sampling methodology test site**
To test the predictive power of the current sampling procedure, a single shellfish production site was selected to serve as a case study. The farm selected is based in Carlingford Lough. Several years of RT-qPCR monitoring show a consistent and predictable pattern of NoV results across winter periods.

**Sampling for individual oyster testing**
In order to assess whether the mean from a sample of size ten is sufficient, NoV concentrations from a population of individual oysters were quantified. On site, oysters are grown in mesh bags of 100 – 200, arranged on submerged trestles. One bag was assumed to represent a single sampling point. 30 oysters were taken from a single bag and tested individually. This was carried out twice, once at the peak of the season, and later when levels were near the limit of detection.

**Site-wide sampling**
Once sample means within an individual bag of oysters can be shown to be relatively homogenous, the entire site can be tested. A 4x3 grid was established across the site (approximately 400m x 300m), and one bag from each of ten divisions was sampled. Ten oysters were taken from each, in triplicate.

**Sampling for viral infectivity**
To assess the ability of RT-qPCR to detect infectious viruses in oysters, samples were taken from five sites which were continually exposed to wastewater effluent over a winter season. Sites selected represented three increasing levels of treatment for wastewater: primary, secondary, and tertiary (UV). From November 2013 to April 2014, samples of at least 24 oysters were taken fortnightly from each site. Each sample was tested for E. coli, infectious GA, and GA and NoV determined by RT-qPCR.

**Oyster processing for virus RNA extraction**
On arrival, oysters were washed and then shucked using sterilised equipment. For E. coli and FRNA analysis, the whole flesh and liquor of ten oysters was homogenised 1:3 with a sterile peptone broth. For RT-qPCR analysis, a sterile scalpel was first used to separate the hepatopancreas (HP). After this, for samples of single oysters, this HP was chopped finely, weighed, and mixed with an equivalent volume of Proteinase K (ProK) solution (100µg/ml). For samples of ten oysters, HPs were combined and homogenised during chopping and 2g of this homogenate was used for the extraction, with procedure as in Flannery et al. (2013).

**RNA extraction and one-step RT-qPCR quantification for NoV in oysters**
100µl of eluted RNA was extracted from 500µl of the HP supernatant, using a NucliSENS miniMAG extraction kit and following the protocol provided. The RNA was either quantified using RT-qPCR either immediately after extraction, or stored at -80°C until use. An Applied Biosystems AB7500 PCR machine was used for the RT-qPCR analysis, according to a previously modified version of a method from the European Committee for standardisation (Anonymous, 2013).
FRNA bacteriophage plaque assay
FRNA bacteriophage enumeration is done according to a ISO agar overlay method (Anonymous, 1995). This is a double agar overlay assay, using a modified strain of Salmonella as host.

Genotyping GA specific plaques with in-situ probe hybridisation
For each sample with plaques resulting from the FRNA bacteriophage plaque assay, plaques were transferred to a Hybond N+ nylon transfer membrane, using either an applicator stick or direct contact with the plate. Genotyping was carried out as described in (Flannery et al., 2013).

E. coli testing of oysters
Serial tenfold dilutions of homogenised oyster flesh were used to assess E. coli concentrations, using a five-tube three-dilution most probable number method (Anonymous, 2005). This was done for any sample where NoV was measured in ten oysters.

Statistical analysis
All calculations and graphs were created in R v3.0.2. For individual oyster samples, margins of error for a sample size of ten were calculated using the standard formula for sample size of the mean. NoV means were bootstrapped to simulate comparisons between different sampling sizes (30000 trials, with replacement). The variance across the site was assessed initially with ANOVA (α = 0.05).

Results and Discussion

Individual oyster testing
NoV results detected in individual oysters showed a wide variance, at both low and high levels of NoV. Bootstrap analysis shows an immediate leap in consistency of results when multiple samples are combined. Further analysis will be done to place these figures in a risk assessment context, particular in terms of expected consumption in a single meal.

Table 1. Individual oyster results (NoV copies/g), and 95% confidence interval for sample size of 10

<table>
<thead>
<tr>
<th>Date</th>
<th>Mean</th>
<th>σ</th>
<th>95% confidence interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nov 2013</td>
<td>187</td>
<td>246</td>
<td>187 ± 152</td>
</tr>
<tr>
<td>Feb 2014</td>
<td>3736</td>
<td>2341</td>
<td>3736 ± 1450</td>
</tr>
</tbody>
</table>

Site-wide sampling
For the samples taken at the peak of the season, one-way ANOVA shows there are significant differences between different regions of the site (P<0.05). Taking rows and columns of the sampling grid as factors, a two way ANOVA test implies that increasing distance from shore, and thus time spent underwater, increases NoV concentrations (P<0.05), while distance from discharge is not as relevant (P=0.701). Almost all results go beyond a threshold of acceptable risk, however. Analysis is forthcoming on results from the low point of the season, which are expected to display a greater spread of results between safe and high-risk levels. Further spatial analysis is also in progress.

Infectivity
Results comparing levels of infectious to non-infectious virus in environments exposed to differently treated sources of wastewater effluent are ongoing. The expectation at this stage, based on previous research, is that the discrepancy between RT-qPCR detection and actual infectious copies will increase as the level of treatment goes up. The challenge will be in incorporating this data into a workable predictive model for NoV results, including environmental factors as well.

Conclusions
In general, results from individual samples should not be relied on. Emphasis should be placed on trends across seasons and regions (DePaola et al., 2010). But if all sampled estimates are biased in one direction, ongoing risk assessment will become over-cautious, and unreliable in predicting health risks. In the future, NoV monitoring will likely look similar to current E. coli monitoring, with sites categorised in broad bands, and subject to increasing sales restrictions (Anonymous, 2004).
surrogate virus like GA may be tested alongside NoV, or RT-qPCR methods may be optimised to discount damaged copies (Hamza et al., 2011). Satellite and weather data are already established for monitoring hydrological pollution (Wang and Deng, 2012), while heavy rainfall has been shown to increase the risk of shellfishery contamination (Flannery et al., 2013). Results like these can contribute to a risk model which balances accuracy with ease of implementation. More information is also needed on the link between oyster contamination and consumer illness.

References


POTENTIAL FOR MATHEMATICAL NANOPARTICLE MIGRATION PREDICTIVE MODELS TO BE USED FOR COMPLIANCE PURPOSES

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\textsuperscript{b}School of Food & Nutritional Sciences, Food Packaging Group, University College Cork, Cork, Ireland.
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Abstract

The migration of nanoparticles from food contact materials has been the subject of numerous studies in recent years. However, few have utilized mathematical models to their full potential. This work focusses on four studies in particular which have presented sufficient data to formulate a mathematical model, but have not done so. Two mathematical models were used to generate migration predictions for the worst case migration conditions. These values were then compared to the experimental values obtained from migration tests performed in the four studies. All of the predicted values with the exception of one, under estimated the level of migration by a significant amount.

Introduction

Due to their enhanced properties nanoparticles (NPs) have gained much attention in recent years in such areas as the food packaging industry. These properties are generated when the surface area increases dramatically with reducing size. Adversely, the decreased size can also produce increased toxicity when compared to the bulk material. Although the use of nanomaterials in Europe is heavily restricted by regulation due to potential human toxicity, it has not deterred efforts by industry and academia at finding nanotechnology applications with acceptable levels of risk, which may be accepted by both regulatory bodies and the public. Given the increasing numbers of studies (see Table 1) focussing on nanoparticle migration and human exposure it is surprising that few studies have considered mathematical models as an alternative to costly and time consuming experimental studies. In the European Union, the use of mathematical predictive models as an alternative to migration studies is encouraged (European Commission 2011). This is provided that the predictive model presents evidence of migration that is to the same degree of severity as migration studies. The objective of this paper is to compare migration predictions obtained from mathematical models to results obtained from experimental studies in literature.

Table 1. Migration studies, mathematical predictive models and numerical models

<table>
<thead>
<tr>
<th>Author</th>
<th>Fortunati et al., 2014</th>
<th>Cushen et al., 2014</th>
<th>Panea et al., 2014</th>
<th>Fortunati et al., 2013</th>
<th>Cushen et al., 2013</th>
<th>Goetz et al., 2013</th>
<th>Echegoyan et al., 2013</th>
<th>Bett et al., 2012</th>
<th>Bett et al., 2012</th>
<th>Shmatova et al., 2012</th>
<th>Song et al., 2011</th>
<th>Huang et al., 2011</th>
<th>Hauri et al., 2011</th>
<th>Bott et al., 2012</th>
<th>Smirnova et al., 2012</th>
<th>Busolo et al., 2010</th>
<th>Simon et al., 2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>NPs - Packaging Matrix</td>
<td>Ag/s-CNC - PLA</td>
<td>Cu &amp; Ag - PE</td>
<td>Ag/ZnO - LDPE</td>
<td>Ag/s-CNC - PLA</td>
<td>Ag - PVC</td>
<td>Ag - PE</td>
<td>Ag - LDPE</td>
<td>TiN - PET/LDPE</td>
<td>Ag - LDPE</td>
<td>Ag - PE</td>
<td>Ag - PE</td>
<td>Ag - PP</td>
<td>Ag - PP</td>
<td>Ag/MMT - PLA</td>
<td>MMT - biopolymer</td>
<td>NP - Polystyrene</td>
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</table>

*Mathematical model used to calculate diffusivity from migration study results
Materials and Methods

Mathematical model

A mathematical model was adapted from a study which focuses on the migration of engineered nanoparticles from polyolefin food packaging to food simulants (Simon et al. 2008). Although the study does not present experimental results for comparison to predictions, numerous succeeding studies have presented migration results that have been validated using the mathematical model.

The model assumes that particles are uniformly distributed within the polymer and are mobile. Moreover, any particle which comes within the average distance travelled by the particle from the packaging-food interphase is assumed to migrate. A number of structured steps were taken to calculate the quantity of nanoparticles migrating into food. The diffusivity ($D$), migratability ($m$) and dynamic viscosity ($\eta$) were calculated for each specific study. As the dynamic viscosity for the packaging materials used in the studies were not included, it was necessary to use the William-Landel-Ferry equation defined as Equation (1).

$$\eta(T) = \eta(T_g) \exp \left[ \frac{c_1(T-T_g)}{c_2+T-T_g} \right]$$  (1)

Where $\eta(T)$ is the dynamic viscosity at the migration temperature ($T$), $\eta(T_g)$ is the dynamic viscosity at the glass transition temperature ($T_g$) and, $c_1$ and $c_2$ are constants which apply broadly to all polyolefins. The constant values are $c_1 = 17.44$ K and $c_2 = 51.6$ K. The quantity of migrating nanoparticles was found using a combination of the diffusivity, migratability and dynamic viscosity which can be summarized into Equation (2).

$$n = SC_0 \frac{K_B T t}{24\pi^2 \eta a}$$  (2)

Where $n$ is the quantity of migrant, $S$ is the contact area between the packaging and food, $C_0$ is the initial concentration of migrant in the packaging, $K_B$ is the Boltzmann constant, $T$ is the temperature during migration, $t$ is the migration period, $a$ is the particle radius and $\eta$ is the dynamic viscosity.

For comparison purposes a similar mathematical model by (Chung et al. 2002) was used to quantify migration of nanoparticles into food simulants. Equation (3) is a simplistic model based on Fick’s Second Law which assumes a negligible effect of partitioned migration.

$$n_b = C_0 \cdot \frac{2}{L_p} \left( \frac{Dt}{\pi} \right)^{0.5}$$  (3)

Where, $n_b$ is the predicted migration into the food and $L_p$ is the thickness of the packaging material. Out of all the current migration studies, only four presented enough information to allow for mathematical modelling (Huang et al. 2011, Song et al. 2011, Echegoyen and Nerín 2013, von Goetz et al. 2013). When modelling each of the studies, inputs were converted into the working units and tabulated into Table 2. Constants used in the calculations are $C_1 = 17.44$ K, $C_2 = 51.6$ K, $K_B = 1.38 \times 10^{-23}$ J.K$^{-1}$, $P_1 = 22/7$ and $q = 0.25$.

Results and Discussion

As could be expected, the results obtained for the predicted migration using Equation (2) and (3) as seen in Table 3 vary significantly from the experimental values. For regulatory purposes, each predicted value must over predict migration under the worst case scenario of use. In all instances Equation (2) significantly under predicts the level of migration. Using Equation (3) predicted values for the study by Song et al. (2011) are overestimated. However,
for the study by Huang et al. (2011) it is apparent that the predicted migration is underestimated by a factor of ten. These trends demonstrate that for both equations the level of migration is under predicted and therefore, impractical for demonstrating compliance with strict migration regulations.

**Table 3. Predicted migration results (n) for model a and b compared to experimental values**

<table>
<thead>
<tr>
<th>D</th>
<th>T</th>
<th>m</th>
<th>n</th>
<th>n_{exp}</th>
<th>n_{exp}*</th>
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<td>[m².s⁻¹]</td>
<td>[m]</td>
<td>[m]</td>
<td>[mg]</td>
<td>[mg]</td>
<td>[mg.m⁻³]</td>
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<td>Echegoyan et al., 2013 (Go Green)</td>
<td>3.21E-19</td>
<td>5.94E-07</td>
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<td>3.78E-05</td>
<td>3.68E+00</td>
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<td></td>
<td>2.00E-20</td>
<td>2.97E-07</td>
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<td>1.35E-19</td>
<td>4.71E-07</td>
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<td>3.54E-07</td>
<td>3.55E-07</td>
<td>8.87E-08</td>
<td>8.48E-05</td>
<td>4.09E-01</td>
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</table>

* Per cubic metre of food simulant

**Conclusions**

Following a comparison between results obtained from four migration studies in the literature and both of the mathematical models it can be concluded that the mathematical models could be considered impractical for compliance purposes as a result of the inherent under predictions.

The mathematical model presented by Simon et al. has been an invaluable tool for one study (Cushen et al. 2014), which predicted the migration of silver from polyethylene plastic. The success of the model in this case could be attributed to the use of stochastic data in a Monte Carlo simulation to account for the variability in the input parameters.

It should be noted that for situations that involve packaging with nanoparticle coatings, no mathematical migration predictive models have been identified.

**Acknowledgements**

This work was funded under the Food Industrial Research Measure (FIRM) as administered by the Irish Department of Agriculture, Food and the Marine.

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EFFECT OF ULTRASOUND PER-TREATMENT ON THE DRYING KINETICS OF BROWN SEAWEED ASCOPHYLLUM NODOSUM

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Abstract

The effect of ultrasound pre-treatment on the drying kinetics of brown seaweed Ascophyllum nodosum under hot-air drying will be investigated. Pretreatments will be carried out at ultrasound intensity levels of 7.00, 35.61 and 75.78 Wcm$^{-2}$ for 10 min using an ultrasonic probe. The study will investigate whether ultrasound pretreatment can be used to reduce the energy cost and drying time of A. nodosum.

Introduction

Seaweeds are a highly sought-after source of biologically active compounds used as functional ingredients in foods. Seaweeds are rich in nutrients such as iodine, calcium, carotenes, Vitamin A and Vitamin C (Rodriguez et al 2003). Seaweeds are generally dried prior to industrial processing. Ultrasound can be employed as a pre-treatment for drying to improve the drying kinetics and to reduce the energy costs involved in the unit operation. The emerging ultrasound assisted air-drying technique seems to be a reliable and promising dehydration method, as the power ultrasound can operate at low temperature and consequently reduce the probability of food degradation (de la Fuente-Blanco et al 2006).

Ultrasonication involves high frequency sound waves above human hearing capacity i.e. above 20 kHz. Unlike electromagnetic waves, they are mechanical waves, which pass through solid, gas and liquid media. These waves propagate by rarefactions and compression. If the pressure exceeds the tensile strength of the liquid then formation of vapor bubbles occurs. These vapor bubbles undergo implosive collapse in strong ultrasound fields which is known as cavitational. The implosion of cavitational bubbles generates macro-turbulence, high-velocity inter-particle collisions, and perturbation in micro-porous particles of the biomass. Cavitation near liquid-solid interfaces directs a fast moving stream of liquid through the cavity at the surface. Impingement by the semicro-jets results in surface peeling, erosion, and particle break down facilitating release of bioactive compounds from the biological matrix.

The main objective of this study is to investigate whether the use of ultrasound as a pre-treatment prior to hot air drying of seaweed can reduce the energy cost and drying time.
Materials and methods

Seaweed material

Fresh brown seaweed (*Ascophyllum Nodosum*) will be obtained from Arramara Teoranta, Co. Galway, Ireland. Seaweed will be washed thoroughly with fresh water to remove epiphytes and salt. It will be chopped using a hand blender to uniform size and stored at 4 °C prior to treatment.

Ultrasound pre-treatment

27 seaweed samples of 20 g will be placed in a beaker and 80 ml of distilled water added ambient temperature conditions. A 750 W ultrasonic processor (VC 750, Sonics and Materials Inc., Newtown, USA) operating at 20 kHz with a 13 m diameter probe will be used for sonication. The schematic diagram of the equipment is shown in Figure 1.

![Figure 1. Schematic diagram of ultrasound assisted extraction assembly with probe system of ultrasound equipment, illustrating mechanism of bubble cavitation (A – Ultrasound generator, B – transducer, C – ultrasound cylinder probe, D – beaker with sample and solvent of extraction, E – bubble cavitation phenomena, F – thermocouple, G – data recorder)](image)

The energy input will be controlled by setting the amplitude of the sonicator probe. The ultrasound probe will be submerged to a depth of 25 mm in the sample. Pretreatments will be carried out at ultrasound intensity levels of 7.00, 35.61 and 75.78 Wcm⁻² for 10 min using an ultrasonic probe. Moisture gain and solid loss will be calculated.
**Hot air drying**

Seaweed samples will be air-dried in a forced circulating air-drying oven (Gallenkamp Plus II, Weiss Technik, UK) after pre-treatment. The forced circulating air-drying oven will be set at 50 °C. The air velocity inside of the oven is maintained at 0.3 ms$^{-1}$ and measured by anemometer (Testo 400, Total Temperature Instrumentation, Inc. USA). Seaweed samples will be kept in trays and will be transferred to the forced circulating air-drying. The seaweed moisture (water content) during the air-drying period will be measured by weighing the samples every 10 min for the first 1 h of drying, every 20 min for the next 2 hours, and every 30 min for the next 2 hours and finally until constant weight will be observed.

**Results and Discussion**

This experimental analysis has not yet commenced. Previous results from similar studies on other biological matrices are discussed here.

The effect of the ultrasonic pre-treatment on drying is mainly observed during the air-drying stage where a significant increase in water diffusivity was found. At the end of the ultrasonic pre-treatment little change was observed in the moisture content of the fruit. Different from the osmotic dehydration where an expressive water loss from the fruit is found, when the ultrasonic pre-treatment was applied the bananas gained water during the treatment. For ultrasound treatments lasting 20 min, water gain was 11.1%. This value decreased to 7.2% when the fruit was submitted to ultrasound for 30 min. The fruit submitted to ultrasonic pre-treatment lost soluble solids to the liquid medium. The amount of sugars lost during the process was 21.3% of the reducing sugars of the fruit after 30 min in ultrasonic bath. The amount of glucose lost was 11.0% after 30 min in ultrasonic bath. Figure 2. shows the sugar loss as a function of the time spent in ultrasonic bath.

![Figure 2](image_url)  
*Figure 2.* Reducing sugars and glucose loss as a function of time in ultrasound bath.
The loss of sugars occurs because of the different sugar concentration (osmotic pressure) between the fruit and the liquid medium, which favors a mass transfer of sugar from the fruit to the liquid medium and a mass transfer of water from the liquid medium to the fruit. The reduction observed in water gain after 20 min compared to the result found for water gain after 10 min is explained by the higher sugar loss from the fruit to the liquid medium found after 20 min, which diminished the solid concentration gradient between the fruit and liquid medium and as a consequence less water enters the fruit to compensate for the osmotic pressure gradient.

Conclusions

Thus ultrasound is a suitable technology for reducing the energy consumption in drying and should be extensively researched for application at large scale industrial operations. For many fruits and vegetables, ultrasound assisted drying prototypes for large scale operations have been successfully developed. Similar prototypes should be developed.

Acknowledgements

The authors wish to acknowledge financial support from the Irish Research Council.

References

TECHNOLOGY TO REDUCE PATHOGENS IN MEAT

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Abstract
Meat is a major food product in daily life in European countries. Meat products belong to perishable foods. In addition, meat products may become hazardous for consumers if pathogens are present in these meat products. Pathogens such as Listeria monocytogenes, Escherichia coli O157:H7, and Salmonella spp. can grow and cause illness by the ingestion of the bacterial cells, therefore, assurance of meat safety and quality is of utmost importance (Shimoni and Labuza, 2000). Foodborne pathogens may cause severe problems in the food industry by posing a health risk for consumers. Lactic acid bacteria (LAB) are usually used to control pathogens on meat products and LAB is a good method to reduce pathogen levels on foods because LAB can inhibit pathogenic microorganisms through various mechanisms without causing unacceptable sensory changes.

Introduction
Food scientists are constantly researching an efficient new method to reduce pathogen levels in meat and ensure the safety of meat products. Meat is suitable for growing of bacterial so that pathogens will rise if restrictive methods are not used to protect meat quality. So far, there are several effective ways used by the food industry for the control of pathogens levels, for example heat treatment, lowered PH and water activity, the addition of preservatives and irradiation (Chiang and others, 2012). These chemical sanitizers and physical processing are often used to ensure food safety and extend the shelf life of meat products. But consumers are always anxious about the dangers of food treatments. Due to this, food researchers are more interested in looking for ecological approaches to food preservation based on natural antimicrobial systems. Biopreservation has got attention as a means of naturally controlling shelf life and safety of meat products. Some microorganisms commonly related to meat quality have been antagonistic towards pathogenis bacteria. LAB is usually utilized to reduce pathogen levels in meat food to improve food safety. LAB can be used in manufacturing and post-processing to reduce the level of pathogens in meat. There are some human pathogens which may survive the manufacturing or storage process and become a safety problem although several efforts can be made to reduce contamination in manufacturing and packaging. These methods can enhance food safety and the shelf life of meat products. Lactic acid bacteria have potential for use in biopreservation, they are safe for human consumption and are the prevalent microflora during storage in many foodstuffs (Castellano and others, 2008). The ability to reduce pathogens levels of lactic acid bacteria is due to the production of antimicrobial metabolites including organic acids and bacteriocins. Acid production from lactic acid bacteria as a result of carbohydrate catabolism is a common feature among LAB. Bacteriocins is produced from lactic acid bacteria as a result of a heterogeneous group of peptides and proteins.
The objective of this project is to improve the methods of reducing pathogens in meat using Lactic acid bacteria.

Materials and Methods

There are 17 target pathogens (Table 1) used to detect antimicrobial activity (Jones et al., 2008). These pathogens were chosen to represent a range of pathogenic organisms of concern to the meat industry. All pathogens were stored at -80 °C in 40% glycerol.

Table 1: Pathogens used to detect antimicrobial activities of lactic acid bacteria isolated from meat

<table>
<thead>
<tr>
<th>Pathogens</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. E. coli</td>
<td>Clinical isolate, ATCC25922</td>
</tr>
<tr>
<td>2. E. coli O111:H12</td>
<td>Clinical isolate, EPEC, NCTC8008</td>
</tr>
<tr>
<td>3. E. coli O113:H21</td>
<td>Verotoxin producer (Vt+) NZRM3616</td>
</tr>
<tr>
<td>4. E. coli O157:H7</td>
<td>NCTC12900, Vt–</td>
</tr>
<tr>
<td>5. E. coli O157:H7</td>
<td>Calf isolate, shigatoxin producer (stx2), EQRA423</td>
</tr>
<tr>
<td>6. E. coli O157:H7</td>
<td>Calf isolate, shigatoxin producer (stx1, stx2), EQRA427</td>
</tr>
<tr>
<td>7. E. coli O26</td>
<td>Vt+, NZRM3537</td>
</tr>
<tr>
<td>8. L. monocytogenes</td>
<td>Meat isolate, L70</td>
</tr>
<tr>
<td>9. L. monocytogenes</td>
<td>Clinical isolate, ATCC35152</td>
</tr>
<tr>
<td>10. L. monocytogenes</td>
<td>Meat isolate associated with food poisoning outbreak</td>
</tr>
<tr>
<td>11. S. Hadar</td>
<td>NZRM4206</td>
</tr>
<tr>
<td>12. S. Menston</td>
<td>NCTC7836</td>
</tr>
<tr>
<td>13. S. Typhimurium</td>
<td>NZRM4215</td>
</tr>
<tr>
<td>14. Y. enterocolitica</td>
<td>Clinical isolate, NZRM1001</td>
</tr>
<tr>
<td>15. Y. enterocolitica</td>
<td>Meat isolate, AJH-Y1</td>
</tr>
<tr>
<td>16. C. jejuni</td>
<td>Clinical isolate, NZRM4198</td>
</tr>
<tr>
<td>17. C. jejuni</td>
<td>Clinical isolate, NZRM4122</td>
</tr>
</tbody>
</table>

The agar-stab test can be used to screen LAB inhibition of target pathogens. LAB were cultured on plates of LA incubated anaerobically for 18-24h at 24 °C. Colonies picked using sterile toothpicks were inoculated into fresh LA plates by stabbing vertically downwards through the agar. The plates were incubated for 18 h at 24 °C to allow LAB growth along the length of the stab-line. After incubation, cells on the surface were killed by exposing inverted plates for 20 min to filter paper disks saturated with chloroform. After allowing residual chloroform to dissipate, each plate was overlaid with 7 ml of molten (50 °C) 0.7% soft agar containing 0.1 ml of a late-log culture of a respective target strain. MHB broth containing 0.7% agar was used to prepare overlays for C. jejuni and C. esterhtheticum. C. esterhtheticum overlays were poured in an anaerobic chamber. Overlays were allowed to set.
then plates were incubated until confluent growth was observed. Plates were then examined for zones of inhibition around the inoculation sites.

The effect of 50 μM hypothiocyanate on E. coli DH5α was first determined. Reaction mixtures each comprised a final volume of 1 ml of 0.1 M sodium phosphate buffer, pH 6.0, containing 1×10⁴ cfu E. coli DH5α cells, 5.0 mM KSCN (−SCN; Sigma), 20 μM lactoperoxidase (LPO; Sigma), and 0.2 mM H₂O₂ (Sigma) added finally in four equal volumes. Mixtures were incubated at 24 °C for 5 min. Residual hydrogen peroxide was neutralized by addition of 20 μl of a solution containing 2 mg catalase ml⁻¹. Reaction mixtures were then incubated for a further 2 h. Viable E. coli numbers were calculated by counting colonies after plating diluted reaction mixture onto plates of LA and incubating for 24 h at 30°. The effect of hypothiocyanate on the growth of E. coli was determined by inoculating 0.5 ml of each reaction mixture into a micro-cuvette containing 1.5 ml LB, incubating the cuvette at 24 °C for 22 h, and recording changes in the optical absorbance at 450 nm. The ability LAB to generate levels of hypothiocyanate inhibitory for E. coli was evaluated by exposing L. sakei to hypothiocyanate precursor molecules. 1 ml volumes of 0.1 M sodium phosphate buffer, pH 6.0, were prepared containing 1×10⁷ cfu L. sakei strains 27, 63, Lb706 and 23K.

Results and Discussion

Approximately 50 μM (range 47–50) hypothiocyanate was detected in reaction mixes containing E. coli cells, −SCN, H₂O₂ and LPO, compared with no hypothiocyanate detected in mixtures lacking LPO. After 2 h incubation little change in viable E. coli cell numbers was observed. After 22 h incubation in LB the cell suspensions exposed to hypothiocyanate took longer to attain exponential growth than untreated cells (Fig. 1). When LPO was substituted for 1×10⁷ cfu L. sakei 27, 63, Lb706 or 23K, hypothiocyanate generation was not detected.

Figure. 1: Growth of E. coli DH5α in Luria broth after exposure to hypothiocyanate (Δ), hypothiocyanate precursors (○), or in 0.1 M sodium phosphate buffer (●).
Conclusions

Nowadays, consumers are very concerned about the relationship between food and health. The additives used in food can be divided into natural and unnatural. In particular, meat is a major food in our daily life, hence the importance to keep safe. LAB has been used as a means to reduce pathogen levels in food for a long time since they are tested as safe additives and they can generate acids and metabolites with inhibitory activity. In addition, LAB are excellent candidates for the control pathogens in meat because they can inhibit growth of these organisms through various mechanisms without causing unacceptable sensory changes.

References


Abstract

Milk and dairy products are frequently contaminated with enterotoxigenic *Staphylococcus aureus*, which is often involved in staphylococcal food poisoning. *S. aureus* and its enterotoxin (SEC) production in milk were modelled at constant temperatures of 25, 20, 37, and 40 °C. Bacterial growth showed the classical exponential phase followed by stationary phase. The model described the early exponential phase of a growth curve linearly with time once the cell population reached about $10^8$ CFU/ml.

Introduction

*Staphylococcus aureus* is an important Gram-positive food-borne pathogen of humans and animals, which cause a wide variety of diseases ranging in severity. The symptoms of staphylococcal food poisoning include abdominal cramps, nausea, vomiting, sometimes followed by diarrhea, fever, and dehydration and they depend on quantity, type, and toxicity of the toxin that is ingested (Normanno et al. 2007).

Staphylococcal food poisoning is an intoxication caused by the consumption of foods containing enterotoxins (SE) that are produced by some strains of *S. aureus*. An enterotoxin dose of $\leq 1.0 \mu$g in contaminated food produces symptoms of staphylococcal intoxication, but this toxin level is typically reached only when *S. aureus* population exceeds $10^5$ CFU/g (Valero et al. 2009).

Milk is a good substrate for *S. aureus* growth and enterotoxins production. In addition, enterotoxins retain their biological activity even after pasteurization. Staphylococcal enterotoxins (SEs) are very resistant to heat; staphylococcal enterotoxin A (SEA), for example, retains some biological activity after 28 min. at 121 °C (Rall et al. 2008). Certain *S. aureus* types can produce small proteins which are toxic when ingested. These proteins are called *Staphylococcal Enterotoxins* (SE). There are 21 immunological types, of which only SEC types was found in unpasteurized milk and cheese.

Enterotoxin A (SEA) and enterotoxin D (SED) are the most common staphylococcal enterotoxins (SE) observed in association with SFP. These SE, together with the enterotoxins B (SEB), C (SEC), E (SEE) and the toxic shock syndrome toxin-1 (TST), have been well known for many years, whereas the toxins SEG, SEH, SEI, SER, SES, and SET and the enterotoxin-like (SEI) proteins SEIJ to SEIQ and SEIU to SEIV have only been reported more recently (Hummerjohann et al. 2014). There are 21 immunological types, of which only SEC types was found in unpasteurized milk and cheese.

The objective of this study was to model growth of *Staphylococcus aureus* enterotoxin in milk at varying temperature conditions.
Materials and Methods

The data for this work was supplied from a previous experimental study.

Experimental design

Strains 178 and 211 were isolated from unpasteurised milk and cheese, respectively. Initial experiments define the boundaries of time, pH and temperature. The strains were cultured overnight, washed and aseptically inoculated into sterilised Multifors 2 Parallel bioreactors containing 500 ml of sterile milk. The initial bacterial concentration was $4.5 \log_{10}$ CFU/ml. The stirring speed was 200rpm. A full factorial experiment with 4 temperatures (25, 30, 37 and 40°C) and pH values (5.5, 6.0, 6.5 and 7.0) was undertaken. Samples were quantified at 5 time points over 66 hours (h). Temperature conditions were repeated with uncontrolled pH. All experiments were undertaken in independent triplicate. *S. aureus* were enumerated using selective agar (Egg yolk Baird Parker; ISO 6888-1:1999) and non-selective agar (Tryptic Soya Agar; Merck, Germany). SEC was quantified using a sandwich enzyme-linked immunosorbent assay (Kérouanton et al. 2007) with a limit of detection of 0.16 ng/ml. Both strains were grown in unpasteurised and pasteurised milk at temperatures of 20, 25 and 30°C for 3 days.

Model

A number of mathematical models and equations for a description of microbial growth in food can be used in predictive microbiology. Number of models such as logistic model are widely used. Baranyi and Roberts (1994) reported on an alternative mathematical model which is a combination of the original logistic model and the Michaelis-Menten model.

New model developed by Fujikawa and Morozumi (2006) successfully described growth curves of *E.coli* and *Salmonella*, but the model was less effective in describing the log-linear growth during the early exponential phase.

Growth of enterotoxin were analysed with a linear model using the software program DMFit and Excel.

Results and discussion

Growth curves for *S. aureus* at all examined temperatures had a similar shape and showed typical linear growth at a log (exponential) phase followed by a stationary phase. With temperature rise the log phase was shorter; and the level of bacteria present when SEC production began was reaching faster.

At constant temperature of 25°C the SEC amount in milk (Figure 1) increases with a time. The toxin began to be detected after 24 hours (0.45ng/ml) when the cell concentration of *S. aureus* reached to approximately $10^8$ CFU/ml.

Similar results were obtain after analysing the data at temperature of 30°C. SEC was detected when the concentration of S. aureus cells reached $10^8$ CFU/ml, and was increasing even after the cells reached the stationary phase (Figure 2). But at this temperature the entetoxin production was already detected after 18 hours.
Conclusions

The model developed in this study can predict growth of enterotoxin of *S. aureus* in milk. Microbial growth showed a classical linear slope for an exponential phase followed by stationary phase. But the enterotoxin in milk was detected only when the level of *S. aureus* reached about $10^8$ CFU/ml at all examined temperatures and was increasing even once the bacteria attained the stationary phase. With temperature increase earlier detection of enterotoxin was observed.

References


APPLICATION OF NIR SPECTROSCOPY TO MEASURE THE
MOISTURE CONTENT OF MILK POWDER ON-LINE DURING
PROCESSING

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Abstract
Moisture content is one of the most important and frequently carried out measurements in the
food industry. Near infrared (NIR) spectroscopic has been reported for the on-line
determination and monitoring of the moisture content in continuous production environments.
This study investigates the potential of NIR spectroscopy to control moisture content on-line in
milk powder manufacture.

Introduction
Milk powder is a very popular manufactured nutritional powder (Wu, Feng and He, 2008). 645,000 tons of WMP (whole milk powder) were produced in the EU in 2013 (USDA, 2013). Milk powder manufacture is an energy-intensive continuous process carried out on a large scale. Generally, during milk powder manufacture, moisture is first removed by boiling milk under reduced pressure at low temperature in a process known as evaporation. The resulting concentrated milk is then sprayed in a fine mist in hot air to remove further moisture and result in a fine powder (Schuck, 2011). Powder moisture content is a one of the most significant parameters influencing the physico-chemical stability of milk powder during manufacture. In addition, the technological functionalities such as wettability and dissolution are easily affected by moisture content. Also, the oxidative stability is a function of varying water content (Reh, Bhat and Berrut, 2004). However, presently the manufacturers lack an appropriate technology to control milk powder moisture during processing. Meanwhile, the legislation is strict for milk powder production, especially where ingredients are used to produce infant formula for the international market.

Near-infrared spectroscopy (NIRS) has been widely used in many sectors for the rapid on-line determination in a non-destructive manner. Compared with the conventional methods, NIR provides a rapid analysis. Additionally, sample preparation is not necessary and it may be used for on-line determination in the manufacturing process. The majority of research on near infrared of milk powder have been in the 1,100- to 2,500-nm region of wavelengths, however some studies have been carried out in short-wave NIR from 700- and 1,100 (Wu, Feng and He, 2008). The aim of this project is to investigate and evaluate near infrared spectroscopy for the prediction of moisture content of milk powder.

Materials and Methods
Sample preparation
Six brands of milk powder were purchased from local markets in Ireland.
Near-infrared laboratory system

Spectra were collected on a Biorad Excalibur series FTS 3000 FT-IR spectrometer (Analytica Ltd., Dublin, Ireland). The instrument scans from 400 to 2500 nm. The measurements were done according to the standard operating procedure using a small ring cup. Samples were scanned in duplicate over the whole range of wavelength (400 to 2500 nm) with a resolution of 2 nm. However, an averaged spectrum was used for further work. For the normalization procedure all NIR spectra were exported as JCAMP (JCM) format from the instrument and converted into absorption values corresponding to each peak using a home-made program. Then, these absorption values were normalized to eliminate texture effects. The normalization was performed using an EXCEL sheet at certain wavelength.

Analysis of chemometric near-infrared spectral data

The moisture content models were built that fully cross validation PLSR models and the pretreatment were accomplished by the Unscrambler software version 9.5 (CAMO AS, Trondheim, Norway). The predictive model were assessed by the root-mean-square error of calibration (RMSEC), root-mean-square error estimated by cross-validation (RMSECV), and the coefficient of determination (R²).

Results and Discussion

The experimental analysis is currently being carried out. Previous results from other studies are discussed. The typical absorbance spectra of milk powder from 800 to 1,025 nm are illustrated in Figure 1.

The normalized NIR absorbance at 1940 nm was determined for the same set of samples and is plotted in Figure 2. The regression shows a very good correlation between both parameters with an R² of 0.94 and a standard deviation of differences of 0.07 wt%. This shows the ability of near infrared spectroscopy to predict water content in milk powders. It also illustrates the ability of the KF method to measure properly the water content. The major advantage of NIR absorbance at 1940 nm is the almost complete absence of interference from other food ingredients. The peak of water is principally only influenced by the texture of the product. Most of the residual variation can be explained by the analytical error of the KF method and the instrumental error of the near infrared spectroscopy method.
Figure 1. Original short-wave near-infrared spectra of milk powder (Wu, Feng and He, 2008).

![Figure 1](image1.png)

Figure 2. Moisture content versus NIR adsorbance (Reh, Bhat and Berrut, 2004).

![Figure 2](image2.png)

Conclusion
The milk powder industry can benefit from the potential of NIR which is a non-destructive and rapid experimental technique which can be applied for the on-line determination of milk powder moisture during manufacture.

Acknowledgements
The author would like to thank Prof Gerard Downey, Teagasc Food Research Centre, for lending us the hyperspectral imaging equipment for excellent technical assistance. The authors also acknowledge the assistance of Dr. Yao-Ze Feng and Dr. Hong-Ju He.
References


EVALUATION OF NATURAL SAUSAGE CASING MODIFIED BY COMBINATION OF SURFACTANT SOLUTION AND LACTIC ACID

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Abstract

In order to render natural hog casings to withstand the high pressure drop during immersion vacuum cooling (IVC), treatment using two different food additive combinations (modules): Module 1 (soy lecithin (SL) concentration: 1:27.5, soy oil (SO) concentration: 1.25%, lactic acid (L): 19.5 ml/kg NaCl (solid), residence time (T): 75 min) and Module 2 (SL: 1:30, SO: 2.5%, L: 21 ml/kg NaCl, T: 90 min) were applied and sausages were made using modified casing. Burst pressure, tensile strength, maximum rupture force and elongation of cooked treated casing were determined by physical analysis. Histological structures of sausages were observed by light microscopy. Images illustrated that the casings porosity increased after treatments, which facilitated IVC processing of sausages. Compared to 67% of IVC successful rate of sausages made using untreated casing, sausages made using modified casing presented a higher successful rate (no burst) during IVC.

Introduction

Natural casings are difficult to handle as they are variable in calibre and elongation capacity. Irrespective of its origin, casing should be strong enough to resist pressure during batter filling and stuffing, and to hold the batter during heating and smoking processes (Harper et al., 2012).

Cooked sausages, as part of cooked ready-to-eat meals, are very perishable. According to relevant guideline of cooked sausages (USDA, 1999), cooling from 55 to 10°C should be last no longer than 15 – 20 minutes for sausages with diameter between 2.8 and 4.0 cm. Rapid cooling thus plays an important role in ensuring sausage safety and immersion vacuum cooling (IVC) can potentially achieve this requirement. However, products subjected to IVC should be porous or resistant to high pressure drops. Therefore, there is a demand for improving casing properties so as to improve not only the stuffing efficiency among sausage manufacturers (Santos et al., 2008) but also the IVC procedure. Although IVC offers greater advantages for reducing cooling time of larger products, using this technology on smaller products allows for the study of how other food systems respond to this process, for example, the unique sausage system where a comminuted meat is encased in a natural permeable membrane (casing).

The objective of the current work was thus to evaluate the effects of food grade additives on the properties of natural hog cooked casings. The modules applied in this study could be used as a reference to meat processors or manufacturers when choosing a suitable treatment for their different requirements.

Materials and Methods

Casing modification
Segments (70 cm length each) of natural hog casings (Irish Casing Co. Ltd., Tullamore, Co. Offaly, Ireland) were desalted with distilled water (25°C) for 10 min. The desalted casings were then submerged in two different modules containing surfactant solutions: Module 1 (soy lecithin (SL) concentration: 1:27.5, soy oil (SO) concentration: 1.25%, residence time (T): 75 min) and Module 2 (SL: 1:30, SO: 2.5%, T: 90 min). Afterwards, treated casings were removed from the surfactant solution (without rinsing) and gently mixed with a slush salt (NaCl) containing lactic acid in accordance to the precedent modules (Module 1: 19.5 ml/kg NaCl (solid); Module 2: 21 ml/kg NaCl). The corresponding time for casing stored in slush
salt (25°C) was the same as the resident time for casing treated in surfactant solution. Casings without treatment (control) were desalted by tap water (25°C) and submerged in distilled water before tests.

Mechanical property measurements and Statistical analysis
For measurement of burst pressure, casings were firstly rinsed with tap water (25°C) for 5 min to eliminate all the modified solution before tests. Afterwards, casing (length: 22.0 cm) was loaded onto a horizontally placed plastic pipe (outer diameter: 1.5 cm; inner diameter: 1.3 cm; length: 34.1 cm) with seven sets of four holes (2.0 cm between each set, diameter: 0.4 cm). One end of the pipe was connected to a hot water source from a circulating hot water bath (80°C) (GD120, Grant Instruments Ltd., Chelmsford, UK) and a pressure transducer. The other end was connected to a ball valve. The two ends of the casing segments were firstly wrapped by soft natural rubber segments (for protection) and then tied up using cable ties. Subsequently, the casing (with pipe) was horizontally immersed into the water bath for 5 min to simulate cooking. The casing was filled with the hot water at a constant flow rate of 1 L/min controlled using a valve and a flow meter (FR2000 Acrylic Flowmeters, Key Instruments, Trevose, PA, USA). After switching off the valve, the internal pressure of the casing increased. Burst pressure was defined as the pressure to break the casing. Pressure were recorded using a data logger (Squirrel SQ2040, Grant Instrument Ltd., Chelmsford, UK) connected to the pressure transducer (Eirelec LG4.0, Digitron Italia, Ferentino, Italy) with 0.09 s acquisition interval.

For maximum rupture force, the device was similar to that described in the experiment of Benli et al. (2008). In the current case, a solid aluminium bar (diameter: 1.94 cm; length: 15.5 cm) was split longitudinally into two equal halves. A casing with the length of 10.0 cm was loaded onto the bar after rinsing the modified solution. Casing with the bars was submerged into the hot water bath (80°C) for 5 min (simulating cooking). The ends of each half bar were fixed to support brackets which were fixed to a tension system (H50KS-0043, Tinius Olsen Ltd, Surrey, UK). The lower bracket was fixed, while the upper bracket was attached to a load cell (1 kN, H1K, Tinius Olsen Ltd, Surrey, UK) to measure the force. The cross-head speed was 5 mm/min. The maximum rupture force was defined as the force to break a segment of casing.

Elongation was determined by the following equation:

\[
\text{Elongation} \, (\%) = \frac{E_m - E_i}{E_i} \times 100\%
\]  

(1)

Where \(E_m\) is the extension at the maximum rupture and \(E_i\) is the initial extension. All the measurements were carried out in triplicate.

The experimental data was analysed by one-way ANOVA program using software SPSS (SPSS Statistics 20, IBM, USA).

Sausage preparation
The percentage of sausages filling (total weight: 2302.03 g) ingredient and sausage preparation procedure were the same as the procedure described by Brunton et al. (2005). The casing used in the current study was the modified casings. Control sausages were prepared using untreated casings. After stuffing, the sausages were sectioned to a length of 8.5 cm and a diameter of 3.0 cm by twisting. For histological structure analysis, sausages were sectioned to a length of 2 cm and a diameter of 2 cm (same batch).

Cooking and cooling processing
Cooking and cooling processing was similar to the study of Feng et al. (2013). The pressure drop protocol used in the current study had three stages: 1) chamber pressure dropped freely from 1013.3 mbar to 410 mbar; 2) pressure drop rate was controlled automatically at 104 mbar/min by an electronic valve from 410 mbar to 50 mbar; 3) pressured reduction rate was dictated by the pump capacity at an average of 5 mbar/min from 50 to 6.40 mbar. The temperature of the water applied to IVC was 42.3°C. The speed of the agitation was 471 rpm
and the condensing temperature was maintained at -7.3°C. The experiments were conducted in triplicate.

**Histological structure observation**

Raw, cooked and cooled sausages were submerged into a primary fixative of 2.5% glutaraldehyde (Merck, Damstadt, Germany) in 0.1 M Sørensen’s phosphate buffer (pH 7.4) at room temperature (25°C). Each sausage was sliced and sausage pieces were washed for 10 min in 0.1 M Sørensen’s phosphate buffer, followed by post-fixation in 1% osmium tetroxide (Oxkem Ltd., Berkshine, UK) in 0.1 M Sørensen’s phosphate buffer. The samples were then dehydrated by ascending grades of ethanol (Merck, Darmstadt, Germany), followed by acetone (VWR, Briare, France). Finally, samples were infiltrated with Epon (Agar Scientific Ltd., Essex, UK), placed in aluminium planchettes and polymerised at 60°C for 24 h. Individual sausage pieces were cross-sectioned by an ultramicrotome (EM UC6, Leica, Ashbourne, Ireland). The sections (500 nm thickness) were stained by toluidine blue (EMS, Hatfield, PA, USA) and imaged by a light microscopy (Eclipse 80i, Nikon, Kanagawa, Japan). The representative images were taken using the NIS-Elements BR 3.0 software (Nikon Instruments Inc., New York, USA) with ×40 lens (Nikon, Kanagawa, Japan).

**Results and Discussion**

**Mechanical properties**

The burst pressure, maximum rupture force and elongation of cooked treated casing are shown in Table 1. Burst pressure of cooked treated casing modified by Module 2 (123.12 mBar) was significantly higher than that of Module 1 (88.72 mBar) and control sample (82.96 mBar) \((P<0.05)\), which may be due to a higher concentration of lactic acid used in Module 2. Santos et al. (2008) reported that lactic acid increased the water vapour permeability (WVP) of the natural casing. Due to protein denaturation, the modified casing structure (net structure) was fixed after cooking. Histological observation illustrated that cooled casing after modification became more porous (Figure 1 (b) vs. (c) & (e)). An improved WVP could reduce the build-up of internal pressure and so decreased the risk of casing burst. It can be concluded that a higher lactic acid level may increase the pressure resistance of the cooked casing. The burst pressure of casing modified by both modules was higher than that of control casing, indicating that casing’s pressure resistance indeed improved after modification.

Maximum rupture force of casing modified by Module 1 was significantly \((P<0.05)\) higher than that of casing modified by Module 2. Although lactic acid increased the WVP of the casing, the resistance against external force may weaken as a result of a formation of porous structure after modification. Another possible reason may be attributed to the thinner casing structure after modification. Casing became thinner after cooking due to the loss of some collagen fibre and elastic material. Casing modified by Module 1 was thicker (about 78.6 μm, Figure 1 (c)) than that modified by Module 2 (approximate 50.0 μm, Figure 1 (e)) after IVC process, indicating that less collagen was lost on casings modified by Module 1 during cooking.

Elongation is a property which is related to elasticity. It provides a scale to estimate the rheological deformation of the casing. As shown in Table 1, no statistically significant differences in relation to elongation of cooked casing were observed \((P>0.05)\).

**Modified casings performance during IVC**

Due to the evaporative cooling nature of IVC, the application of IVC technology is restricted to porous foodstuffs. If packaged, the packaging material should be perforated or permeable to allow vapour to easily escape from the product so that chilling can occur. In present experiments, 33% of sausages prepared using the control casing burst during IVC, compared to 100% and 98% successful rate of sausages made using the casings modified by Module 1 and 2, respectively. This demonstrated that both applied modules reduced the risk of sausages bursting, which can be economically and competitively advantageous for sausages manufactures.
Table 1. Comparison of mechanical properties of casings and successful rate of sausages stuffed in modified casing and control casing

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Burst pressure (mBar)</th>
<th>Maximum rupture force (N)</th>
<th>Elongation (%)</th>
<th>IVC successful rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Module 1</td>
<td>88.72\textsuperscript{a}</td>
<td>46.08\textsuperscript{a}</td>
<td>1.54\textsuperscript{a}</td>
<td>100\textsuperscript{a}</td>
</tr>
<tr>
<td>Module 2</td>
<td>123.12\textsuperscript{b}</td>
<td>29.94\textsuperscript{b}</td>
<td>1.22\textsuperscript{a}</td>
<td>98\textsuperscript{a}</td>
</tr>
<tr>
<td>Control</td>
<td>82.96\textsuperscript{a}</td>
<td>35.09\textsuperscript{c}</td>
<td>1.25\textsuperscript{b}</td>
<td>67\textsuperscript{b}</td>
</tr>
</tbody>
</table>

Note: Means with different letters with a row are significantly different (P<0.05). IVC: immersion vacuum cooling.

Figure 1. Light microscopy images of cross sections of sausages. (a) stuffed in raw control casing; (b) control casing and then cooled by IVC; (c) casing modified by Module 1 and then cooled by IVC; (d) casing modified by Module 1 and then cooked; and (e) casing modified by Module 2 and then cooled by IVC. The cooked sausage (d) was stored in a cold room (4°C) overnight before histological analysis.

Conclusions

Burst pressure and maximum rupture force of natural hog casing were improved after being modified by two different food grade additives combination modules. Histological observations displayed that casing after modification became more porous. Burst during IVC did not happen to sausages that were made using casing modified by Module 1.

References


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METHODS FOR DETERMINATION OF PROTEIN DENATURATION IN MILK POWDER: A REVIEW

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Abstract
This paper reviews the current methods applied to quantify protein denaturation in milk powders. The Kjeldahl method and WPNI are the traditional methods, while HPLC and PAGE have also been developed to investigate the changes of individual protein content during milk powder manufacturing processes. Fluorescence spectroscopy is considered as an innovative method to quantify protein denaturation due to its good reproducibility, high sensitivity and short analysis time.

Introduction
Proteins represent around 27% of milk solids, and they play a fundamental role in human nutrition and the dairy industry. Milk proteins mainly consist of 80-85% of caseins and 15-20% of whey proteins (Fox and McSweeney, 2013) Both caseins and whey proteins are nutritional supplements and functionally valuable food ingredients. Milk powder is one of the most important dairy products which are widely used in many applications, such as food ingredient and infant milk powder. Based on the fat content milk powder can be classified as skim milk powder (SMP) and whole milk powder (WMP). Generally, the milk powder manufacturing process includes preheating, evaporation and spray drying. All these processes involve heat treatment which could cause partial protein denaturation. Protein denaturation is a process in which the protein secondary and tertiary structures are disrupted or destructured by application of some external stress or compound, such as an acid or a base, a concentrated inorganic salt, an organic solvent or heat. Protein denaturation occurs because the bonding interactions responsible for the secondary structure and tertiary structure are disrupted. This structure changes affect the properties of proteins. Therefore, to achieve the desired functional properties of milk powder, it is important to measure and control the degree of protein denaturation during manufacturing.

Many chemical analysis methods can be used to quantify protein denaturation, including nitrogen analysis, chromatography, electrophoresis and spectroscopy. The Kjeldahl method and whey protein nitrogen index (WPNI) are most widely used measurements to determine protein content by calculating protein nitrogen in milk powder. The changes of individual protein can be determined by HPLC and PAGE. Compared with previous methods, spectroscopy methods are more sensitive to protein denaturation, especially fluorescence spectroscopy, considered as a potential ideal method to determine protein denaturation.

The objective of this paper was to review protein denaturation experimental methods and outline innovative techniques to determine protein denaturation in milk powder.

Kjeldahl method
Kjeldahl nitrogen is one of the most widely used methods for determining protein nitrogen and is the official AOAC (AOAC, 1980.) recommend method. Due to its good reproducibility,
as an approved standard method, the Kjeldahl method is still used to quantify protein denaturation (Gaiani et al. 2010). However, this method is also known for being time consuming. Since the Kjeldahl method measures total nitrogen content to quantify protein, it increases the risk of miscalculating of non-protein nitrogen, consequently, affecting the reliability and accuracy.

**Whey protein nitrogen index (WPNI)**
Whey protein nitrogen index (WPNI), a measurement of undenatured whey protein present in the milk powder (expressed as mg of WPN per g of powder), is traditionally used to indicate the degree of whey protein denaturation (Patel et al. 2007). Results of WPNI can be applied to determine the extent of heat treatment. Similar with the Kjeldahl method, non-protein nitrogen is a factor affecting the accuracy. The disadvantage of traditional WPNI test is poor reproducibility due to variable and unstable turbidity (Patel et al. 2007). Nevertheless, both WPNI and the Kjeldahl method can only provide an overall level of protein denaturation. Since individual proteins have different thermal stability levels, more methods are developed to investigate the effects of milk powder manufacture on the individual protein.

**High performance liquid chromatography (HPLC)**
High performance liquid chromatography (HPLC) is the most common method for this purpose. Reverse-phase HPLC (RP-HPLC) is widely used to determine the degree of denaturation of α-la and β-lg during milk powder manufacturing processes (Table 1). Other chromatographic techniques, such as size exclusion (SE)-HPLC and fast protein liquid chromatography (FPLC) are also been investigated to quantify protein denaturation (Table 1). Chromatographic techniques can measure major whey proteins β-lg and α-la with high reproducibility in a short time. However, it is difficult to quantify BSA and immunoglobulin, with high cost and low sensitivity.

**Polyacrylamide gel electrophoresis (PAGE)**
Polyacrylamide gel electrophoresis (PAGE) is a common electrophoretic method used for separation and determination of protein denaturation. Quantitative PAGE including non-dissociating (native-PAGE), dissociating but non-reducing (SDSNR-PAGE) and dissociating and reducing (SDSR-PAGE) were widely applied to investigate the denaturation/aggregation of whey protein (Table 1). The advantages of PAGE are high reliability and easy operations. Compared with HPLC, it can measure BSA and immunoglobulins, while requires more time.

**Fourier transform infrared (FTIR)**
FTIR is a common method to determining the amide I and amide II regions of secondary structure, specifically the polypeptide backbones of proteins while in solution, to quantify protein denaturation (Table 1). FTIR requires short analysis time, represents high sensitivity. However, the operation is complexity and the cost is high.

**Fluorescence spectroscopy**
Fluorescence spectroscopy is a novel technique to quantify protein denaturation. Tryptophan
is a well-known luminescent amino acid that has been used extensively in fluorescence spectroscopy. β-lg contains tryptophan at residues 19 and 61 of the amino acid sequence, which under native conditions are buried in the globular structure of the protein. Whey protein denaturation can be monitored using fluorescence spectroscopy by monitoring changes in fluorescent intensity and emission wavelength (Strasburg and Ludescher 1995). This technique represents good reproducibility, high sensitivity and requires short analysis time.

Table 1: previous research on methods for determination of protein denaturation in milk powder

<table>
<thead>
<tr>
<th>Techniques</th>
<th>Comments</th>
<th>reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reverse-phase high-performance liquid chromatography (RP-HPLC)</td>
<td>Determining of isolation of denatured whey proteins (BSA, α-LA, and β-LG-B and B-LG-A) and their separation by reversed-phase HPLC. The individual whey proteins were identified by means of the retention time and peaks were quantified by comparing native standards.</td>
<td>(Murphy et al., 2013), (Anandharamakrishnan et al., 2008), (Bernard et al., 2011), (Sidney et al., 2011)</td>
</tr>
<tr>
<td>Size exclusion (SE)-HPLC</td>
<td>The chromatographic separation of whey protein was performed on a HPLC column and eluted components were detected by UV absorption at 280nm.</td>
<td>(Dissansaye and Vasiljevic, 2009)</td>
</tr>
<tr>
<td>Fast protein liquid chromatography (FPLC)</td>
<td>Quantification of native β-LG was performed by acidification to pH 4.6, centrifugation and FPLC was applied to analyse the supernatant.</td>
<td>(Dickow et al., 2012)</td>
</tr>
<tr>
<td>Kjeldahl method</td>
<td>Denatured whey proteins were precipitated at pH4.6. After centrifugation, the degree of denaturation was deduced from Kjeldahl analyses before and after precipitation.</td>
<td>(Gaiati et al., 2010)</td>
</tr>
<tr>
<td>Polyacrylamide gel electrophoresis (PAGE)</td>
<td>Native-PAGE was used to determine the amount of native whey protein present. SDS-PAGE-PAGE measured both native protein and aggregates in the supernatant that were not linked via disulfide bonds. SDS-PAGE-PAGE measure total whey protein present. The amount of whey protein that co-sedimented with the caseic micelles was calculated from the difference in concentration between the whey protein in the original skim milk and the total whey proteins in the supernatant (SDSR-PAFE) of the sample.</td>
<td>(Oldfield et al., 2005), (Gulat et al., 2011), (Farg et al., 2012),</td>
</tr>
<tr>
<td>Fourier transfer infrared spectroscopy (FTIR)</td>
<td>Data of the under-peak areas in the spectra was calculated for quantifying the secondary structure of the proteins in the Amide I and Amide II regions, specifically the polypeptide backbones of proteins while in solution, to quantify protein denaturation.</td>
<td>(Yazdanpanah and Langrish, 2013), (Haque et al., 2011), (Gaiati et al., 2010)</td>
</tr>
<tr>
<td>Fluorescence spectroscopy</td>
<td>Using fluorescence of tryptophan (excitation 280nm and emission 373 nm) provides a clear indication of the protein denaturation of the sample by monitoring changes in fluorescent intensity and emission wavelength.</td>
<td>(Blecker et al., 2012, Diez et al., 2008)</td>
</tr>
</tbody>
</table>

Conclusion

Currently the dairy industry requires information on the changes of individual protein content during manufacturing instead of total protein nitrogen thus HPLC, PAGE and FTIR have developed and employed to investigate protein denaturation. Comparing these methods, fluorescence spectroscopy seems to be a potential ideal method to determine protein denaturation in milk powder due to its good reproducibility, high sensitivity and short analysis time.

Acknowledgements

The authors would like to thank the financial support the FIRM program.

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determined by synchronous fluorescence spectroscopy and turbiscan', Food Chemistry, 135(3), 1809-1817.
ULTRASOUND ASSISTED EXTRACTION OF FUCOIDAN FROM A. NODOSUM

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Abstract

This research work investigates the application of ultrasound for the improved extraction of bioactive compound fucose from brown seaweed (*Ascophyllum nodosum*). Key process parameters of ultrasonic intensity (UI), extraction time and solvent type were investigated to optimize extraction yields. The maximum yields on dry basis (db) of fucose was 135.76 mg/g db. Maximum bioactive yield was obtained using 0.03 M HCl as solvent at an UI of 75.78 W cm\(^{-2}\). Extraction kinetics over a 22 hour period were successfully modelled using Peleg's model. This extraction kinetic study demonstrates that ultrasound pretreatment can significantly enhance extraction of fucoidan from brown seaweed.

Introduction

*Ascophyllum nodosum* is a brown seaweed which forms single bladders centrally in long strap-like fronds. It is mainly confined to the north atlantic basin and is harvested in many countries including Norway, Ireland and Iceland (Guiry, 2013). *A. nodosum* is a good source of biologically active compounds including phenolics, fucoidan, alginites, ascophyllan, etc. (Jiang et al., 2010). *A. nodosum* is one of the most widely researched brown seaweed species and is employed in many agricultural and food applications (Khan et al., 2012) including biofertilizer, soil conditioning agent, animal and human nutritional supplements (Fan et al., 2011).

Fucoidan from *A. nodosum* is composed mainly of fucose (52.1%), galactose (6.1%), glucose (21.3%), and xylose (16.5%) (Foley, Mulloy, & Tuohy, 2011). Structurally fucoidan is composed of 13-linked \(\alpha\)-L-fucopyranosyls or of alternating 1→3- and 1→4-linked \(\alpha\)-L-fucopyranosyl residues that may be sulfate substituted (Figure 1). Fucoidan has been extensively researched for its medicinal properties (Morya, Kim, & Kim, 2012) including antitumor, immunomodulatory, antithrombotic, anticoagulant and anti-inflammatory properties which are attributed to fucopyranosyl and its sulphated residues (Marcel Tutor Ale, Jørn D. Mikkelsen, & Anne S. Meyer, 2011b). Fucoidan is commonly extracted using acid or hot water solvent. Acid is useful in hydrolysing fucoidan to lower molecular weight fucoidans for use in drug applications (Hahn, Lang, Ulber, & Muffler, 2012).

Currently employed techniques for extraction of bioactives require long extraction times and have low extraction efficiencies. There is a need to develop novel extraction methods with improved extraction rates and yields. Ultrasound is a potential novel extraction technology which uses high frequency sound waves above 20 kHz and has been studied for the extraction of bioactives from plant matrices. The use of ultrasound-assisted extraction to enhance the yield of fucoidan has not been reported to date. In addition, the investigation and modelling of extraction kinetics is critical for developing new ultrasound extraction processes. **The objective of this work is to investigate the effects of UAE on extraction yield and kinetics of fucose from *A. nodosum***.

Materials and methods

Seaweed samples

Brown seaweed *A. nodosum* was supplied by Arramara Teoranta, Co. Galway, Ireland. Seaweed samples were washed thoroughly with fresh water to remove epiphytes and salt. Fresh seaweed samples were oven dried using air at 40 °C for 12 hours. Dried seaweed was powdered using a hammer mill (Retsch SM100, GmbH, Germany) and sieved through a 0.5 mm mesh. Samples were stored at 4 °C prior to extraction studies.
**Ultrasound pre-treatment**

Four grams of *A. nodosum* powder were extracted using 40 ml of 0.03 M HCl. A 750 W ultrasonic processor (VC 750, Sonics and Materials Inc., Newtown, USA) with a 13 mm diameter probe was used (Figure 1). Samples were processed at a constant frequency of 20 kHz. Ultrasonic energy was controlled by setting the amplitude of the sonicator probe. Ultrasound pretreatment was applied for 10 min at amplitude levels of 20%, 60% and 100% which correspond to UIs of 7.00, 35.61 and 75.78 W cm\(^{-2}\). For control samples no ultrasound pretreatment was employed. Ultrasonic power dissipated was calculated at each amplitude level, with temperature (T) recorded as a function of time (t) under adiabatic conditions using a T-type thermocouple. Ultrasonic intensity (UI) dissipated from an ultrasonic probe tip with diameter \(D\) is given by Eq. (2)

\[
UI = \frac{4P}{\pi D^2}
\]  

Ultrasound pretreated samples were transferred to an orbital shaker (Model S01, Stuart Scientific, United Kingdom) operating at a constant speed of 250 rpm. Samples were withdrawn after 1, 2, 3, 4, 6, 8, and 22 hours and centrifuged at 5,000 rpm for 10 min using a laboratory centrifuge (Rotina 380, Andreas HeHich GmbH & Co. KG, Germany). Supernatant obtained from the extract was fucose content as a measure of fucose containing sulphated polysaccharides.

**Figure 1.** Schematic diagram of ultrasound assisted extraction assembly with probe system of ultrasound equipment, illustrating mechanism of bubble cavitation (A – Ultrasound generator, B – transducer, C – ultrasound cylinder probe, D – beaker with sample and solvent of extraction, E – bubble cavitation phenomena, F – thermocouple, G – data recorder)

**Fucose content**

Fucose content was determined by the method of Dische and Shettles (1948) with slight modification. Extract of 0.2 ml was added to 0.9 ml of a 6:1 mixture of sulfuric acid and distilled water. This mixture was maintained at room temperature for 3 min followed by 10 min at 100 °C. Test tubes were cooled to room temperature and 20 µl of L-Cysteine-hydrochloride solution was added. After storing at room temperature for 60 min, absorbance was measured at 400 and 430 nm. The effective absorbance was calculated as A\(400\)-A\(430\) nm.

**Extraction kinetics**

Peleg’s kinetic model was fitted to the experimental data obtained for extraction of fucose. Nonlinear regression was carried out using GraphPAD Prism Version 5.0 software. The following two-parameter, non-exponential model proposed by Peleg (1988) for sorption kinetics was employed to model the extraction kinetics fucose.
\[ C(t) = C_0 + \frac{t}{K_1 + K_2 \cdot t} \]  

Where, \( C(t) \) is the concentration of targeted compound at time \( t \) (h), \( C_0 \) is the initial concentration of fucose at time \( t = 0 \) (mg/g<sub>db</sub>), \( K_1 \) is Peleg’s rate constant (min g<sub>db</sub>/mg) and \( K_2 \) is Peleg’s capacity constant (g<sub>db</sub>/mg).

**Results**

The yield of fucose increased with increasing UI (Figure 2). When the UI was increased from 7.00 to 75.78 W cm\(^{-2}\) with 0.03M HCl as solvent, the yield of fucose increased from 81.03 to 135.76 mg/g<sub>db</sub> respectively after treatment.

![Figure 2](image_url)  

*Figure 2.* The extraction kinetics of fucose content with acid as a solvent for control (○) and UI of 7.00 W cm\(^{-2}\)(□), 35.61 W cm\(^{-2}\)(△) and 75.78 W cm\(^{-2}\) (●) respectively. (symbols – experimental data; lines – predicted values by Peleg’s model).

The products of partial hydrolysis of fucoidan are monosaccharides such as fucose and oligosaccharides which possess biological activity (Ale et al., 2011b; Hahn et al., 2012). Marcel Tutor Ale, Jorn Dalgaard Mikkelsen, and Anne S. Meyer (2011a) reported that 0.03M HCl concentration was optimal for the extraction of fucose containing sulphated polysaccharides from *Sargassum* sp. The extraction yield of bioactives was significantly time-dependant and increased with extraction time, especially over the first 2 hours of shaking.

**Conclusion**

At the experimental conditions investigated in this study, the yield and the kinetics of solid–liquid extraction of fucoidan from *A. nodosum* were shown to be strongly influenced by solvent type and UI level.

**Acknowledgement**

Authors acknowledge the financial support from the Irish Research Council Embark Postgraduate Research Scholarship Scheme.

**References**


ULTRASOUND-ASSISTED RELEASE OF PHENOLIC COMPOUNDS FROM OAK CHIPS INTO A MODEL WINE

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Abstract

The enhancement of the release of oak-related compounds from oak chips during wine aging with oak chips may interest the winemaking industry. In this study, the 25-kHz ultrasound waves were used to intensify the mass transfer of phenolics from oak chips into a model wine. The influences of acoustic energy density (6.3-25.8 W/L) on the release kinetics of total phenolics were investigated. The results exhibited that the total phenolic yield released was not affected by acoustic energy density significantly during sonication. Furthermore, there was no significant phenolics degradation during sonication in the current experimental range.

Introduction

Wine aging is a widely used winemaking practice to improve wine quality in oenology. The aging process is usually carried out in oak barrels. Nevertheless, this conventional technology has several drawbacks, such as its time-consuming, expensive, space-consuming, etc. (Tao et al., 2014). Therefore, oak chips are occasionally used in the winery. In this case, the extraction rate of oak-related compounds from oak wood is increased and several distinct sensorial characteristics also can be produced (Gortzi et al., 2013).

In the practical application, wine aging with oak chips usually lasts for at least a couple of weeks. However, it is reported that only a small portion of wines have the potential to improve significantly during aging (Robinson, 2003). Therefore, when it comes to age wines with low aging potential with oak chips in stainless steel tanks, the acceleration of the extraction of oak-related compounds from oak chips into wine could be welcome. Ultrasound can be considered suitable to intensify the mass transfer process occurred in wine due to cavitation phenomenon generated and the degassing function of ultrasound (Chemat et al., 2011).

The aim of this study was to investigate the mass transfer of phenolic compounds from oak chips into a model wine system under ultrasonic irradiation. The effect of acoustic energy density (AED) on the release kinetics of total phenolics was estimated. Meanwhile, the occurrence of phenolics degradation during sonication was also verified.

Materials and methods

Oak chips and model wine

The French oak chips with a light toasting (mixed varieties of Quercus sessiliflora and Quercus robur) were purchased from a local homebrew company in Ireland. These oak chips were heterogeneous in size and shape, from which oak chips in cylindrical shape with similar size were carefully selected for the following study. They had a mean diameter of 0.54 mm and length of 5.70 mm, which were measured using a Vernier caliper with an accuracy of 0.02 mm.
Furthermore, the model wine used was a 12% (v/v) aqueous ethanol solution, acidulated to pH 3.5 with tartaric acid.

**Ultrasound-assisted release of phenolics from oak chips into model wine**

An ultrasound bath system with a working frequency of 25 kHz (CQBF-1025, China Shipping Company, China) was used to assist the release of phenolics from oak chips into model wine. Concretely, this bath was a rectangular container equipped with six piezoelectric transducers at the bottom. A temperature circulator (LTD 6G, Grant, Cambridge, United Kingdom) was connected to the ultrasound bath to regulate the processing temperature. 220 mL of model wine was loaded in a 500 mL Erlenmeyer flask and the French oak chips were added to the solution at 5 g/L. After sealing tightly, this flask was immersed in the ultrasound bath and fixed well in the same position during sonication. The calorimetric method was used to measure the actual power dissipated in the flask (Mason, Lorimer and Baters, 1992). The AED was then calculated by dividing measured power with the volume of solution inside. Three AED levels were used in this study, including 6.3, 14.9 and 25.8 W/L. Furthermore, the ultrasound processing was performed at 25 °C under a continuous mode. The content of total phenolics in model wine was monitored at different time intervals (5, 10, 20, 30, 40, 50, 60, 90, 120, 150 min). All the treatments were performed in triplicates.

**Determination of total phenolic content in model wine**

The Folin-Ciocalteu method was used to determine the content of total phenolics in model wine and the result was expressed as mg/L of gallic acid equivalents (Singleton and Rossi, 1965). All the samples were analyzed in triplicates. The release yield of total phenolics was expressed as mg gallic acid equivalents per gram of the oak chip sample.

**Verification of the degradation of phenolics during sonication**

The occurrence of degradation of phenolics during ultrasound processing within the current experimental range was also verified. Specifically, the model wine solution (220 mL) with oak chips at 5 g/L was first sonicated at 14.9 W/L and 25 °C for 60 min. After that, the oak chips were withdrawn from the liquid solution by filtration. In the next step, the model wines containing phenolics from oak chips (220 mL) were sonicated at 25.8 W/L and 25 °C. The concentration of total phenolics in the model wine was monitored at 6 time intervals (0, 30, 60, 90, 120 and 150 min). All the treatments were carried out in triplicates.

**Results and discussion**

Acoustic energy density (AED) or ultrasound intensity is an important factor that should be taken into account during ultrasound processing. Figure 1 depicts the influence of AED on the amount of total phenolics released from oak chips during sonication. It can be seen that the kinetic curve of phenolics release during sonication is similar to that of batch solvent extraction of bioactive compounds from plant-based materials, which is characterized by a sharp increase of extraction yield at the beginning, namely washing stage followed by a slow increase called diffusion stage (Cacace and Mazza, 2003).

During sonication at 25 °C, the increase of AED could promote the release of phenolics from oak chips. Nevertheless, the enhancement of total phenolic yield along with the increase of AED was not prominent. After sonication for 150 min, the total phenolic yield merely increased from 24.38 to 25.30 mg/g with the increase with AED level from 6.3 to 25.8 W/L. This result was consistent with the study of Pan et al. (2011) about the pulsed ultrasound-assisted extraction of antioxidants from pomegranate peel, who found that the total phenolic yield increased slowly when the ultrasound intensity augmented from 23.7 to 45.0 W/cm². The enhancement of release of phenolics with the increase of AED was ascribed to
the improved mechanical and cavitation effect of ultrasound while the low magnitude of this enhancement was probably due to the comparatively hard surface of oak chips. Considering that the effect of AED on the phenolics release was insignificant, a low AED level can ensure the rapid leaching of phenolics from oak chips into wine, thus potentially increasing the wine flavor and nutritional value within a short aging time (Tao et al., 2014).

On the other hand, it should be kept in mind that ultrasound treatment may result in the degradation of phenolic compounds, probably due to the generation of highly reactive hydroxyl radicals (Tao and Sun, 2013). The degradation of phenolics during ultrasound processing of wine in presence of oak chips in our case should be strictly controlled, since phenolics are the main contributor to the organolectic and nutritional characteristics of wine. The stability of phenolics in model wine during ultrasound treatment in the current experimental range was investigated in terms of the total phenolic concentration in model wine. As can be seen from Figure 2, the 150-min sonication of model wine containing phenolics from oak chips at 25.8 W/L and 25 °C did not result in any significant change in the total phenolic concentration. In view of the results obtained, it could be concluded that no significant ultrasonic degradation of phenolics from oak chips occurred under current experimental conditions, although minor reactions between some specific phenolic

**Figure 1.** Influence of acoustic energy density on the kinetics of release of total phenolics from oak chips during ultrasound processing at 25 °C. Red: 6.3 W/L; Blue: 14.9 W/L; Black: 25.8 W/L. The error bars show ± standard deviation values.

**Figure 2.** The change in total phenolic concentration in model wine containing phenolics during sonication at 25.8 W/L and 25 °C. The error bars show ± standard deviation values.
Compounds and hydroxyl radicals may be generated.

Conclusions

Ultrasound (25 kHz) was utilized to assist the release of phenolics from oak chips into a model wine. Ultrasound was able to intensify the mass transfer process and a significant increase of total phenolic content in model wine was observed under ultrasound treatment for 150 min. However, the influence of acoustic energy density on the release kinetics was insignificant. Meanwhile, no significant degradation of phenolics occurred during sonication at 25.8 W/L and 25 °C. This is a preliminary study about enhancing the extraction of oak-related compounds from oak chips into wine by mean of ultrasound technology. In our future studies, the influence of temperature on the release kinetics, as well as the modeling of release kinetics will also be studied. All these studies could provide guidance for utilizing ultrasound to process wines during the aging period with oak chips and optimizing this process.

Acknowledgements

Yang Tao thanks the Chinese Scholarship Council for supporting his Ph.D. study (under UCD-CSC funding programme).

References


STUDY OF MICROWAVE-VACUUM DRYING OF APPLE SLICES USING IMPROVED METHODS

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Abstract
Drying of apple slices with improved microwave vacuum drying methods is investigated in the present study. Water puffed out of the foods due to the internal vapor pressure and is kept at the bottom of the vacuum container during microwave vacuum drying (MWVD). In order to achieve the desired moister content ratio, the water is usually removed by evaporation in the normal microwave vacuum drying process. In the present study, improved methods for removing the water are being studied, like using a vacuum line to suck the water at the bottom of the glass container, which at the same time can maintain the desired level of vacuum pressure inside the container. Drying times and qualities of dried apple slices are compared between the improved methods and normal MWVD process.

Introduction
Apple as one of the most common fruits and is an important source of vitamins and cellulose, drying processes have been widely used for a long time in food processing industries, it can assist the shelf-life of the final products. The basic objective in drying food products is the removal of water from the fresh product reaching a level at which microbial spoilage is avoided. Dried apples are great for snacks and lunchboxes. In recent years, there is increasing consumer demand for dried fruits and vegetables that retain most of their original characteristics. Convective drying as a well-known method, is the most popular way to dry fruits and vegetables (Calín-Sánchez et al., 2014). However, there are some limitations in convective drying, for example, it may have a negative effect on important flavor and nutritional compounds as well as color alteration due to the temperature of the hot air used during the process (Calín-Sánchez et al., 2014).

Microwave-vacuum drying (MWVD) is an innovative drying technology, it can dehydrate food products at acceptable expense, (Dak et al., 2014) and it has been investigated as a potential drying technology that leads to the acceleration of both heat transfer and moisture removal, resulting in quick drying at low temperatures. Because of the saturated vapor pressure of water corresponds to a certain saturation temperature, the greater the vacuum degree, the lower the saturation temperature of the water, and the easier to evaporate moisture of the targeted product (Giri and Prasad, 2007). The sensory, chemical and nutritional quality of the dried products can be maintained by the MWVD method (Han et al., 2010).

There is much research into MWVD used in food drying, however, few have studied the effect of the water which is puffed out of the food being dried on the drying time during MWVD processing. This moisture needs microwave energy for its evaporation before the foods could be dried further during the drying process. According to previous experiments, when drying the apple slices using MWVD, a portion of water from the samples was kept at the bottom of glass container during the drying process. In order to achieve the desired moister content, this water needs to be evaporated. As a result, MWVD drying time could be reduced by removing the water at the bottom of the container directly by some other ways. Meanwhile, it can also help to reduce microwave energy consumption due to the reduced need to evaporate the water.

The objective of this study is to investigate possible methods to reduce the drying time of apple slices to reach a desired moisture content ratio and evaluate the physical and chemical changes of these dried apple slices.

Materials and Methods
Sample preparation
Golden Delicious apples were purchased from a local supermarket. After being peeled, the samples will be sliced into ring form with the thickness of 0.5 cm and the cores will be removed.

Figure. 1 Schematic figure of microwave-vacuum dryer used in the present study

MVD equipment and drying process
A domestic microwave oven was modified and developed into a microwave vacuum drier. A vacuum pump with a pressure regulating valve is connected to a desiccator working as a vacuum container for maintaining the desired level of vacuum pressure inside the container. The extent of vacuum in the container is monitored with a pressure transducer. A condenser is used between the container and the vacuum pump to condense water vapor released from the samples during drying. About 80-100 g samples will be dried in the desiccator at about 20 mbar until its moisture content is reduced to c.a. 10%. Different microwave power densities are used. The weight of the sample will be recorded periodically when the microwave oven is off, using an external balance. Temperature of a slice is monitored using a fibre optic thermometer during the drying process. Improved methods are carried out to remove water from the apple slices at the bottom of the desiccator.

1) A vacuum line is installed to suck the water at the bottom of the container during drying, and meanwhile maintain the vacuum pressure inside the container.
2) The water is removed by using tissues after the container is opened. Since the operation would break the vacuum and hence prolong the drying, the operation is carried out only once. As a result, a suitable occasion should be found to remove as much water as possible.

Qualities of dried apple slices

Colour
The colour of apple slices were determined by CIE L*, a*, b* method (Hunter Lab, 2008), using a Chroma meter (CR-400, Minolta, Japan).
\[ TCD^* = \sqrt{(L_0^* - L^*)^2 + (a_0^* - a^*)^2 + (b_0^* - b^*)^2} \]

where \( L^* \), \( a^* \) and \( b^* \) are the average colour values for each dried apple slice, and \( L_0^* \), \( a_0^* \), \( b_0^* \) are those for the corresponding fresh slice.

**Instrumental texture measurement**
An Instron Universal Testing Machine (Instron Corporation, Canton, MA) is used to measure the texture of the samples (Pappa et al, 2007).

**Vitamin C**
The 2, 6-dichloroindophenol titrimetric method (Han et al. 2010) will be used to determine the contents of vitamin C for both original and dried samples to calculate the percentage of damaged vitamin C.

**Rehydration ratio**
Rehydration ratio is one of the most important characteristics of dried apple slices. It can be determined by immersing the samples under water at room temperature (25 °C) and weigh the immersed samples after 30 min (Giri and Prasad, 2007).

\[
\text{Rehydration ratio} = \frac{\text{rehydrated sample weight (g)} - \text{dried sample weight (g)}}{\text{dried sample weight (g)}} \times 100\%
\]

**Results**
As experimental work is under preparation, only expected results are given here. Samples and chemicals are well prepared based on the demand of the present study, and the equipment for the improved MWVD methods is being modified to collect the water from the foods being dried and to supply a vacuum line to suction the water. The drying time with the improved methods should be shorter than that in the normal MWVD drying process. Less energy consumption using the improved methods is also expected. The improved methods should not have negative effects on the dried food qualities.

**Conclusions**
Drying is an important process for preservation of fruits and vegetables. Nowadays, different drying technologies have been applied for apple and apple products. MWVD is an effective way to achieve good drying quality. Improved methods to remove the water driven out of the slices can reduce the drying time and energy consumption. The methods would not give negative effects on the dried food qualities.

**References**


APPLICATION OF FLUORESCENCE SPECTROSCOPY FOR QUALITY ASSESSMENT AND PROCESS CONTROL APPLICATIONS IN DAIRY MANUFACTURE: A REVIEW

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Abstract
Fluorescence spectroscopy is a sensitive, rapid and non-destructive technique, which has potential for quality assessment and on-line industrial process control applications. Its applications in various food systems, i.e., dairy, fish, meat, egg, oil, etc. has been investigated actively in the last two decades. This review aims to provide a comprehensive overview of scientific activities (i.e., quality assessment and process control) concerning fluorescence spectroscopy in dairy manufacture.

Introduction
In recent years, public interest in food quality and production has increased, which is related to changes in eating habits, consumer behaviour, and the development and increased industrialization of the food supplying chains (Christensen et al. 2006, Karoui and Blecker 2011). The high quality and safety demand in food production necessitate high standards in quality and process control. Therefore, appropriate, sensitive and rapid analytical tools are required. Due to its high sensitivity and specificity and possible use as a non-destructive technique, fluorescence spectroscopy has been exploited for studies of molecular structure and function in the discipline of chemistry and biochemistry (Karoui and Blecker 2011, Strasburg and Ludescher 1995). It has also been used to characterize food quality and monitor and control processes in various food systems (Christensen et al. 2006, Karoui and Blecker 2011). In dairy manufacture, the studies of fluorescence spectroscopy can be traced back to the 1990s, and a number of scientific attainments have been made since then (Karoui and Blecker 2011). The objective of this study is to provide the basic principles of fluorescence spectroscopy, and the use of this technique for the quality assessment and process control in dairy manufacture.

Fluorescence Spectroscopy

Principle of fluorescence spectroscopy
Fluorescence is an emission of light caused by a fluorescent molecule or substructure, called a fluorophore, after absorbing ultraviolet or visible light (Karoui and Blecker 2011). The detailed fluorescence characteristics of fluorophores are normally obtained by excitation and emission spectra. Compared with other spectroscopic techniques based on absorption, fluorescence is characterized by two wavelengths that significantly improve the specificity of the method (Karoui and Blecker 2011).

Instrumentation
The spectrofluorimeter instrument usually consists of a light source, a monochromator and/or the excitation wavelengths selecting filters, a sample compartment, a monochromator and/or the emission wavelengths selecting filters, a detector, and a unit for data acquisition and analysis (Karoui and Blecker 2011), a basic spectrofluorimeter setup is shown in Figure 1.

Traditional right angle fluorescence spectroscopic technique has been applied on transparent and diluted solutions with known fluorophores (Andersen and Mortensen 2008). Indeed, when the concentration is below a certain level, large absorbance and scattering of light lead to the decrease of both emission and excitation spectra, and excitation spectra are distorted (Karoui and Blecker 2011). To avoid these issues, front face fluorescence spectroscopy (FFFS) can be applied directly on the turbid or solid intact sample to measure various quality related parameters (Karoui and Blecker 2011, Diez et al. 2008). More recently, peoples interests are not limited to the use of only excitation and emission wavelengths to determine the quality of food systems, instead, the simultaneous determination of compounds in several food-stuffs using variation in the excitation
and emission wavelengths is required (Karoui and Blecker 2011). Therefore, synchronous fluorescence spectroscopy (SFS), which allows the consideration of the whole fluorescence landscape and retains information related to several fluorophores compared to a classical emission spectrum, which is mainly specific to a sole fluorophore, can be used (Karoui and Blecker 2011).

![Figure 1. Basic setup of a spectrofluorimeter (Karoui and Blecker 2011)](image)

**Data analysis**
Fluorescence is inherently multidimensional, and the fluorescence signals recorded from a sample can conveniently be presented as a matrix of fluorescence intensities as a function of excitation and emission wavelengths (Christensen et al. 2006). Because of the wealth of independent information contained by the fluorescence emission process, fluorescence data is highly related to the fluorophore and its surroundings. In this case, many data analysis techniques, e.g., principal component analysis (PCA), common component and specific weights analysis (CCSWA), partial least squares regression (OLS), factorial discriminant analysis (FDA), parallel factor analysis (PARAFAC), artificial neural network (ANN), have been proven to be powerful method for the extraction of valuable information (Christensen et al. 2006, Karoui and Blecker 2011, Hammami et al. 2010). Smilde et al. (2004) and Adams (2004) have well established the use of chemometrics tools in analytical spectroscopy and data analysis of fluorescence spectra.

**Applications of Fluorescence in Dairy Products**

**Fluorophores in dairy products**
Food products contain a range of naturally occurring fluorescent compounds, which are strongly related to the nutritional, compositional, and technological quality (Christensen et al. 2006). In dairy products, the fluorescence emission is primarily caused by fluorophores such as riboflavin, vitamin A, tryptophan, Maillard reaction products, porphyrins, chlorophylls, aromatic amino acids and nucleic acids (AAA+NA) and some fluorescent oxidation products (Andersen and Mortensen 2008). Fig. 2 describes the excitation and emission maxima of these fluorophores. These characteristic excitation and emission spectrums could be used to separate and identify molecules, and for the differentiation between substitutions and conformations of the same molecule (Andersen and Mortensen 2008).

**Quality assessment applications**
A number of studies introduced the applications of fluorescence spectroscopy for quality assessment in dairy manufacture. Table 1 illustrates some recent studies and fluorophores used in each study. Abbas et al. (2012) measured some chemical parameters of French blue veined cheeses using SFS, the determination were based on the riboflavin, vitamin A and tryptophan spectrum. Milk product adulteration for both vegetable oil (Ntakatsane et al. 2013) and melamine (Vasimalai and Abraham John 2013) were investigated for several dairy products.
Figure 2. Excitation and emission maxima of fluorophores present in dairy products

source: Andersen and Mortensen (2008)

Table 1. Fluorescence studies illustrating applications of quality assessment in dairy manufacture

<table>
<thead>
<tr>
<th>Applications</th>
<th>Fluorophores</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical parameter (i.e., fat, dry matter, pH,</td>
<td></td>
</tr>
<tr>
<td>protein, soluble nitrogen, etc.) determination</td>
<td>Riboflavin, vitamin A and tryptophan</td>
</tr>
<tr>
<td>Texture and other sensory attributes(b)</td>
<td>Tryptophan and vitamin A</td>
</tr>
<tr>
<td>Geographic origin determination(c)</td>
<td>Tryptophan, vitamin A and phenylalanine</td>
</tr>
<tr>
<td>Genotypes and feed systems identification(d)</td>
<td>AAA+NA, tryptophan, riboflavin and vitamin A</td>
</tr>
<tr>
<td>Milk fat adulteration with vegetable oil(e)</td>
<td>Vitamin A</td>
</tr>
<tr>
<td>Melamine determination(f)</td>
<td>Melamine</td>
</tr>
</tbody>
</table>

\(a, b, c, d, e\) and \(f\): Applications illustrating were cited from Abbas et al.(2012), Kraggerud et al (2014), Karoui (2006), Hammami et al. (2013), Ntakatsane et al. (2013) and Vasimalai and Abraham John (2013), respectively.

Process control applications

Fluorescence spectroscopy also shows potential for process control applications in dairy manufacture. In dairy manufacture, fluorescence spectroscopy could be a perfect tool for the thermal process monitoring and control, for both the temperature and Maillard browning. Also, its applications during milk coagulation and cheese ripening have been studied. Furthermore, researchers also measured the light-induced changes in different dairy products during their storage using fluorescence spectroscopy (Karoui and Blecker 2011, Andersen and Mortensen 2008, Karoui and De Baerdemaeker 2007).

Table 2. Fluorescence studies illustrating process control applications in dairy manufacture\(a\)

<table>
<thead>
<tr>
<th>Applications</th>
<th>Fluorophores</th>
</tr>
</thead>
<tbody>
<tr>
<td>Online monitoring and control of thermal processing of milk</td>
<td>Tryptophan, vitamin A, lactulose, furosine,</td>
</tr>
<tr>
<td>Maillard browning in milk during thermal processing</td>
<td>AAA+NA, NADH and FADH</td>
</tr>
<tr>
<td>Network structure and molecular interactions during milk coagulation</td>
<td>Advanced Maillard products and tryptophan</td>
</tr>
<tr>
<td>Chemical and physical changes in fats and proteins take place during cheese ripening</td>
<td>Tryptophan and vitamin A</td>
</tr>
<tr>
<td>Light-induced changes (oxidation) in dairy products during storage</td>
<td>Riboflavin, tryptophan, AAA+NA, tyrosine and</td>
</tr>
<tr>
<td></td>
<td>vitamin A(b)</td>
</tr>
</tbody>
</table>

\(a\): Information illustrating were mostly gained from review papers written by Andersen and Mortensen (2008), Karoui and Blecker (2011) Karoui and De Baerdemaekke (2007); \(b\): fluorophores used were introduced by Andersen et al. (2005).

Conclusion

This review gives an overview of the use of fluorescence spectroscopy for the assessment of dairy
products’ qualities and process control in dairy manufacture. It was shown that fluorescence spectroscopy has an ability to determine several quality attributes (i.e., chemical parameters, geographic origin, adulteration, etc.) as well as to control and monitor critical processes (i.e., thermal process, milk coagulation, cheese ripening, etc.). Even so, the application of this spectroscopy technique requires further research to investigate operational issues and test the instrument feasibility for the on-line measurements.

Acknowledgements
The authors would like to thank the financial support from the Chinese Scholarship Council (CSC) and University College Dublin (UCD).

References
Vasimalai, N. and Abraham John, S. (2013) 'Picomolar melamine enhanced the fluorescence of gold nanoparticles: Spectrofluorimetric determination of melamine in milk and infant formulas using functionalized triazole capped goldnanoparticles', Biosensors and Bioelectronics, 42(0), 267-272.
Abstract

Desorption isotherms of Microcrystalline Cellulose (MCC), for water activity ranging from 0.064 to 0.97, were determined by three methods with different dehydration procedures. The gravimetric static method using saturated salt solutions (GSM) was used as a standard method. Moisture content of MCC in GSM was lowered by taking equilibrium with 9 environments of different relative humidity ordered from high to low. In two fast hygrometric instrument methods, MCC were forced to remove moisture by silica gel (SGM) and oven-heating at 60°C (ODM). Time expenditure and repeatability/reproducibility of the three desorption isotherm measurement methods were compared. The experimental data show that these three methods gave quite similar results; however, it is obvious that the two hygrometric instrument methods were capable of recording more data points and consuming quite less time comparing with SSM methods.

Introduction

Desorption isotherms data indicate interaction forces of food biopolymers with water and availability of polar sites to water vapour, which are extremely important in predicting the product behaviour during drying, such as drying rate, energy requirements, the proper end-point of drying. They are therefore useful for modeling, designing and optimizing dehydration units and procedures, such as drying, baking, mixing, storing and packaging, to improve drying processes while minimizing processing costs. For this reason, more than 1000 scientific papers on the moisture sorption behaviour of foods have been published during last three decades (Basu, 2006). For measurement of isotherm data, Gravimetric Static Method using saturated salt solutions (GSM) is one of the most popularly proposed methods and has been used as the standard method until now. However, it takes a long time to get equilibrium, generally 3 weeks for one isotherm data (Bell & Labuza, 2000). So accelerated methods based on GSM have been proposed as modified isotherm determination methods in recent years, including oven-heating dehydration methods. However, previously published experimental data show that not all these modified methods give reliable results; some of them are capable of recording more data points and consuming quite less time, while resulting in data differentiated from that of Gravimetric Static Method (Teng, 1991), some of them were reported to be used only at a high or low water activity range, not applicable to the whole water activity range from 0.064-0.97 (Demarchi, 2013).

Considering that very few experimental sorption isotherms methods concerning accelerated techniques for isotherm determination have been reported, information on assessment and comparison of various isotherm determination methods is still limited in the literature. The objective of this paper is to investigate a novel technique to force samples into various moisture levels using Silica Gel (SGM). By comparing with Gravimetric Static Method (GSM) and Oven-heating Dehydration Method (ODM), this newly developed method is examined to see if it is a better method with greater accuracy and precision, while reducing time cost with a wider applicable range of water activity.
Materials and Methods

Microcrystalline Cellulose preparation

70 g microcrystalline cellulose (MCC) was submerged in 250 ml water and placed under a vacuum for 20 min to remove any air bubbles. The solution was stirred to reject MCC particles of large size in the sediment. Afterwards, distilled water was added until the total volume equalled as four times volume of wet MCC. After the precipitation of MCC by sitting 90 min, the supernatant with fine particles was pour off. The procedure of suspension, precipitation and remove of supernatants was repeated three times until cloudy supernatant could not be observed. Then the wet MCC was sealed in a jar in the incubator at 25 °C to get equilibrium with saturated K2SO4 solution with the known relative humidity of 97%. The equilibrium should take no less than 3 weeks.

Gravimetric Static Method (GSM) (Gal, 1975)

27 × 0.5 g samples were sealed in 9 jars to get equilibrium with 9 saturated salt solutions with different relative humidity at 25 °C (LiBr 6.4%, LiCl 11.3%, CH3COOK 22.5%, MgCl2 32.8%, K2CO3 43.2%, NaBr 57.6%, NaCl 75.3%, KCl 84.3%, K2SO4 97.3%). Samples were weighed once a day until the difference between two consecutive measurements was less than 0.0002 g. After equilibrium, dry basis of each MCC samples was determined by oven drying (4 h / 105 °C). Isothermal curve of MCC was determined in the standard Gravimetric Static way.

Oven-heating Dehydration Method (ODM)

27 × 0.5 g samples were put in the oven at 60°C. One sample was weighed every 5 min. When the weight of the measured sample reached at around (M - 0.01 × n) g (M means the original weight of the sample before moving into the oven; n means the ordinal number of sampling times), three of all the samples were taken out and sitting in small sealed pot for no less than 3 days to get uniform moisture distribution under 25 °C. Water activity was then determined by Novasina LabMaster-Aw (Switzerland, Novasina Ltd.). Moisture content was calculated afterwards by dry basis measurement drying in an oven at 105 °C for 4h.

Results

The experimental data show that these three methods gave almost the same results; however, it is obvious that the two hygrometric instrument methods (SG, OH) were capable of recording more data points and requiring quite less time comparing with GSM methods. It is worth mentioning that, for real food such as fruits, the oven-heating method (OH) was reported to be used only at a high water activity arrange for non-hygroscopic behaviour of sugar-rich samples after processed by oven-heating (Demarchi, 2013). While it was possible to determine the sorption isotherms of whole water activity range from 0.064-0.97 by silica gel method (SG), which helped retaining sample’s structure during dehydration.
Figure 1. Comparison of three isotherm determination methods (GSM, SG, OH)

Conclusions

Through agreement assessment, the three methods led to almost the same results. Considering the reduced cost of time and retaining food structure at the greatest degree, dehydration with silica gel and sitting for moisture homogenization for around 3 hours were recommended.

Acknowledgements

The authors gratefully thank the financial support from the European Commission, 7th Framework Programme.

References

COMPARISON OF THE PROPERTIES OF SYNTHETIC FUELS PRODUCED FROM PLASTIC WITH RESPECT TO CONVENTIONAL FOSSIL FUELS

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Abstract
Alternative fuels in the form of synthetic diesel can play an important role in Ireland achieving its 2020 transport fuel targets. All synthetic diesels must meet the standards set down by the European committee for standards to be used for road transport. This study tested samples produced by Cynar PLC which has a capacity to produce 9500L of synthetic diesel daily. The results of the testing will show what affects different blends of plastics used in the production of the diesel have on its properties.

Introduction
In response to the European Commission Directive 2009/28/EC, Ireland implemented a biofuels obligation scheme to meet targets set down by the EC (EC 2009). The target for 2020 for transport in Ireland is that a minimum of 10% of transport be fuelled by renewable energy. However the EC and subsequently Irish policy has not included any alternative fuels i.e. fuel from waste (cyn-diesel) in this target. This is something that should be given serious consideration as the 2010 transport target fell short of 5.75% set down achieving only 3% fuelled by renewables (DCENR 2012). Currently in Ireland Cynar PLC are capable of producing 9500L of synthetic diesel a day from 10 tonnes of plastics through a pyrolysis procedure. This could be used to help Ireland meet its targets if synthetic fuels were considered along with renewable fuels.

Fuels sold for transport must meet specifications to ensure they perform adequately in combustion engines. The European committee set the EN 590:2009 standard to which fuels sold for transport must adhere. The methods for testing fuel specifications are also set in this standard. Therefore the properties of the fuel are critical if it is to meet these standards. Viscosity is very important as it may limit the use of the fuel in engines. The viscosity will affect the atomisation quality and size of the drops on injection into the combustion chamber. Too low a viscosity can cause leaks in the system where as too high can lead to incomplete combustion and the untimely build-up of deposits leading to premature wear on the engine and early pump and injector failure. The density of the fuel has direct effects on the performance of the engine (Torres-Jimenez et al 2011). The cetane number and heating value are linked to the density of the fuel. The minimum cetane number is 51 and maximum density at 15°C is 845kg/m³. Changes in fuel density will alter the power output of the engine. The pour point is used to define the lowest temperature that the fuel can be moved at before it turns to gel. This is important especially where the fuel is to be used at lower temperatures such as cold climate conditions. The distillation is used to class the fuels in terms of the boiling point of its components. This is of particular importance to engine performance and safety as it affects flash point. The maximum distillation at 95% v/v is 360°C, maximum PAHs are 8% m/m, maximum sulphur content is 10mg/kg and maximum FAME – EN14078 is 7% v/v (EC 1998).

The aim of this study is to test the properties of samples of synthetic diesel produced from different blends of plastics.
Materials and Methods

The samples are provided by Cynar PLC and testing will be carried out in the oil laboratory in Rialta environmental and in UCD. A sample of the light fuel fraction and the diesel fraction will be tested and these will be compared to petrol and diesel produced from conventional fossil fuels. 5 replicates of each sample will be tested to demonstrate reproducibility in the testing. Tests will be carried out to determine any differences in the properties of the synthetic and conventional diesel samples and the synthetic light fuel and conventional petrol samples.

Flash point
The flash point will be determined using a Setashift Series 3 Plus Closed Cup Flash Point Tester-Auto Ramp which can determine the flash point of a sample within a temperature range of 0°C to 300°C.

Water content
The water content will be determined using an Automatic Volumetric Karl Fischer Titrator Water Content Analyser.

Viscosity
In accordance with the standard D445 testing methods the kinematic viscosity will be determined at 40°C by multiplying the constant of the viscometer tube and the measured efflux time. The efflux time is the time taken for a known volume of liquid to flow through the capillary viscometer under gravity (Alptekin and Cankci 2008).

Density
Density will be measured using the D941 standard testing method which will be carried out at 15°C using a density meter (Alptekin and Cankci 2008).

Polycyclic aromatic hydrocarbon (PAH) content.
PAH content will be carried out using gas chromatography. The sample will be prepared in hexane using standard lab procedures and PAH levels will be measured for each sample.

Sulphur and metal contents
Sulphur content and metal/element content will be determined by X-ray fluorescence analysis (XRF). Samples will be prepared using standard lab methods and loaded into the XRF analyser for analysis.

Ash and particulate content
Ash content will be determined by difference of weights before and after combustion taking into account the water content. Particulate matter will also be determined by difference of weights after a filtration procedure and subsequent drying process.

Statistical analysis
Statistical analysis will be carried out to determine the level of significance in the results and to show any correlation between plastics used and properties of the diesel samples.

Results and Discussion

As the experimental work is in its very early stages there are no results to report on yet. It is expected that the diesel sample will meet or be very close to meeting the EN 590:2009 standards. A study by Murphy et al (2012) showed that samples of synthetic diesels produced from varying blends of plastics met the standards when blended with road diesel up to 40%. It is anticipated that differences will be determined between the synthetic diesel and conventional diesel along the possible impacts these differences will have on the use of the...
diesel in engines. The light fuel sample should differ slightly from conventional petrol and a
will determine to what extent they do differ and what this means for the use of the light fuel
fraction of the pyrolysis procedure.

Conclusions
In conclusion the results of the experimentation carried out will determine how the synthetic
fuels compare to the conventional fossil fuels. This will give Cynar a better understanding of
where their final product is in comparison with what is currently available on the market. If
the synthetic fuels can be shown to meet the EN590:2009 standards then there may be a call
for discussion on potentially including the use of synthetic fuels to help Ireland meet its
transport 2020 targets. The properties of the fuel will be influenced by the plastics they are
made from so determining what these properties are may allow for the manipulation of the
plastic feedstock to produce a more desirable fuel. In a study by Pinto et al (1999) it was
shown that the composition of the plastics used had certain effects on the product formed
from the pyrolysis. Of the 3 plastics used polyethylene (PE) had the highest octane number
followed by polypropylene (PP) and then polystyrene (PS). They all had varying boiling
points and in most cases with the exception of density the product differed slightly from each
of the plastics. PE had the lowest density of the three. It may be expected that different blends
of feedstock may contribute to different quality of fuel output

Acknowledgements
The authors would like to thank Rialta Environmental for the use of their laboratory and
equipment.

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plastic waste composition on product yield”. Journal of Analytical and Applied
Pyrolysis. 51(1-2), 39-55.
ECOLOGICAL FOOTPRINT OF A MULTIFUNCTIONAL DUBLIN CITY-CENTRE VENUE

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Abstract
The hospitality sector is a competitive market. To survive in this market, a business must out trump its competitors. This study focuses on the key aspects of this industry: food, interior and energy consumption with the aim of reducing waste in the named areas. Securing comfort level for the clientele and an intransigent approach regarding business operations is the objective. Cross-disciplinary collaborations with various sectors were approached. The latter guarantees best results, expands relations and establishes new possible dealings amongst the sectors. Innovative ideas and teamwork was the course of action in this study.

Introduction
Global warming, acidification potentials of various kind, and waste management problems are increasingly the centre of daily conversations amongst modern society. Across the globe, media reports of raising environmental problems warn the population of possible health risks. The political aspect, as well as the environmental and economical of the current situation lead to the conclusion that society must change its ways. Resources are being used in a careless manner. News of countries with the transgression of air pollution level of acceptable limits is being reported in shorter intervals. Not to mention the “Fishlove” campaign (http://www.fishlove.co.uk) against the serious problem of over fishing, this has a massive impact on the ecosystem and may even lead to a mass extinction of aquatic species. Their example of the plight of the Sturgeon fish in Russia might illustrate the gravity of the situation. From a consumers’ perspective therefore, a clear labelling of products favours the support of personal beliefs and preferences, e.g. sustainable versus common produced goods. Namkung et al (2013) highlights that 62% of consumers are more likely to spend their money in a ‘green restaurant’. Their paper highlights the importance of green practice in the hospitality sector, as this is a crucial aspect of the creation and management of a strong brand in a highly competitive sector. Depending on the classification of the restaurant, consumers’ perception varies. Using recycled paper is highly regarded in a fast food establishment whereas organic meals are priority in casual dining surroundings. Chen et al (2012) state that compared to other commercial building restaurants uses approximately five times more energy per square foot. An improvement of environmental approach requires therefore a new way of thinking. The psychology behind human-behaviours’ prediction and its understanding is crucial, since this appears to be key to gain customers loyalty and satisfaction. In the latter study, one out of three Taiwanese is health conscious but not concerned about environmental sustainability. Still encouraging the green approach, Chen et al (2012) emphasize that implementing this model is economical and environmentally friendly as well as it raises public awareness. Acceptance of a new way takes time and further analysis is encouraged.
There is also another very important aspect: energy consumption. Bohdanowicz (2006) lists the upper limits in energy consumption, established by Nordic Swan Eco label as 235- 460 kWh/m². The average Swedish hotel consumes 198- 379 kWh/m². Depending on location and services offered. The SEAI website does not list a precise Irish consumption in this sector, nor could Irish data of this nature be found as per date.

The objective of this study was to determine the ecological footprint of a multifunctional venue by lowering the water/ energy footprint and securing an organic food source.
Principle of Design and Operation

Alternative Protein-source

Meat production in selected countries in Europe has increased by between 5% and 13% over the last 15 years; the increase in consumption leads to an increase in energy consumption per tonne between 14% and 48% amongst those countries. The trend in the meat consumption is a higher demand for white meat such as poultry caused by several scandals in the beef sector such as BSE. For the health conscious population the option of a low fat meat such as poultry meat seems to be the solution. From a producer viewpoint: low prices are due to an increased saturation in a very liberal market and, compared to other meat, animal efficiency. According to European reports, non-dairy cattle take 24 kg of feed to produce 1 kg of meat and pigs require 6.2 kg of feed to match the 1 kg of meat production. Compared to these numbers a chicken only takes 3.1 kg of dry matter feed (Ramirez et al (2006). Bird Flu and antibiotic scandals dominate the consumers concern. In order to restrict external negative influences, the solution for this Dublin restaurant would be to produce its own meat.

The restaurant’s menu ideology is to produce only 10% of meat dishes. Summing up the outcome of the meetings between the researchers and the business; the aim is to find a low impact meat in the category water-footprint, energy consumption and as organic as possible (which logically derives a high water-footprint). Guinea Pigs are Peru's national dish. Bland (2013) highlights that more people are open to this alternative meat/protein source. To establish a market-potential for this meat, the public’s perception was asked in Dublin City around Christmas 2013. Thanks to a high number of American female tourists who already experienced this meat or would be willing to do so the response was rather positive. A proper survey will be conducted and will include several European countries. The reason for this is explained in Dublin being a tourist attraction. For this aspect of the research, health and safety will be a priority. Regulatory requirements, appropriate slaughter methods for the animals and a minimising of waste will be respected.

Sustainability of products - sugar

Another important aspect of this research is the guaranteed supply of core nutritional products that match the philosophy. Various online footprint calculators may illustrate the individual impact of some products. When looking at everyday products such as tea or coffee, some practices may appear questionable. Moving to the sugar-industry, a look at the Forbes list 2013 may illustrate that this industry is led by a handful of companies/individuals. With LCA being one of the methods of choice to evaluate environmental impacts, Moya et al (2013) proceeded with a comparison of alternatives to reduce the environmental burden.

The nature of this research is to find new, alternative solutions for an everyday impact. Since the focus of this research lies in finding alternatives: the aspect of subsidizing the majority of sugar requirements with the Date fruit appear to be a way to go. This fruit is found to be rich in potassium, iron and vitamin B12 amongst other benefits. The restaurant will operate mostly on a vegetarian scale; therefore this fruit could bring more benefits to the consumer than just its use in desserts. Being a desert plant and reaching an average height of 20 metres, this could be a great opportunity for cross-discipline collaboration within Dublin City. For example with the botanic garden or other institutions specialised with plants of all kinds. Not only could this be beneficial for the profile and ranking, a possible new sector raising Ireland’s profile may lie ahead.

Sustainability of products: shiitake mushroom

This restaurant aims to make an impression to the visitor as well as illustrate that what society considers as normal (e.g. strawberry supplied in winter) is in fact a marvellous collaboration of various scientists in food, energy and many other sectors. The truth of the matter is that nature is breath-taking. The shiitake mushroom grows due to vibrations in the earth. In
Ancient China, mushroom pickers used to create mini vibrations in the earth-trees. The palpitation encouraged the mycelium fungus to produce the fruiting body; the shiitake mushroom (Merkt, 2013). If this mushroom was to be grown in the restaurant, small vibrations caused by the average noise level in a restaurant ranging from 50-90 decibels may enhance the mushrooms growth. Not only would it add a futuristic and novel aspect of the restaurant but perhaps add to more knowledge and respect for nature. As well as that, it would ensure a low impact product is obtained.

Electrical appliance
Electrical equipment as a source of energy consumption is a focus of this study. As mentioned previously, Bohdanowicz (2006) illustrated the average energy consumption in the Swedish hospitality sector is 198-379 kWh/m². In the greater Dublin Region, Liu et al (2012) investigated the aspect of energy use in household heating in various housing conditions. The latter study can be implemented in this project for the following reason: energy efficient housing and the focus in sustainable urban planning are methods to reduce emissions and meet targets. The study highlights that apartment and houses built after 2001 require less energy for heating. Modifying our model to these conclusions may lead to a significant reduction in this aspect since the aim for all green corporations is to reduce energy consumption to a minimum while maintaining the comfort level of the clientele and workforce and not compromising business operations. The ideal scenario leaves no room for energy inefficiencies. Addressing the vast dimension of electrical appliances present within this area of premises, energy saving mechanisms must target all electrical appliances to secure savings opportunities. The key is a monitoring and recording of power consumption readings and evaluating whether equipment is properly operated. As for the latter, the authors approached a Dublin based company called Wattics, voted 2012's Best Emerging company in Ireland by InterTradeIreland. In an email and telephone response with the CTO of Wattics, Anthony Schoofs (2014) explained that appliance-level monitoring can immediately uncover energy saving opportunities over 20%. An implementation of the Wattics solution combines the deployment of an electric meter to collect electricity readings and the application of software on the readings to automatically discover wasted energy and to recommend immediate energy saving actions. Data collection may be permanent or performed over a 2-month period and repeated every year to secure the best savings patterns. This solution might outperform existing restaurant models and prove to be a key aspect of achieving the 'green goal'.

3D printer
Another way of reducing the ecological footprint could be to introduce a 3D printer. Plates and glasses could be made with a company logo which would be the key asset in this establishment: brand creation as explained by Namkung et al (2013). The plates and glasses would be moulded again into new shapes with perhaps the launch of a new menu, which mostly occurs four times a year. This was the result of a low profile investigation across Dublin's restaurants and were explained with the four seasons and therefore secured seasonal fruit and vegetable supply to a reasonable cost and margin balance. Further research has to be done to secure health and safety regulations, as well as ensure critical endeavours are met.

Menu cards
McDonough et al (2009) printed their book in plastic instead of paper. They admit their unconventional idea was 'stupid' but that's seen from a publishing-profit (quite costly) and durability of the book (compared to a paper book the lifespan is shorter) side of view. The plastic resins and fillers can be washed off and reused to print a new menu in our concept. Therefore in the case of our study it actually makes sense not to use paper. Plastic in this aspect appears to be the better solution. In an environment, where the menu changes with the seasons, as established in the 3D printer section, this solution is futuristic and actually more hygienic, considering the amount of guests touching the cards.
Discussion

As responses from companies are outstanding, only possible options are listed here. Not knowing the exact location of the restaurant and its size narrow this research to assume generalised needs in this sector. As well as that, questionnaires for countries including: Switzerland, Germany, France, Norway, Italy, Croatia-Bosnia, China, Belgium, UK, America and Spain, in various languages will be circulated and evaluated. This is in regards of the alternative meat source and for the reason that there are tourists as well as locals that one can expect in Dublin. Nevertheless the team showed already great results and is keen to deliver more.

Conclusions

This study will include various collaborations across various sectors and all over the Leinster area and the boundary might be even extended depending on the communication outcome. It is obvious that this is an ambitious project and therefore a team effort of all involved parties. The study has been split into different sections to quantify the individual footprints of each section. Diverse experiments will be carried out to determine the latter.

Acknowledgements

This publication could not have occurred without the generous participation of the public in expressing their thoughts on various aspects. As well as that, Wattics was the first company offering their expertise. This could be the key factor for the permanent reductions in electricity consumption of the restaurant.

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ASSESSING THE PUBLIC PERCEPTION OF WIND FARMS IN IRELAND THROUGH QUANTITATIVE RESEARCH

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Abstract

There is a need in Ireland for more theoretically based social research that seeks to understand why members of the public accept or reject wind farm developments. This objective of this study is to conduct a case-control survey to identify what factors influence the public perception of wind farms in Ireland and to test the hypothesis of whether there is an overriding negative perception of wind farm developments in Ireland. Two case studies and two control studies in County Clare will be surveyed with the results being interpreted using a variety of data analysis techniques. The results are expected to be highly variable across each study with the main hypothesis likely to be disproved. The research will aim to highlight the complexity of variables that shapes an individual’s perception and opinion of wind farms.

Introduction

Concern has increased amongst scientists and policy makers over the potentially harmful consequences of climate change. As a result, many countries have sought to increase the amount of energy generated from renewable resources (Devine-Wright 2005). Wind turbine technology is the most frequently used and economically profitable of all renewable energy technologies, and as of 2011, 83 countries have employed wind power on a commercial basis (Read et al. 2013). According to the Global Wind Energy Council (GWEC), the annual global capacity has grown by 30% every year from 17 GW in 2000 to 318GW in 2013 (Read et al. 2013). Closer to home, Ireland has a total installed capacity of 2232 MW from 192 wind farms, with this figure is set to increase in the coming years. But despite broad public support in Ireland for wind energy, wind farm developments are often met with opposition from the public, particularly from local residents living within close proximity to these developments. Research into social perceptions of wind energy developments has become an active, if still evolving area. The existing research into public perception highlights that there is a fundamental difference between attitudes towards wind energy and attitudes towards wind farms. Public opinion research has shown that wind power has the highest approval rating of any method of electricity generation with an 82% approval rating overall. However there is still disjunction between public support for wind energy and successfully building wind energy facilities (Graham et al. 2009). Opponents cite local environmental impacts, visual impacts, economic and social impacts as reasons for challenging the construction of wind energy facilities (Graham et al. 2009). Opponents cite local environmental impacts, visual impacts, economic and social impacts as reasons for challenging the construction of wind energy facilities (Bidwell 2013). This gap between general public support and local opposition to commercial wind farms is commonly attributed to a “not in my backyard” (NIMBY) mind-set within the public (Bidwell 2013). This explanation means that while people view wind energy as beneficial to society, their self-interest leads them to oppose the construction of wind farms in their community. This has been discredited by researchers in recent years and is now generally viewed as a pejorative. However, others researchers highlight that opposition is more complex than simply a lack of knowledge, a lack of participation or NIMBYism, and that theoretically based social research that seeks to understand why members of the public accept or resist wind farm developments is strongly needed in Ireland.

The objective of this study is to develop a case-control survey to identify what factors influence the public’s perception of wind farms in Ireland and to test the hypothesis of whether there is an overriding negative perception of wind farm developments in Ireland.
Literature

From the literature, it is evident that the vast majority of studies focus on the analysis of public perception of planned wind farms. Very few studies deal with issues of public acceptance in areas with existing wind farms. In a review by Devine-Wright (2005) he identifies several distinct aspects of wind power that shape public perception. He characterises them as ‘independent variables’ influencing how wind farms are perceived and accepted (see Table 1). These include physical, contextual, political, socio-economic, social and personal aspects that reflect the multi-dimensional nature of forces shaping public perception (Devine-Wright 2005). A study by Warren et al. (2005) analysed public attitudes towards existing and proposed wind farm developments by using case studies in Scotland and Ireland to test three counter-intuitive hypotheses. These hypotheses were derived from previous attitudinal research. These were (a) that local people become more favourable towards wind farms after construction; (b) that the degree of acceptance increases with closer proximity to them; and (c) that the NIMBY syndrome does not adequately explain variations in public attitude. They identified that the larger majority favoured wind power developments in principle and in local practice, and that even though some aspects of NIMBY attitudes existed in their findings, they found that their surveys revealed an ‘inverse NIMBY’ syndrome, whereby those living near wind farms still strongly supported the technology (Warren et al. 2005). Baxter et al. 2013 conducted a case-control study in Ontario, Canada, to study the roles played by the perceptions of health risk, economic benefits/fairness and intra-community conflict. The report compared findings from communities living with and without turbines in their communities. They found that 69% of residents in the case community would vote in favour of local turbines compared to 25% in the controlled community. They also found that concern about intra-community conflict is high in both communities (83% for case & 85% for control) as is concern about fairness of local economic benefits (56% and 62% respectively) (Baxter et al. 2013). An interesting study conducted by Eltham et al. (2008) assessed whether pre-construction opinions held by communities near wind farms changed after an extended period of time. The residents of St. Newlyn, Cornwall, were asked to recall their opinion of Carland Cross windfarm in 1991 and 2006. The results of the study showed significant statistical changes in opinions regarding the windfarm’s visual attractiveness and the energy security it provides. There was an increase in both the number of residents that found the turbines visually attractive and the number of residents that considered the secure form of energy that the wind farm provides to be a valuable asset (Eltham et al. 2008).

Table 1. Devine Wrights (2005) (p 135) ‘summary of factors identified in past research as affecting public perceptions of wind farms and renewable energy’.

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<td>Public participation and consultation</td>
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<td>Social and communicative</td>
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<td>Symbolic and ideological</td>
<td>Representations of wind turbines</td>
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<td>Local</td>
<td>Place and identity processes</td>
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<td></td>
<td>Local or community benefit and control</td>
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<td>NIMBYism</td>
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<td>Personal</td>
<td>Previous experience and knowledge</td>
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Methodology
Based on the findings of previous research explored in the literature review, an appropriate survey will be developed to test the hypothesis of whether there is an overriding negative perception of wind farms in Ireland. The survey will compare communities that live within close proximity to wind turbines with communities that do not have wind turbines in their immediate vicinity. This case-control approach will highlight analytical relationships that will more closely resemble “explanations” than just descriptions as described in (Devine-Wright 2005). Univariate summaries and bivariate analysis will be used alongside multivariate analysis, as multivariate analysis can sometimes mask important relationships (Baxter et al. 2013).

Questionnaire and Analysis
Although there are no set rules for developing a questionnaire, a set of guidelines based on the collective experience of numerous researchers will be followed. Utilising these guidelines will minimise the likelihood and severity of data validity problems. The questionnaire for this study will be divided into several key areas of public perception. These areas include current knowledge and experience of wind energy, visual impacts, health impacts, environmental impacts, economic impacts, social impacts and awareness of site selection procedures. The majority of questions on this survey will be measured using a five point Likert Scale from strongly disagree to strongly agree (Baxter et al. 2013). The univariate analysis will consist of measuring the percentage of respondents in each ordinal Likert category with the case and control values beside each other (Baxter et al. 2013). Two forms of bivariate analysis will be considered in this study, these include either a (1) chi-squared (chi²) test and a comparative mean t-test or (2) the ordinal Spearman correlation (Baxter et al. 2013). Linear regression analysis will also be considered as some items may have to be aggregated into multi-item scales (Baxter et al. 2013).

Target Populations
Two case studies will be examined as part of the research, the current Booltiagh Wind Farm (Case Study 1) and the proposed Shragh Wind Farm in Co. Clare (Case Study 2). The Booltiagh wind farm is 3 km from the villages of Lissycasey, Kilmaley and Inagh, and the proposed Shragh wind farm is located directly south east of Doonbeg on the coast. Booltiagh Wind Farm is the largest in the county at 36MW with plans for an extension which will see the capacity increase to 47MW. The Shragh Wind Farm if built will be located within an area popular to tourists, attracting golfers, surfers and holidaymakers. Two controls will also be examined in this study, the town of Ennis, Co. Clare and its immediate surroundings (Control 1) and also the North West of Clare (Control 2). The area in the North West of Clare will include the villages of Ennistymon, Lahinch, Lisdoonvarna Doolin Liscannor and Kilfenora. These villages form a circle roughly 10km in diameter, and there are no wind farms in the immediate vicinity of any of these towns.

Sampling
The sample size will be about 50 for both case and control studies, making the overall sample size 200. A random sample of houses will be chosen within a 5 km radius of each wind farm for both case studies, the town of Ennis and its surroundings will be taken on its own, and for the control study in North West Clare houses will be selected at random within a 5 km radius of Ennistymon. Accessing the target populations set out in the study will require several approaches. The first approach will be to conduct the survey face-to-face. This could be done using a tablet computer. The response rate is normally high with this approach, but it can be time consuming. The other approach would involve sending a letter to each house explaining the outline of the survey enclosed with the survey URL. The intent of the survey will be clearly introduced as “perceptions of wind turbines and how they are linked to residents support or opposition to wind turbines in their community”. This approach doesn’t always
guarantee a response, so the amount of houses that will need to be targeted will have to be high to guarantee that the sample size is met.

Results and Discussion

As research is currently ongoing, only expected results will be discussed in this section. The hypothesis will more than likely be disproved; however the results may be highly variable across each study. The results from both case studies will probably be very different, and there is an expectation that communities living near Case Study 2 will have a more negative perception of wind farms than communities living near Case Study 1. Concerns surrounding environmental, visual and economic impacts are expected to be more apparent in Case Study 2 due to the area's visual beauty and the potential impact the wind turbines could have on tourism in the area. Results for Control 1 should reveal strong support for wind power, with economic and political interests expected to dominate. Control 2 could be split down the middle, with one half in support of wind turbines and the other half against. Further research and precise data analysis should shed more light into the complex matrix of public perception within these populations.

Conclusions

This research illustrates the complexity of variables that shape an individual’s perceptions and opinion of wind farms. Some say much of the debate over windfarms comes down to location, and that site selection and scale is crucial and that cumulative impacts must also be considered while others say that factors other than siting location and turbine construction play a large role in influencing perception. This research has the potential to produce some rich findings which will only further enhance our understanding of wind farm perception.

References

WATER FOOTPRINT IN THE MEAT INDUSTRY

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Abstract

The water footprint related to consumption of animal products stands out significantly in the total water footprint of humanity. Agriculture accounts for about 92% of the fresh water footprint of humanity out of which one third relates to animal products and the rest relates to industrial products and domestic water consumption. In this study, the water footprints of the meat industry in different countries and their policies are reviewed and compared to the Irish meat industry. A general outlook is obtained about the water usage in different European countries for different types of meat such as beef, pork and lamb.

Introduction

In meat processing, water is primarily used to for cleaning of the carcass after hide and hair removal and evisceration. Its secondary usage is cleaning and sanitizing the mechanical equipment like pumps and compressors. The desire of reducing carbon footprint is highly recognized, but the relative and equally important need to reduce the water footprint is often ignored. Animal products such as meat have a particularly large requirement of water per unit of nutritional energy or calorific value when compared to the food from plant origin. The total grain(wheat) cultivated throughout the world is not for the human consumption but for animal consumption. According to the Food and Agriculture Organization of the United Nations (2011), 37% of the cereals that were produced in the world were used as animal feed.

Yet, very little attention is given to the relation between meat consumption and water use. It is also important to note that meat production not only doubled during the period from 1980-2004 (Ternes 2014) but is also projected to double again in the period from 2000-2050 (Steinfeld et al. 2006).

Ireland is known for quality meat products and the Irish beef industry remains as one of the most important source of exports for the country. Irish beef plants can be categorised on the basis of final products which can be chilled sides, cutting and boning, cooking, canning, etc. Apart from meat production, it also needs to emphasise reducing production cost along with improving efficiency, quality and environmental standards.

As the production cost of meat is significant, it is obvious that a large amount of water is used in the production of this meat, which may directly or indirectly have an effect on the environment. To control this, the EPA has set several guidelines for meat processing facilities. These guidelines will be discussed further in the report. The major attributes that will be considered will be the water footprint within individual processes of the meat industry and their overall impact. Additionally, the water footprint of some major European meat processing industries will be assessed and compared to the Irish meat industries.

The objective of this study was to determine the water footprint in meat industry from an Irish perspective and compare the results with the meat sector throughout Europe.

Materials and Methods

European Beef Processing

Europe is one of the major meat producers of the world and the EU alone accounts for about 16% of global meat production('Global Meat News' 2013, Reed 2013). The current EU policies in the meat sector are designed to encourage the production of meat in a nutritious safe and economically affordable way. These policies are geared continuously to meet the needs of livestock producers,
consumers and the environment in a balanced way. Details of some of the major European meat producing countries are discussed below.

Denmark

Denmark is one of the largest pork producing countries in the EU, producing about 28 million pigs every year of which 90% is exported mainly to the EU. Demark has improved its pork producing programme extensively. With the employment of Best Available Techniques (BAT), there has been a reduction of the water footprint by about 50%. Also with the government strategy plans like 'Green Growth', the Danish slaughter houses, which are ISO 14001 certified, have observed a significant drop in waste water emissions (e.g. Chemical Oxygen Demand (COD)).

Germany

Germany is one of the top EU meat producers and has the second largest cattle population in Europe. It is the European leader in pork production and comes second after France in beef production. Numerous approaches have been adopted by the government to control the nation's water footprint. There have been Life Cycle Assessments done to calculate the water footprint in the pork processing industry which includes green, blue and grey water. The first water footprint of pork was calculated in 2012 which is 59.7 litres for 1kg of pork (slaughter weight). To control the waste water discharge in the meat industry, waste water treatment plants have been deployed. Under the UN Global Impact principles, further reduction in water footprint is forecasted in the coming years.

Netherlands

Netherlands is another major player in meat production in Europe. About three quarters of the total meat produced in the country is exported. Pork is the country's largest meat sector and accounts for more than 50% of domestic consumption. The Netherlands has demonstrated efficient water management systems with relatively small total water footprint for all meat sectors but external water footprints account for 50-80% of total water footprint.

Ireland

Ireland is the 4th largest beef exporter in the world yet only 10% is consumed by the domestic market with more than 50% exported to the UK. Ireland has a natural geographic advantage. Being a 'green island', it can be one of world leaders in sustainability. Cranfield University, UK, conducted a study on the carbon and water footprint of meat and dairy production of Ireland and found that these industries have one of the world's lowest water stress measurements. 27% of the country's total water footprint comes from meat production and consumption(Mekonnen and Hoekstra 2011). The Irish meat processing sector has undergone a significant rationalisation with old and less efficient plants closing down and production shifting to state-of-the-art meat processing plants which are far more than just typical slaughterhouses. Table 1 shows the water level consumption of Ireland in comparison with some of the other European countries.

| Table 1. Comparison of water level consumption by beef processing industries (Feeney 2009) |
|-----------------------------------------------|-----------------|-----------------|-----------------|
| Country           | Water Use (m³/head) | Average Carcass Weight (kg) | Water Use (litres/kg carcass) |
| Ireland           | 2.19             | 324             | 6.79            |
| Denmark           | 0.625            | 250             | 2.5             |
| Sweden            | 1.7              | 290             | 5.86            |
| Norway            | 1.12             | 263             | 4.26            |

Figure 1 shows the results from a report, Sustainable Practices in Irish beef processing by Enterprise Ireland, the amount of water consumed and wastewater discharge in the Irish beef sector.
In many countries, a water footprint assessment has not been done specific to meat industries. There are various factors that contribute to the water footprint. Some of the major attributes are type of water that is used in processing meat like Blue, Green and Grey water. The water footprint also varies widely from the type of meat that is produced and the country in which it is produced.

To determine the exact water footprint, a visit to a meat processing factory is required to record the details specific to the type of meat processed, type of water used, etc. This will be carried out as part of this study.

**EPA Guidelines**

The primary guideline in the meat processing industry is to treat the waste water with BAT standards and invest in more sophisticated systems to reduce emissions. IPPC licences are in place to continuously monitor the plant activity, efficient use of energy and reduce the emissions to air, soil and water.

**Results and Discussions**

Unlike many European beef processing industries which discharge waste water that is partially treated, Irish meat plants discharge fully treated wastewaters into rivers and streams. All the plants use sophisticated treatment systems in compliance with their discharge licences. In a recent study (2009) of 16 major beef processing companies, all of them were in compliance with the IPPC licence emission limits and operate on Best Available Technique (BAT) Standards. These companies are working to further reduce the water usage in processing meat.

**Conclusion**

Ireland shows great potential for being a global leader in sustainable water in the meat processing sector. It has one of the most sophisticated and advanced technologies to control water footprints in
the meat industry. It appears that Ireland has a very stable meat processing industry, but more information and data is required to draw final conclusions as part of this study.

References

WASTE MANAGEMENT IN THE MEAT INDUSTRY

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Abstract

Waste management is an important factor to be considered in Ireland and also throughout Europe for a more sustainable future. The meat sector is a major industry in Ireland and it is essential to review the waste management aspects of it. This study focuses on waste management strategies in order to achieve more sustainable methods of producing meat. It also includes key aspects such as the comparison in consumption of meat across Europe and the US and the waste management techniques used to treat the by-products of the industry.

Introduction

There has been a steady increase in the amount of waste due to the increase in global population and urbanization. The meat sector is a growing business around Europe and especially Ireland. Beef production is the most dominant enterprise on most Irish farms with approximately 68,000 farms involved in specialist beef. Ireland produces 500,000 tonnes of beef and 90% is exported which can meet the requirement of more than 30 million European consumers (AgriAware 2013). There are about 30 major slaughter houses in Ireland, processing 1.5 – 1.6 million cattle annually; they are approved and licensed under EU hygiene legislation and also operate under an Integrated Pollution Prevention and Control (IPPC) licence from the Environmental Protection agency (EPA).

Animal waste may be defined as carcasses or animal parts which are not intended for direct consumption. The slaughtering process is the largest contributor to liquid waste in the meat industry. Treatment of the solid residues and wastes, particularly residues from the waste water treatment process has been an emerging major concern in meat industries. A typical waste management system comprises of collection, pre-treatment, processing, and final abatement of residues. The main purpose of waste management is to provide sanitary living conditions reducing the amount of matter that enters or leaves the society and also encourage the reuse of the matter within the society (Demirbas 2011).

Waste disposal and by-product management in the food processing industry pose problems in the areas of environmental protection and sustainability. Large quantities of waste cannot be eliminated; however impacts to the environment can be reduced by making more sustainable use of waste. This is known as the waste hierarchy which is the cornerstone of most waste minimization strategies (WWF 2014).

The objective of this study is to analyse waste management practices in the meat processing industry with a view to making them more sustainable for the future.

Material and Methods

This research will take the form of a desktop study along with site visits in order to further understand and analyse the waste management practices being followed.

Meat industry and consumption in the Europe

The meat sector is one of the most important sectors in the world with European agriculture accounting for over 16% of global meat production and it is the main diet for many consumers, particularly in developed countries. The total meat can be broken down into red meat (beef, pork and lamb), processed meat (smoked meats, beacons and sausages) and white meat (chicken and turkey). The average meat intake for men and women in the UK and Ireland is 108 g and 70 g and 168 g and 107 g, respectively
Ireland produces nearly 7% of EU’s beef, representing over 25% of gross agricultural output. The red meat industry, especially beef, is a massive industry in Ireland; the meat from 9 out of every 10 cattle produced in Ireland is exported (AgriAware 2013). Figure 1 shows beef exports and Table 1 provides data on meat consumption.

![Irish beef exports in tonnes](image)

Figure 1. Irish beef exports in tonnes (AgriAware 2013)

The pig industry has also seen a huge growth in Europe mainly in the UK exporting 250,000 tonnes and Ireland exceeding 60% of its meat production in exports (EC 2003). From a sustainable point of view, due to Ireland grass-based system, the carbon footprint for Irish beef production is amongst the lowest in the world.

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<th>Table 1. Meat intake in several European countries (McAfee et al. 2010)</th>
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**Meat industry and consumption in the US**

The meat industry in the US is the largest segment of US agriculture. Animal by-products in the US are divided into two classes, edible and inedible. Variety meats are wholesale edible by-products which are segregated, chilled and processed under sanitary conditions and later are inspected by the US meat inspection service. The US exported 921 million tonnes (MT) of beef and 1.75 billion MT of pork in 2011. The average consumption of total meat of an American man is 195g and women are 120g per day (AMI 2011).
The US markets will open to the Irish beef sector during 2014 as the US has changed the BSE rule. As the exports increase there is a greater necessity for a better waste management system, which is essential to improve the sustainability of meat production globally (Reed 2014).

**Waste management characteristics**

The meat industry slaughters a variety of animals and the majority of the waste is obtained from the slaughtering process. The waste includes materials such as bones, tendons, skin, internal organs and blood which cannot be sold or used in meat products (Jayathilakan et al. 2012). This activity produces large amounts of solid waste, also including manure and bedding. The quantity of by-products from cattle often exceeds 50% of the animal’s live weight and 10 to 20% for pigs (IFC 2007). The specific amounts of wastes generated for different types of animal are given in the table below. It is the mass of accumulated waste divided by the mass of saleable product.

**Table 2.** Specific waste index for slaughter houses with respect to type of animals

<table>
<thead>
<tr>
<th>Animal</th>
<th>Specific waste index ($m_a/m_s$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cow</td>
<td>0.56</td>
</tr>
<tr>
<td>Calf</td>
<td>0.87</td>
</tr>
<tr>
<td>Pig</td>
<td>0.2</td>
</tr>
<tr>
<td>Sheep</td>
<td>0.1</td>
</tr>
</tbody>
</table>

$m_a$ - Mass of accumulated waste  
$m_s$ - Mass of saleable product

The European Union produces over 18 million tonnes of waste per year from the meat industry. The crisis caused by the Bovine Spongiform Encephalopathy (BSE) disease created the necessity for alternative solutions for meat waste management. The solution may include cleaner technologies such as pollution prevention and recovery of energy from the waste. The literature indicates that half of the by-products is not suitable for normal consumption because of their varying physical and chemical characteristics. For example the meat-and-bone-meal (MBM) treated by means of thermal treatment such as pyrolysis and gasification are promising alternatives for MBM in many European countries. The MBM can be used as a valuable biofuel and the ash from it could be used for phosphoric acid production (Krupa Zuczek and Kowalski 2007). The recovery of fat from meat waste can be used as a useful fuel, a substitute of natural gas similar to bio fuels (Cascarosa et al. 2013).

**Discussion**

Some of the recommendations regarding the best available techniques (BAT) for improved waste management are:

- Collection of blood and other solid waste separately from water streams
- Regular collection of waste and conversion of waste to energy using incineration, gasification, pyrolysis and recovery of fat as a useful fuel

One of the major successes of the Irish meat industry in UK and European markets is largely achieved by the unique offering of grass fed steer. There is a growing consumer demand for environmentally sustainable products and thus Ireland’s grass based beef production rather than livestock reared indoors from birth creates a positive perception among consumers.
Conclusion

The meat sector is a major industry in Ireland and it is essential to review the waste management aspects of it. The quantity of by-products from animal slaughter can exceed 50% of live weight. It is expected that this study can outline how materials that are often considered as waste can be recovered for added value products.

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USE OF A DIVIDED BAR APPARATUS TO MEASURE THE THERMAL CONDUCTIVITY OF ROCK FRAGMENTS

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Abstract

The Thermal Conductivity (TC) of rock is an important factor in many types of investigation of the subsurface. This experiment will measure the TC of rock fragments in an attempt to correlate them to whole rock. A divided bar apparatus is one of the methods that can be used to determine the Thermal Conductivity of a rock sample. The divided bar apparatus operates by measuring the heat drop across a material of known conductivity and comparing that to the heat drop across the rock being studied. This paper documents an experiment undertaken with a divided bar apparatus recently built in the School of Civil, Structural & Environmental Engineering, University College Dublin, Ireland and builds upon earlier work measuring the TC of whole rock conducted by Turlough McGuinness and Tim Waters for their masters theses. It differs from standard practice with the divided bar as it is proposing to measure the TC of rock chippings as opposed to whole rock.

Introduction

Irish dependence on fossil fuels is one of highest in the EU. Geothermal energy is utilising energy stored in the sub surface of the earth, and along with wind, biomass and hydro will work to reduce Irish dependencies. Although geologically Ireland is not well placed to offer true deep geothermal electricity generation potential, situated as it is far from the Alpine mountain building episodes of the recent geological past, and distant from tectonic plate boundaries (O’Connell et al. 2005) the shallower applications useful for heating are already seeing increasing adoption. A recent paper (Allen and Burgess 2010) reports over 9000 ground source heat pump units (GSHP) in operation in Ireland, mainly in the domestic market.

By 2008, 90% of Ireland energy needs were imported. Widespread adoption of GSHP technology would help reduce the national dependence on this supply, at least as far as heating is concerned as approximately 30% of energy is used for thermal (Hemmingway and Long 2011).

Geothermal investigations require good knowledge of the rock in which the heat exchangers will be placed, since over extraction of the heat resource will result in depletion. To ensure proper sizing and deployment of a geothermal system, an estimate of the thermal conductivity of the rock is essential. Towards this end, rock core can be drilled and recovered and then tested to determine its TC value. However, whole rock core requires more expensive drilling techniques and even if available, is otherwise often too informative as an intact geological specimen to be used for destructive TC testing.

Much cheaper forms of drilling return chippings of rock instead of whole core and this experiment explores the possibility of using these rock chippings instead to determine TC (Sass et al. 1971). Indeed there are many drill holes that exist worldwide that have no core at all, but abundant drill cuttings. A method for determining TC from chippings makes these holes available for meaningful heat flow analysis. An attempt will be made then to correlate these values to the known TC of the whole rock core from which they are derived so as to estimate the accuracy of this chip based method.

The objective of this study is to examine the correlation between the TC of rock fragments and the TC of the same rock in whole core and to correlate the relationship between the two measurements.
Materials and Methods

Design
This divided bar apparatus used was developed for the masters thesis of Turlough Mc Guinness (McGuinness et al. 2013) and this paper follows the same procedure for operation. The principle of a divided bar apparatus is a steady state apparatus where a cylinder or "bar" of material whose conductivity is known (Perspex in this case) is "divided" into 2 discs (the reference discs in figure 1 below). These discs are inserted into a stack containing the samples and copper discs as illustrated. The stack is heated to a steady state temperature, and the temperature is read at thermocouples T1, T2, T3 and T4 via a data logger and laptop. An excel spreadsheet is used for the calculations.

![Divided Bar Apparatus stack setup](image)

The conductivity of the sample is measured by calculating the heat flux coming from above (through reference 1) and separately coming below (through reference 2) using Fourier's law

\[
Q = \lambda \times \Delta T
\]

Where
- \(Q\) = heat flux (W/M²)
- \(\lambda\) = thermal conductivity (W/mK)
- \(\Delta T\) = temperature drop (measured via thermocouples)

Therefore the heat flux through the entire stack can be calculated and thereby the conductivity of the sample. A correction factor specific to this apparatus developed by McGuiness is also applied, giving a corrected value.

Sample preparation
4 samples of core were provided for this experiment as shown below.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Location</th>
<th>Depth</th>
<th>Rock type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>UCD campus, Dublin</td>
<td>17.5</td>
<td>Limestone</td>
</tr>
<tr>
<td>2</td>
<td>ESB office, City Centre, Dublin</td>
<td>95.42</td>
<td>Dark lime shale</td>
</tr>
<tr>
<td>3</td>
<td>Lyons Hill, Co. Kildare</td>
<td>162.4</td>
<td>Sandy Breccia</td>
</tr>
<tr>
<td>4</td>
<td>Lyons Hill, Co. Kildare</td>
<td>140.4</td>
<td>Granite</td>
</tr>
</tbody>
</table>

Each sample was ground into chips, from these, 3 classifications of chips were made: Large, where each chip was between 10 and 15mm, medium, from 5-10mm and fine which was a sieved fraction from 1.8mm -5mm. The purpose of the differing sizes is to determine if sample porosity or packing has any effect on conductivity.
The rock chips are placed in a specially designed nylon walled container of diameter 42mm and height 21 mm; this is the same size as the stack into which it will be placed. The container is water proof and has an oxygen free copper lid and bottom constructed from the same copper bar as in the stack. The chippings are placed inside, saturated with liquid of known conductivity, and then placed within the heating stack. Liquids used were glycerol and water.

The TC of these liquids was also measured in the divided bar. Therefore it can be seen that 4 samples of core each gave 3 ranges of chips, all of which were tested in both water and glycerol. This gives a total of 24 tests run in the divided bar apparatus, or approximately 2.5 hours each.

![Figure 2. Sample container loaded with chippings and glycerol (left) and sample heating in stack (right)](image)

**Testing**

The sample container is loaded into the divided bar as in figure 1 above, and a confining pressure of 6 bar is applied. The heat rise is measured at thermocouples T1, T2, T3 and T4 and monitored on the laptop screen. After approximately 2 hours the temperature curves are straight and the experiment is determined to be in steady state.

**Results and Discussion**

All results were saved in specific Excel files with the average steady state temperature entered into a calculation spreadsheet where Fourier's law and instrument correction were applied. Further work will be required to separate the thermal conductivities of the rock chips, fluid and sample container from the bulk sample conductivity. It is also planned that thin sections of rock shall be cut and a microscope investigation undertaken in an attempt to find some geological control on the TC. If time allows a bulk rock TC analysis may be undertaken, using a finely ground rock sample so as to remove any structural control on the results.

**Conclusions**

The majority of the experimental work is complete at this time, however the results have not yet been interpreted and as such support no conclusion as of yet. Interpretation shall be on the basis of work done by Sass and Mc Guinness and it is expected that the TC of rock chips in both water and glycerol will be found to give a similar result to whole core. Sass (1971) determined chips to be within 10% of whole core. It is hoped that this level of accuracy can be obtained in this experiment.

It is expected that a correction factor can be found that will relate chip TC measurements with the whole core, and that this is constant for all chip sizes and rock types.
References


WATER FOOTPRINTING OF THE DAIRY INDUSTRY IN IRELAND

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Abstract

In the circumstances of rapid industrial and population growth, there is continuous demand for freshwater for human life and agriculture. The need for conducting water footprint analysis for food and dairy products has become inevitable. It can help in predicting the water requirements of each process and assist in reduction in its use. There is a pressing need for making the dairy and food industry more sustainable to minimize the effects of freshwater pollution. It will help in mitigating the issues of water scarcity and food security to a certain extent for the future generation.

Introduction

Freshwater has always been an indispensable resource to human and ecological life. As there is significant growth of human population and rapid industrialization, the requirement of freshwater has increased. There is uneven distribution of freshwater across the globe and as result of climate change, the water cycle has been changed leading to drought and deluge in many parts of the world (Grace Communications Foundation 2014). The amount of water use along supply chains has gained interest after the introduction of the ‘water footprint’ concept by Hoekstra in 2002 (Hoekstra 2003). Water footprints assist in revealing the quantity of water being used at an individual up to a national level and in the various processes associated in manufacturing and production of goods and services. The water footprint assessment for a wide range of products has increased the awareness for preservation of freshwater (Ridoutt et al. 2009). As per the United Nations (Worldometers 2014), seventy per cent of fresh water is used for agriculture globally with industry using twenty two per cent and domestic use accounting for less than ten per cent. Meat and dairy products are considered as being large water consumers but proper analyses are to be carried out from a sustainability perspective taking into account the amount of water required and impact produced on the environment. In this study, the water footprint assessment will be carried out on the dairy industry in Ireland.

The water footprint is an indicator of freshwater use which includes the direct and indirect water use of a consumer or producer. The water footprint of a product is the volume of freshwater used to produce the product, measured over the full supply chain. The blue water footprint refers to consumption of blue water resources (surface and groundwater) along the supply chain of a product. Consumption refers to loss of water from the available ground-surface water body in a catchment area. Losses occur when water evaporates, returns to another catchment area or the sea or is incorporated into a product. The green water footprint refers to consumption of green water resources (rainwater in so far as it does not become run-off). The grey water footprint refers to pollution and is defined as the volume of freshwater that is required to assimilate the load of pollutants given natural background concentrations and existing ambient water quality standards (Hoekstra et al. 2011)

The objective of this study is to estimate the water footprint of the Irish dairy industry from the cradle to the factory gate level.
Materials and Methods

A site visit to the different dairy processing plants will be organized to understand the process flow and manufacturing of the dairy products. The data will be collected for water consumption, milk and other value added products annual production from commercial dairy processing. The water data for the operation of the plants in manufacturing of dairy products will be used to calculate the water footprint of the Irish dairy industry. The annual cow milk intake for the creameries and pasteurizers is taken from the Central Statistical Office, Cork and shown in Figure 1.

Figure 1. Annual intake of cow milk by creameries and pasteurisers in Ireland (CSO 2014)

There are a number of unit processes involved in the dairy industry for different types of products such as materials handling, unpacking and storage, mixing, homogenization, centrifugation, filtration, pasteurisation, sterilization, packing, filling, cleaning or sanitization, energy generation or consumption, water treatment, refrigeration, compressed air generation, neutralization, brining etc. The water use for each process will be analysed and compared to find out the process having the largest water footprint. The major dairy products manufactured include cheese, butter, yoghurt, casein, milk and skimmed milk powder, whey production and ice cream (EPA 2008). A system model will be generated in Excel to study and calculate the water footprint per functional unit in each plant individually using the input data from the monitoring of plant parameters. The approach to be followed will be in accordance to the Water Footprint Assessment Manual (2011). The dairy industry uses large amounts of water and consequently generates large amounts of wastewater in sustaining the needed level of hygiene and cleanliness in the plant. The water used is as process water, cooling water, transportation water, auxiliary water and sanitary water etc. Generally, the wastewater has high BOD and COD levels and sometimes high concentrations of particulate solids.

The efficiency of the dairy industry in Ireland will be benchmarked against other global competitors. Sustainable water management practices can be carried out by reducing the volume and strength of wastewater generated, eliminating or decreasing the concentration of certain pollutants, recycling or re-use of water, wastewater treatment or by the combination of both.

Results and Discussion

The results from this study will be compared with earlier investigations carried out in the Irish dairy industry. Between 2005 and 2009, the average annual water consumption per plant was reduced by 20% from 1,094,421 cubic metres to 874,828 cubic metres representing to a saving of approximately 200 million litres of water per plant. The earlier studies shows that
during this period, mean water use fell by 28% per tonne of dairy product produced and 18% per cubic metre of milk processed (Geraghty 2011). As the figures show, there is still scope for further reduction in water consumption for the dairy industry in creating a sustainable business for the future. The system diagram for the study to be carried out is shown below in Figure 2.

![System diagram for Irish dairy industry.](image)

**Figure 2.** System diagram for Irish dairy industry.

There is a range of consumption and emission levels for dairy processes of Europe as per Best Available Techniques (BAT) for food and dairy sectors as shown in Table 1.

<table>
<thead>
<tr>
<th>Product type</th>
<th>Water consumption</th>
<th>Waste water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production of market milk from 1 litre of received milk</td>
<td>0.6-1.8 l/l</td>
<td>0.8-1.7 l/l</td>
</tr>
<tr>
<td>Production of milk powder from 1 litre of received milk</td>
<td>0.8-1.7 l/l</td>
<td>0.8-1.5 l/l</td>
</tr>
<tr>
<td>Production of 1kg of ice cream</td>
<td>4.0-5.0 l/kg</td>
<td>2.7-4.0 l/kg</td>
</tr>
</tbody>
</table>

**Table 1.** Consumption and emission levels of dairy processes in Europe (EC 2005)

**Conclusion**

The results of this project will be used to determine efficient water use in the Irish dairy industry which is a major contributor to the economy. A cradle to factory-gate water footprint of the dairy industry will be developed using the collected data. It will provide a baseline for reducing the water consumption in each process. This will be a significant step for ensuring proper water management system and bringing about sustainability towards the growing demand and supply of dairy products from Ireland to other parts of the world.
Acknowledgement

This support of the dairy industry in Ireland is acknowledged in this project.

References


THE FEASIBILITY AND BENEFITS OF COMBINED HEAT AND POWER FOR INDUSTRY IN IRELAND

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Abstract
Energy prices driven high by the increasingly unstable fossil fuels market has seen a pitch towards more efficient, renewable and greener technologies in the last decade. Coupled with this, an environmental approach adopted worldwide to reduce harmful greenhouse gas emissions and initiatives to become more sustainable have targeted everyone from businesses to the everyday consumer. The deployment of energy efficient combined heat and power technologies will be studied in terms of feasibility for the Irish industry sector. These systems are just one of the modern, efficient technologies on the market available to businesses and residential consumers alike. To assess this feasibility study, a case study will be included.

Introduction
The importance of utilising modern and highly efficient energy technologies is none more apparent than at the present time for the commercial and industrial sector. The rising cost of energy prices, the fossil fuel depletion of reserves worldwide and the abundance of CO₂ and other greenhouse gases are catalysts for the implementation of a more efficient method of energy production.

Combined heat and power (CHP) is the simultaneous generation of heat and power, usually electricity, in a single process (Hinnells 2008). CHP (or cogeneration) is a thermodynamically efficient method of fuel use, utilising the waste heat produced from electricity generation as a usable product, for space heating, district heating or manufacturing processes. Traditional electricity generation is associated with heat losses through cooling towers and flues, resulting in losses of about 60% of the original fuel input. A combined heat and power system can operate to an efficiency of approximately 80% of fuel input, meaning losses of only 20%. Efficiencies may be higher if distribution and transmission losses are minimised. These higher efficiencies mean that a lower amount of fuel needs to be consumed to produce the same amount of energy needed (Streckiene et al., 2009).

Combined heat and power technologies are still being utilised in relatively low numbers in Ireland at the present time. For the year ending 2010, CHP units totalled 156 with the vast majority of these powered by natural gas. Oil fired and biomass fuelled units made up the remainder. Some 14 of these units exported additional electricity to the grid. Efficiencies of the technologies have risen from 48% to 84% since 2001, and have avoided emitting 531 kt of CO₂ in the year 2010 alone. The primary energy savings from this year alone was 26% with CHP compared to heat and electricity production (SEAI, 2012).

The objective of this project is to assess the feasibility of energy saving combined heat and power technologies for Irish industry, technically, financially and environmentally, backed up with a case study from the relevant field.

Materials and Methods
The purpose of this study is to assess the technical, financial and environmental benefits of installing a suitable combined heat and power system for an industry. There will be two methods used to compile the relevant information.
Desktop study

The desktop study will incorporate the gathering of information from journals, commercial documents and relevant energy databases.

Energy prices due to a volatile market will be studied in detail, as this provides one of the base reasons to switch to a more sustainable energy technology to obtain a more cost effective means of supply with added energy security. Figures, tables and data relating to fossil fuel prices will be assessed and compared with that of cogeneration achievable via combined heat and power. Current energy prices must be assessed, along with predicted prices. Business sizes are allocated a range of different tariffs according to the size of business e.g. band system.

![Figure 1. Rising electricity prices for band ID large business consumers 2007-2013 (SEAI) (S1 denotes semester 1 January-June, S2 denotes semester 2 July-December)](image)

The technical feasibility must also be assessed in terms of financial value to the business. Combined heat and power systems are often made to measure and can be constructed to business requirements based on their annual electrical and thermal demand. Different models incorporate different fuels (e.g. natural gas, biomass), turbines, engines and generators. To evaluate the different models of CHP for a business, system efficiencies are of key importance. The ratio of delivered usable energy to the energy input is called the total energy efficiency (Ertesvag, 2007). This can be expressed as:

$$\eta_{\text{tot}} = \frac{W + Q}{H} = \eta_{\text{el}} + \eta_{Q}$$

Where $W$ is the mechanical work or electricity produced, $Q$ is the thermal energy and $H$ is the input energy. This can be used to evaluate what is produced and to compare to what has been consumed. The different types of technologies will be covered in the desktop study of this dissertation to examine the benefits of each type of system and its fuel supply.

The range of CHP technologies include gas turbines, gas engines, steam turbines and adapted biofuel engines. In these technologies, the fuel is combusted to turn a shaft in a generator with the output being electricity and heat. Each technology operates at different efficiencies over time, and identifying the energy demand of the business is an important aspect of technology selection.
Case study
This project will also examine a relevant industry case study from Baxter Healthcare Ltd, a large pharmaceutical business who invested in a CHP unit to provide 3MW of energy to their renal dialysis products production plant. The sustainable ethics of the company along with their vision of future cost savings provided the springboard to install the CHP system. Inside the facility, two gas fuelled CHP units are providing 3MW of electrical and thermal energy, allowing Baxter to self-generate 75% of its annual energy demand, at a lower cost and environmental burden. The additional 25% will be supplied by existing means of the national grid during peak loads. The requirements of existing medium grade fuel oil, with its expensive price tag and high greenhouse gas emissions, are no longer necessary as the CHP will provide a large proportion of the thermal energy needed by the production facility.

In order to achieve a successful case study, site visits in coordination with the relevant staff members shall be undertaken to determine the data sources in relation to previous annual energy demands, costs of natural gas, heat and electricity requirements, maintenance and predicted energy demands for the future. The opportunity for site visits also allows judgement to be made on the size of the system, noise levels, performance and integration into the facility.

Results and Discussion
As this study is on-going, it is anticipated that positive results will be shown from the feasibility of combined heat and power for industry in the areas of cost savings, energy security, reducing CO₂ emissions and portraying a cleaner sustainable image for the company in question.

The initial capital cost of installing a CHP system is sizeable, but for a large industry consuming electricity and heat on a 24 hour basis, the investment will pay off in less than 5 years. Large industry with a heat demand as well as electricity demand are advised to
consider CHP options, as waste heat totalling approximately 40% of the system process can be utilised in space or district heating, instead of using inefficient existing boilers.

Conclusions

With the option to build a CHP system around the requirements of a business, large industrial facilities have the potential to pin point their energy needs and in turn reap financial and environmental rewards. CHP technology has advanced to provide high efficiencies and become a positive investment for forward thinking businesses.

Acknowledgements

The authors would like to thank Mr Seamus Maughan, facilities manager, Baxter Healthcare and Mr Damien Kearney, energy management manager, Baxter Healthcare for their invaluable time and information during the course of this project.

References

OPTIMAL NODE POSITIONING METHODS IN WSN FOR ENVIRONMENTAL MONITORING IN POULTRY FARMS – A REVIEW

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Abstract
The positioning of nodes in a wireless sensor network (WSN) is crucial for the optimization of area coverage, network connectivity, network longevity and data fidelity of the network. The effects of positioning of nodes on the various factors under consideration have been analyzed based on the works of different scholars. The study shows that controlled deployment of sensors is the methodology that is optimal for the indoor environment monitoring systems in poultry farms. Further, it is also clear the optimization of node positioning improves the above said characteristics of the WSNs.

Introduction
The application of wireless sensor networks (WSNs) has grown across boundaries into numerous fields like factory automation, environmental monitoring, space exploration, security installations, surveillance, and forest management and so on (Akyildiz et al. 2002). The poultry industry too has taken in remote monitoring using WSNs to optimize the environmental conditions of the farm for poultry production. In temperate regions like Ireland, optimization of the environmental conditions in a poultry farm is very essential.

In WSNs, autonomously operating sensing nodes are scattered around within the boundary of the system being studied or monitored. They study and record the changes in their immediate vicinity and transmit the data to a base station. The nodes operate on batteries. A lot of research is being carried out on improving the data latency and data integrity of the WSNs. Also considerable amount of development is seen in the areas of conserving energy and increasing the life of the WSNs.

Another optimization strategy is the strategic placement of the sensing nodes within the boundary to achieve desired coverage and performance. As the number of nodes is relatively small in comparison to the outdoor monitoring networks, controlled placement of the nodes can be employed to achieve the desired performance. The context of this optimization strategy is mainly static in the sense that assessing the quality of node positions is based on distance, network connectivity and/or basing the analysis on a fixed topology. There are other systems that suggest dynamic positioning of the nodes as in many cases in outdoor monitoring systems, the initial position of the node may become void due to dynamic changes in boundaries (Younis and Akkaya 2008). As in this case of poultry farms, since it is an indoor environment, the static optimization approach is considered and explored.

The objective of this study is to analyze the various static optimization techniques of node placement for indoor environment monitoring in poultry farms.

Materials and Methods
The positioning of the nodes in a WSN has a great impact on its effectiveness and efficiency. Fig. 1 is a summary of the different classifications of static strategies for node placement.
As for this case, it is deterministic that the deployment methodology is controlled and the node’s role on WSN is that of a sensor, thus the focus here is on the optimization objectives.

**Area Coverage**
Maximal area coverage has received the most attention in literature. Chen et al. (2010) assume a disk coverage zone with the sensor in the centre and the radius of coverage area equalling the sensing radius of the sensor. Various authors use the ratio of the covered area to the size of the overall deployment region as a measure for the quality of coverage.

**Network Connectivity**
Unless the base station is mobile and can interface with the WSN through any node, establishing a strongly connected network is not essential in WSNs since data are gathered at the base-station. Therefore, ensuring the presence of a data route from a node to the base-station would be sufficient and thus fewer nodes can be employed to achieve network connectivity (Younis et al. 2003).

**Network Longevity**
The positioning of nodes has a significant impact on the lifetime of the network. A uniform node distribution may lead to depleting the energy of nodes that are close to the base-station faster than the other nodes and thus shorten the network lifetime (Akkaya et al. 2005).

**Data Fidelity**
A sensor network basically provides a collective assessment of the detected phenomena by fusing the readings of multiple independent (and sometimes heterogeneous) sensors. Data fusion boosts the fidelity of the reported incidents by lowering the probability of false alarms and of missing a detectable object. Ganesan et al. (2006) have studied sensor placement in order to meet some application quality goals. The problem considered is to find node positions so that the fused data at the base-station meets some desired level of fidelity.

The above factors will be parameterized and inputted into a mathematical model designed by mathematical modelling software of choice (currently under investigation).

**Discussion**
The data collected over various periods of time so far will be analyzed using the mathematical model and the results will be compared with the data that will be acquired in future through
different strategic placement methods optimized using the model. The results will be helpful in finding an optimal positioning method for the sensors in a poultry farm.

Conclusions

Further study and analysis needs to be done on the data collected and placement strategies employed to finalize the optimal method and model for positioning the sensors. The results gathered by deploying various positioning models will be analysed and the models will be optimized progressively.

References

FOOD VS FUEL CROPS – SURFACE WATER RISK ANALYSIS

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Abstract

With the increasing demand on food and energy, and intensive agricultural practices to meet these demands, we have forgotten about the environmental impacts of the same. Increasing pressure to use biofuels has also created a battle between growing food and fuel crops. Food Crops (Wheat, barley) and energy crops (miscanthus and short rotation crop willow (SRCW)) were selected as the crops under study in this paper. There is a significant difference in the production system of both crops. This paper investigates the risks to surface water involved in growing these crops in various regions across Ireland. Agricultural inputs (e.g. fertilizers and pesticides) which are transported to surface water are considered to have various impacts. This paper discusses agricultural practices, route by which agricultural inputs enter water and uses a qualitative risk assessment approach to investigate the potential risk to surface water.

Introduction

Ireland has set a target that 33% of its electricity will be generated from renewable source by 2020 (Rourke et al. 2009). Bioenergy has the potential to make a significant contribution to this target. Grants are been provided to farmers under the Bioenergy Scheme to grow miscanthus and SRCW for the production of biomass suitable for use as a renewable source of energy. To meet the demand more intensive agricultural practices e.g. fertilizers, pesticides, herbicides etc. are applied to elevate the growth rate. “Surface water is inland waters (except groundwater), transitional waters, and coastal waters, except in respect of chemical status for which it shall also include territorial waters” (European communities environmental objectives regulations 2009). Agriculture inputs will eventually reach surface water through leaching, seepage, and surface run-off. N and P losses in particular can negatively affect the quality of soils, groundwater, surface water, and the atmosphere (Schröder et al. 2004). When these inputs enters aquatic ecosystems, they cause problems such as toxic algal blooms, loss of oxygen, fish kills, loss of biodiversity, loss of aquatic plant beds and coral reefs. The N and P can have a risk on drinking water quality. They may also affect the functioning of the ecosystem (Schröder et al. 2004). The financial consequences of these losses on a societal scale are also considerable (Pretty et al. 2003). All rivers, lakes estuaries and coastal water quality are regulated under EU water framework Directive (Directive 2000/60/EC). The aim is to achieve and maintain good status in all water by 2015. For the protection of water against nitrates from agricultural sources, Nitrate Directive (91/676/EEC) is adopted. Every member state has to make a Nitrate action plan in accordance with this directive. Irelands Nitrate Action Plan (NAP), 2013 is given effect by the European Union (Good Agricultural Practice for Protection of Waters) regulations 2014. The NAP has instructions on farmyard management, nutrient management, prevention of water pollution from fertilizers and certain activities etc. There are best practice manuals available for crop production (Teagasc 2012). If these directives and manuals are judicially followed, there can be less threat of environment degradation. Risk assessment considers the likelihood of occurrence and the consequences of the occurrence of an event (Assessment and Sites 2007). Risk assessment analysis is widely adopted by government in waste, water, food etc. sectors. Risk assessment considers the source, pathway and receptor. The outcomes of risk assessment can be utilized to prioritize hazards, comparison of alternative actions, setting standards etc.

The objective of this study is to develop a qualitative risk assessment model to ascertain the influence of food and fuel crops on contaminant risk to surface water.
Materials and Methods

A qualitative risk assessment approach is being developed to determine whether food or fuel crops production systems are more detrimental to the surface water quality. The focus of study is on wheat and barley for food crops and miscanthus and SRCW for energy crops. The area of winter wheat is estimated to be 45,000 ha, spring wheat 15,000 ha, winter barley 36,000 ha and spring barley 181,000 ha (Teagasc 2013). Under the Bioenergy Scheme total area planted in 2009 for willow was 166 ha and Miscanthus was 709 ha (Teagasc 2010). According to the national soils database (Teagasc 2007), the study considers five major geographical regions of Ireland based on the spatial distribution maps, soil and rock type maps. The regions are Central North East (A); The South East (B); Cork, North Kerry and Clare (C); Western Seaboard (D) and the Midland (E) (Figure 1). The study will evaluate different sites for food and energy crop cultivation in all these five regions with respect to the risk. The assessment requires the source (fertilizers, pesticides, farm), pathway of inputs to water and the receptor i.e. surface water to be defined (Table 1).

![Figure 1. Five major geographical regions in Ireland based on the soil types for study (Teagasc 2007)](image)

Table 1. Model showing sources, transport factors and end points for risk assessment

<table>
<thead>
<tr>
<th>SOURCE</th>
<th>TRANSPORT FACTORS</th>
<th>END POINT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farm at various sites in Ireland</td>
<td>Rainfall</td>
<td>Type of Water</td>
</tr>
<tr>
<td>Type of Crop</td>
<td>Nearness to water</td>
<td>➢ River</td>
</tr>
<tr>
<td>Pesticides</td>
<td>Soil Type</td>
<td>➢ Lake</td>
</tr>
<tr>
<td>Fertilizers</td>
<td>Agricultural Practices</td>
<td>➢ Stream</td>
</tr>
<tr>
<td></td>
<td>Irrigation</td>
<td>➢ Ocean</td>
</tr>
</tbody>
</table>

Impacts on Surface Water

For the risk assessment, potential hazards from the diffusion of agricultural inputs to water are identified. Due to over enrichment, P and N causes eutrophication problems in rivers, lakes, estuaries and coastal oceans. Eutrophication causes growth of aquatic plants and algae which leads to lack of oxygen and harm aquatic life. Large amounts of pesticides can contaminate water, and when consumed by animals cause reproductive damages. When agricultural nutrient run-off contaminates drinking water, nitrate levels in water increases. This results in an increase of nitrate levels in drinking water potentially above the recommended safety
levels. This causes a potentially fatal disease in infants called blue baby syndrome. On the bases of hazards on aquatic life, wildlife, humans and their priorities, the control measures will be decided.

To assess the impact and likelihood of identified risks and to prioritize according to their impact, a likelihood and severity matrix and risk rating matrix is prepared (Table 2). The risk rating values are grouped into low, medium, high and very high on basis of the range of risk. This results in a ranking system.

<table>
<thead>
<tr>
<th>LIKELIHOOD</th>
<th>RARE</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unlikely</td>
<td>2</td>
<td>4</td>
<td>6</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>Likely</td>
<td>4</td>
<td>8</td>
<td>12</td>
<td>16</td>
<td>20</td>
</tr>
<tr>
<td>Almost Certain</td>
<td>5</td>
<td>10</td>
<td>15</td>
<td>20</td>
<td>25</td>
</tr>
</tbody>
</table>

Table 2. Risk likelihood severity matrix and risk rating matrix

<table>
<thead>
<tr>
<th>Risk Rating</th>
<th>1-6</th>
<th>6-12</th>
<th>13-18</th>
<th>19-25</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>Low</td>
<td>Medium</td>
<td>High</td>
<td>Very</td>
</tr>
<tr>
<td>Medium</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Very High</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Various transport factors for fuel and energy crop in five regions of Ireland are considered to calculate the risk score. The scores will be considered on the bases of environmental permitted levels and exposure. The risk rating matrix is supplemented by an action matrix, for considering appropriateness of crop and site. Risk scores will be calculated for different sites in above mentioned regions considering various transport factors by their likelihood and impact. According to the risk scores various actions will be recommended (Table 3).

Table 3. Action Matrix

<table>
<thead>
<tr>
<th>Risk Score</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-6</td>
<td>Crop can be cultivated in the region</td>
</tr>
<tr>
<td>6-15</td>
<td>Crop can be cultivated on the basis of severity matrix</td>
</tr>
<tr>
<td>12-25</td>
<td>Crop cannot be cultivated in the region</td>
</tr>
</tbody>
</table>

Results and Discussion

An assessment of wheat, barley, SRCW and miscanthus will be carried on the bases of agricultural inputs, production methods and external environmental conditions which can transports input to surface water and have negative impacts. A qualitative risk assessment approach will evaluate the regional risk involved in producing these crops on surface water. Possible risk mitigation strategies will be advised to reduce the risk.

Conclusions

The qualitative risk assessment will enable an evaluation of the environmental risk associated with the production of both food and energy crops. The intensity of the risk of transport factors on different production systems will be determined. The transport factors will vary according to the geographical location. Food crop production is increasing due to food shortages while more fuel crops have been adopted due to environmental concerns. The model will assist to minimise the risks to surface water.

References


DEVELOPMENT OF SMART SENSING FOR HYBRID AD REACTORS

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Abstract

The development of an E. coli whole cell based biological sensor capable of detecting the concentrations of the individual Acetate and Propionate volatile fatty acids (VFAs) within anaerobic digestor leachate samples. The detection and analyses of a leachate sample’s VFA concentration is with a view to being able to fully automate and remotely control deployed Anaerobic Digestor (AD) systems.

Introduction

The efficiency of 2 phase ADs with regards their methane outputs per substrate inputs, depend entirely on their respective monitoring and control implementations. It has been extensively documented that if the AD generated volatile fatty acids’ (VFA) concentrations are known in conjunction with other well established monitoring techniques (biogas, methane yield, and pH ) then a novel performance indicator profile can be established and the necessary adjustments to optimise ADs operational parameters made (Miyamoto, 1997; Andersson and Björnsson, 2002; Pind et al.,2004; Ahring et al., 1995). The volatile fatty acids, acetate and propionate, are the indicator chemicals that are being examined to identify via the proposed biological sensor. An E. coli species has been selected that can selectively distinguish between both acetate and propionate by mapping its respiration rate for a given VFA concentration to a dataset containing known respiration rate to chemical concentration correlations. The E. coli respiration rate for a given VFA concentration can be measured by use of a dissolved oxygen (DO) probe. Overall VFA concentrations within an AD leachate sample can be indentified by titration (Dr Lange Cuvette Test®) or by an enzymatic assay (Zeravik et al.,2010; Rajashekhara et al., 2006) but both methods require extensive sample pre-treatments, are expensive and do not identify the individual VFA concentrations required. Pind et al. (2003) proposed an automated method for identifying an AD leachate sample’s individual VFA concentrations which comprised of an expansive sample extraction and pre-treatment array coupled to GC enabled individual VFA component identification. Although accurate measurements of the individual VFAs were made, the expense of the proposed system coupled with the extensive sample pre-processing requirements, make this an unsuitable automated monitoring and control system for anything other than large scale AD deployments. The proposed E. coli biological sensor is based on whole cell biological oxygen demand (BOD) sensors which are already in operation (Hikuma et al., 1981; Liu and Mattiasson, 2002). These sensors use a DO probe to map the oxygen usage profile a genetically engineered yeast strain for an unknown BOD sample, to a dataset containing known oxygen usage to BOD concentration correlations. The sensors have been reported as being quite robust, cheap, possess update frequency rates of less than 20 minutes and operational functionality in excess of 1 month (Liu and Mattiasson, 2002). Unlike whole cell BOD sensors which can only identify overall BOD, the proposed sensor exploits E. coli’s individually expressed acetate utilising Citrate Synthase and propionate utilising 2-Methylcitrate Synthase enzymes (Textor et al., 1997; Man et al., 1995) to indentify a leachate sample’s individual acetate and propionate concentrations. Two independent E. coli sensors are thus produced and when a combined acetate and propionate sample is supplied to each, the correlation between the two sensor’s unique respiration slopes are mapped to a data profile containing known respiration rate to chemical concentration correlations and the individual acetate and propionate concentrations identified.

The objective is to develop a long lasting E. coli based biological sensor capable of detecting acetate and propionate concentrations within leachate samples exiting the hydrolytic phase of a two-phase anaerobic digestor.
Materials and Methods

Construction of the E. coli based biological sensor
Six 2L conical flasks three of which contain 800ml of 30mM Acetate minimal media and the other three which contain 800ml of 30mM propionate minimal media are each inoculated with 15ml of E.coli pre-inoculated TSB media. Acetate and Propionate containing minimal media is used so that the Acetate and Propionate identification enzymes which are required to produce the respective acetate and propionate detecting sensors are independently expressed. Acetate grown cells are grown on the shaker flask for up to 12 hours whereas the slower growing propionate sells require 36 hours of incubation. Cells are extracted by centrifugating @ 9000 rpm for 7 min before being washed and the centrifugation process repeated.

The supernatant is discarded and the cells are re-suspended in Tris Buffer at a concentration of 400mg cells per 20ml. Three 800ml containing 2L flasks yield in excess of eighteen 20ml samples and these samples are stored for 24hrs before testing.

A 20ml cell sample is placed in a 37°C water bath for 15minutes before being placed in the 25ml beaker which contains a stirrer bar, is clamped in position at the centre of the stirrer plate and possesses a Dissolved Oxygen (DO) probe. The set up is depicted in fig. 1 below. DO readings are logged at 5 second intervals and once the O₂ concentration raises to 6.5mg L⁻¹, a predetermined acetate or propionate concentration is added and the cell respiration slope is plotted (fig. 2). As many DO respiration rate plots can be run as there are samples available.

![Image of the experiment setup](image1)

**Figure 1.** E. coli respiration rate profile measurement set up

![Graph of respiration rate](image2)

**Figure 2.** Acetate grown E. coli cells’ respiration rate profile for a 0.3mM Acetate sample addition.
Results and Discussion

An extensive respiration rate to chemical concentration mapping profile, which illustrated \textit{E. coli}’s ability to differentiate between acetate and propionate concentrations within a buffered solution, was made. Individual Acetate and propionate concentrations ranging from 0.03 to 0.7mM could be determined at increments of 0.02mM for 0.03 to 0.015mM and 0.05mM for 0.015mM to 0.7mM respectively. The 0.02mM and 0.05mM increments correspond to acetate and propionate target precisions of 2.8\% to 7.14\%.

To allow full deployment of the biological sensor, the sensor must be capable of determining the Acetate and Propionate concentrations in the presence of other background interfering chemicals. These background chemicals can also produce a respiration reaction with \textit{E. coli} which is particularly problematic in the case of lactate. Lactate concentrations within AD leachate samples exiting silage fed 2 phase ADs have been documented as exceeding twenty times the concentration of acetate for the first two to five days of operation (Cirne et al., 2006). \textit{E. coli}’s lactate respiration rate response when tested equalled that of acetate and considering Lactate can exist at x20 the concentration of acetate in real world AD deployments the proposed identification of acetate within such leachate samples requires \textit{e.coli}’s Lactate utilisation capability to be fully removed. \textit{E. coli} possesses two Lactate dehydrogenase enzymes capable of oxidatively utilising Lactate as a carbon source, D-Lactate dehydrogenase (DLD) and L-Lactate Dehydrogenase (LLDD). Acetate and Lactate utilisation respiration rate reactions were performed using genetically engineered \textit{E. coli} strains which contained either a single DLD or LLDD gene knock-out. A x100 decreases of the \textit{E. coli} mutant’s specificity for its corresponding Lactate isomer (D or L) when compared to acetate was observed. From the observed respiration rate assays for single gene knockouts a double DLD and LLDD \textit{e.coli} knock-out strain is currently being engineered and it is proposed that 100\% of \textit{e.coli}’s lactate utilisation capability will be removed.

When \textit{E. coli}’s lactate utilisation pathways have been fully inactivated it is hoped that the sensor can be deployed on a synthetic AD leachate and an acetate and propionate respiration rate to chemical concentration mapping profile for synthetic AD made.

Conclusions

To date there is no existing affordable robust sensory equipment capable of providing automated real time analysis of AD Leachate samples’ VFA compositions. The provision of such a sensor coupled with other well established monitoring techniques (biogas, methane yield, and pH) would allow for the implementation of automated maintenance and control systems capable of providing continuous optimal operational parameter to remotely deployed AD units thus maximising methane yields.

Acknowledgements

This publication has emanated from research conducted with the financial support of the Charles Parsons Energy Research Programme.

References


HUMAN HEALTH RISK ASSESSMENT OF LEAD AND E. COLI
IN WATER SUPPLIES IN IRELAND

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Abstract

Drinking water quality is an increasing global public health concern with many treatment plants constructed to improve water quality. In Ireland, for almost 90% of the population, water consumption is provided by public and private water supplies which have the potential to be polluted. This study will evaluate the risk from a chemical hazard (lead) and a microbiological hazard (E. coli) in public and private water supplies in Ireland. A quantitative risk assessment approach will be adopted with a framework model presented in this paper.

Introduction

Public water supply systems are ‘schemes regulated by the local authority providing water for residents’ consumption in a distribution network, while private water supply is sourced and treated privately and managed by dwellers (EPA, 2010). The source of raw water and treatment processes are different for both public and private water supply systems. Surface water (including rivers and lakes) provide raw water for further treatment in public water supplies, whereas private water is from groundwater ranging from shallow to deep aquifer (50 to 1000 feet) (Hynds et al. 2013). Additionally, treatment processes are different for these two water supply systems. Compared to private water supply which treats raw water privately, public water supplies provide a comprehensive treatment process which may include coagulation, flocculation and clarification for removing suspended solids and forming larger floc, filtration for colour and impurities and disinfection for removal of pathogenic microorganisms (EPA, 1995). Lead (Pb) is a heavy metal and is toxic in high concentrations to humans. It is introduced into drinking water by anthropogenic activities and lead-containing pipes in public water supplies (Sublet et al. 2003). The accumulation of lead in human organs can cause serious health effects such as coma, seizures, behavioral disorders, and even death. Once it is absorbed through drinking water, lead will be transmitted into the bloodstream which can cause lead toxicity. Children are more vulnerable and influenced by intake lead intake than adults (Wang et al. 2012). E. coli is an enteric bacteria widely existing in animals, especially in cattle. It can be transmitted into surface and ground water effluent by agricultural activities (Avery et al. 2008). It can cause asymptomatic excretion, mild non-bloody diarrhea and hemorrhagic, and similar to lead, children are more susceptible (Schets et al. 2005). Private water supply systems with incomplete treatment may provide a greater possibility for consumers to get ill following consumption of contaminated water.

The objective of this study was to evaluate if there is any difference in the public health risk from chemical (lead) and microbial (E. coli) hazards originating from water derived from either a public or private supply.

Materials and methods

Water sampling
The objective of the study will be achieved by a small monitoring programme followed by the construction of a quantitative risk assessment. Samples of water will be taken from both private and public water supply systems. Public water samples will be collected around Dublin public water systems and private water samples will be from groundwater outside Dublin.
Contaminant test

_E. coli_ will be tested for using Colilert-18 system based on the detection of β-galactosidase. It is a novel method that using _o_-nitrophenyl-β-D-galactopyranoside (ONPG) and 4-methylumbelliferyl-β-glucuronide (MUG) as substrates which will be degraded by β-galactosidase enzyme produced from _E. coli_. ONPG, which is colourless originally, will be changed to a yellow colour during the reactions which can be considered as an indicator of the existence of _E. coli_. Compared to conventional methods, the Colilert-18 system produces a similar result in a shorter time within 18 hours (Kämpfer et al. 2008).

![Image of E. coli and MUG metaboism](image)

Figure 1. _E. coli_ use β-glucuronidase to metabolize MUG and create fluorescence.

A spectrophotometer will be utilized in this study to test the content of lead in water samples. The samples will undergo a fast test of standard comparable analysis. It will test the lead from 0.1 to 2.0 mg/l and the result is for total lead digestion using CRACK SET LCW902.

Framework model

A module structure of flows of water supply and human health effects should be established in order to construct a quantitative risk assessment. This study constructs a simple framework model (Figure 2) of water treatment processes based on information from EPA documents (EPA, 1995).

![Diagram of water treatment processes](image)

Figure 2. A framework model of raw water through water treatment processes

The diagram flow divides water treatment processes into three sections: primary, secondary and tertiary treatment (Cummins et al. 2010). Primary treatment refers to screening raw water
from both ground water and surface water and it removes fish and large debris like leaves and
sticks (EPA, 1995). Secondary treatment including coagulation, flocculation, sedimentation
and filtration aims to exclude suspended, colloidal and dissolved matter from source water.
Coagulation, flocculation and clarification are combined as pretreatment processes for
filtration where light particles are formed into floc to be removed subsequently. Disinfection,
fluoridation and other disinfection technologies are classified in tertiary treatment, which
inactivates disease-causing organisms (EPA, 2012). These water treatment processes have
effects on the removal of hazards in water and provide viability for quantitative risk
assessment (Cummins et al, 2010).

This model structure provides a common layout of the processes which water undergoes
before human consumption. The probability of water contaminated by E. coli and lead in each
step of the model and water consumption parameters will be applied to conduct the
quantitative risk assessment.

Quantitative risk assessment
In the section of quantitative risk assessment, levels in water, probability of occurrence of
lead and E. coli and drinking levels and final exposure levels of consumers will be considered.
Monte Carlo simulation will be used in this risk assessment based on the framework model
above. In this study, chemical (lead) and microbial (E. coli) hazard exposure levels will be
calculated based on the fundamental equation below.

\[ E = L \times C \] (1)

Where :
E chemical/microbial exposure levels (µg for lead, CFU for E. coli)
L chemicals/microbes initial levels in raw water (µg/l for lead, CFU/l for E. coli)
C likely water consumption (l)

This study will measure lead and E. coli levels in both public and private water supplies and
the units for measurement are µg/l for lead and CFU/l for E. coli. Chemical/microbe initial
levels in raw water and likely water consumption are identified as inputs and the exposure
level is the simulated output. The distribution mode for this risk assessment will be selected
based on previous publications and the basic equation will be developed with more
information of variability and uncertainty in future study.

Results
According to the standards for drinking water quality, there are specific limits for levels of
E. coli and lead in water. Drinking water should contain no E. coli and once it is monitored,
remedial methods should be taken (EPA, 2010).

There is a change in the lead standard for water quality since December 2013 when the
maximum concentration of lead in water was decreased to 10µg/l from 25µg/l. Where levels
are exceeded methods should be introduced to reduce lead level in water, otherwise there is a
risk to public health (EPA, 2010). The results from contamination test section will be
compared with the standards of the EPA to evaluate whether the water quality satisfy the
requirements of the EPA.

The data required to develop the risk assessment model will be collected in further research.
Comparison of risk scores of human exposure to water from public water supplies and private
water supplies will be presented in the Monte Carlo simulation model.
Conclusion

Waterborne disease is a major cause of mortality globally and hence water quality needs to be carefully monitored and controlled. Water quality can be improved through risk assessment procedures which can identify critical stages in the process. The framework developed here will be further developed into a quantitative analysis. The results of the risk assessment can provide guidance on improving water quality and reducing public health risks.

References


VALORISATION OF WASTE IN THE DAIRY INDUSTRY

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Abstract

The production of mass marketed dairy products requires the use of natural resources and energy which generates a number of impacts on the environment. When a product is wasted it also means a loss and wastage of the resources used and this has not only environmental but also social and economic implications. There are pollution prevention controls in the industry that help reduce the amount of waste produced. Methods include reducing losses by better production control, changes in the packaging of products, management of wastewater sludge and the use of production waste in lower grade products. This study helps to pinpoint the main areas where waste valorisation can be improved to create more environmentally sustainable products.

Introduction

The food industry has a major impact on the environment, where almost one third of the food produced globally is wasted (European Environment Agency 2012, Eriksson et al. 2014). This is often food that is still edible and safe for human consumption. The wastage of this food puts a strain on resources such as land, water and energy and it is important to find ways to protect and manage resources so food production can be sustainable into the future. Although the exact figures for food waste are hard to calculate, the European Commission estimates that up to 90 million tonnes of food is wasted each year in the EU alone. Wasting food while millions are starving raises moral issues for the wealthier nations of the world, which has led to strategies to reduce the amount of wastage in the life cycle of food production. Under the European 2020 growth strategy, the European Union commissioned a report to minimise waste, improve production processes, and manage resources more effectively (European Commission 2011).

As dairy products play a significant role in the nutritional requirements for humans, the sector plays an important role in diets globally. Over a dairy products life cycle there are significant impacts on the environment, especially regarding Greenhouse gas emissions and water consumption (Milani et al. 2011). Djekic et al. (2013) conducted a life cycle assessment of different dairy products which found that the greatest impact on the environment was from the milk production stage at farm level, cradle to farm gate. However there is also a need to reduce the substantial waste that is created at all production processes, from processing to consumers. Wherever dairy products are wasted, they can end up in landfill where they will become an environmental problem. With the Food Harvest 2020 strategy there will be a possibility for expansion of operations at farm level and processing level. The abolition of the EU milk quota is expected to lead to higher productivity which will impact on resources and emissions to the environment. So it is important for the dairy sector to implement and develop ways to ensure the industry is sustainable in its growth. There is an opportunity for companies to benefit from the implementation of practices that ensure minimal resource losses from the sector, which will result in energy and resources cascading through the system and being utilised.

The objective of this study is to examine the utilisation of waste from the dairy industry and the valorisation of this waste to reduce environmental impacts.
Materials and Methods

The outcome of this study will be to isolate the best techniques and technologies to effectively manage waste that is created in the dairy industry. By understanding the best options for waste management it will be possible to give value to a waste stream, and prevent any adverse impact on the environment of human health from its disposal. An effective way to do this will be to undertake a desk-based study. This will comprise researching information that is available through previous studies, statistical publications, journals, the internet, and industry guidance documents.

A literature review will be carried out to gain an understanding of the important issues that affect the industry and how these may have been addressed in the past. Using this knowledge it will be possible to propose future ways to manage waste from dairy production and products in an environmentally sustainable way. To gain some first-hand knowledge of the food and dairy industry there will be some site visits undertaken. A site visit will help gather data on the volumes and type of waste created at a functioning production facility, and provide a clearer picture with regards the management of this waste. Speaking to industry professionals will also be beneficial in the collection of information and insights on waste issues in the sector and the practicalities of the utilisation of new techniques.

The dairy industry in Europe operates under Integrated Pollution Prevention and Control (IPPC) licences, enforced by the different environment agencies in each member state. Guidance notes on the Best Available Techniques (BAT) or BAT Reference (BREF) documents, for the dairy sector will be examined for Ireland and other European countries (EPA 2008). Examining these documents will help understand the current techniques employed and the environmental performance that is required by license conditions. Also by researching current practices in the dairy industry internationally, it will be possible to compare approaches and highlight any possible technological imbalances in the Irish dairy industry.

Results and Discussion

The research on the project thus far has revealed the current trends in the industry with regards growth and technology. The Irish dairy industry is in a healthy place and has opportunity for future growth (Geary et al. 2010) which can be sustainable both economically and environmentally. A review of the literature and current technologies is still ongoing and an accurate assessment of the main issues in dairy waste valorisation can be realised as more research is completed through a desk based study and site visits at production facilities.

There has been some recent research completed within the dairy sector regarding valorisation of dairy waste and ways in which by products can be used rather than wasted. For an ideal situation all components of raw milk (RM) can be used to create products. As all dairy products are interrelated, a by-product of one process can be used in another process. When a processing facility receives a supply of RM, an optimal result would be to completely use all constituents of the inputs to the facility. There are many different products that can be created through complete use of RM which can be seen in figure 1. The model reflects how the value of raw milk is in its components, and any inefficiency used component is a loss for the manufacturer (Banaszewska et al. 2013).

Conclusions

As the world’s population increases and developing nations improve economically there will be a greater need for sustainable agriculture and food production. Dairy is an important part of humanity’s dietary needs and it is important that sustainability is at the forefront of growth...
in the industry. Reducing waste in the dairy sector will be a critical part of this target and intelligent production and management of food will need to be implemented. The increase in food supply will be an important part of future growth and doing this with less damage to the environment should be an important focus for the dairy sector. The valorisation of waste is the best way to achieve this goal.

References


Figure 1. Representation of dairy flows (Banaszewska et al. 2013)


European Environment Agency (2012) Food Waste, Copenhagen, Denmark: EEA.


ASSESSING THE POTENTIAL OF PULSED ELECTRIC FIELD TREATMENT FOR IMPROVED DIGESTIBILITY OF ANAEROBIC DIGESTION FEEDSTOCK

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Abstract

Ireland still remains heavily dependent on fossil fuels as its primary source of energy. However a target of 40% contribution of renewable energy sources to overall power generation by 2020 encourages an increased investment in renewable energy technology. Although wind energy has been the primary focus of renewable energy development, anaerobic digestion (AD) may provide a more consistent source of energy. However the generation of usable energy from AD is not instantaneous and relatively long retention times of the feedstock is a significant disadvantage. This study aims to investigate the application of Pulsed Electric Field pre-treatment of some AD feedstock materials and predict its efficacy as a means to decrease retention times through enhancing the digestibility of these materials.

Introduction

Anaerobic Digestion is a naturally occurring process whereby organic matter is broken down by bacteria in the absence of oxygen. This process produces biogas composed primarily of methane (60%) and carbon dioxide (40%) (Molino et al. 2012). AD can be described as a multi-step process whereby different components of the organic material are progressively broken down to simpler compounds through metabolic reactions, namely hydrolysis, acidogenesis and methanogenesis (Khalid et al. 2011). One significant disadvantage of AD however is the relatively long retention times required to complete these steps and digest the material to a satisfactory level. The hydrolysis step, which involves the initial degradation of complex organic matter, is considered to be the rate limiting step in the process. This is particularly evident for the digestion of solid or lignocellulosic materials e.g. grass, maize and food waste, which is the focus of this study (Khalid et al. 2011). This hindrance to process efficiency can often result in a requirement for pre-treatment of the feedstock prior to its introduction into the AD system in order to enhance its biodegradability. Pre-treatment aims to improve efficiency either by decreasing the residence time or increasing biogas yield for an already established residence time. These pre-treatment methods may be biological, mechanical or chemical (Mata-Alvarez et al. 2000). Some of these pre-treatments methods include, alkali or acid addition, feedstock particle size reduction, pre-digestion, pre-composting and the addition of enzymes (Mata-Alvarez et al. 2000; Yadvika et al. 2004).

This study explores the use of pulsed electric field (PEF) technology as an alternative pre-treatment method for solid feedstock pre-treatment. PEF has been primarily limited to food processing as well as various biotechnological applications (Ravishankar et al. 2008). However its application in the enhancement of biofuel technology, including AD, has also been explored. Exposure to a PEF is reported to exert significant damage on the treated materials. Membrane breakdown, increased permeability and cell rupture are all possible effects induced by PEF treatment (Salerno et al. 2009; Kumar et al. 2009; Kumar et al, 2011).

The objective of this study is to investigate the application of pulsed electric field treatment as means to enhance the digestibility of selected, solid anaerobic digestion feedstock.
Materials and Methods

Feedstock Characterisation
In this study a number of typical biomass to energy feedstock materials are considered for analysis. These are maize, miscanthus grass, wood residue (sawdust, pellets) and organic, food waste. Prior to PEF treatment, these materials will be analysed for dry matter content, moisture content, ash content and energy content using standard oven drying methods and bomb calorimetry. Crude fibre (CF) content will also be approximated using proximate/Weende analysis methodology.

Pulsed Electric Field Treatment
PEF treatment will be performed using a pilot-scale PEF system (ELCRACK HVP-5, DIL, German Institute of Food Technologies). Samples will be homogenised and sieved where appropriate. Samples of miscanthus will be cut to a uniform size as required by the PEF system compartment specifications and to ensure homogeneity. As the materials will be treated in a solid form the system will be operated in batch mode. Parameters will be systematically varied in order to assess the impact each adjusted parameter has on the material as determined by the post-treatment analyses. The parameters include output voltage, pulse width, pulse frequency, pulse number, treatment time and energy emitted.

Post-Treatment Analysis
Post-treatment analysis will be composed of a number of qualitative and quantitative analyses which will be used as indicators of improved digestibility potential. Any initial, observable effects on the treated samples will be noted. Crude fibre content will also be determined post-treatment using the same methods mentioned above in order to determine any change in fibre (cellulose, hemicellulose and lignin) content. Crude fibre is calculated as a percentage of the mass of dry matter within the samples using the equation below:

\[
\text{Change in structural integrity and texture will be analysed using the Ottawa Pea Tenderometer method. This method measures the force required for a plunger to compress the test material through a wire grid.}
\]

Treated samples will also be centrifuged in order to examine the release of cellular material which will also be used as an indicator of cell wall degradation from PEF exposure and increased permeability and porosity. The contribution of PEF treatment to this release will be assessed through comparison of centrifuged, control (untreated) samples.

Response surface methodology will also be applied in order to determine any relationships between the PEF system variables (parameters) and the response variables as determined by the above analyses. This will enable the determination of optimum PEF operational parameters for any future treatment and analysis.

Expected Results
As experimental analysis and preparation is on-going, expected results are discussed here. As stated in previous studies, exposure to a pulsed electric field is capable of exerting significant cellular damage and ultimately plant tissue damage depending on the PEF system operating parameters (Kumar et al. 2009). With this in mind a number of results are predicted. As pores are formed within the cell wall and material is degraded a decrease in crude fibre content is expected as this is a primary constituent of the outer cell. It is important to note however that there can be an inherent loss of material when applying this method which may yield in accurate results and therefore consideration for alternative methods may be necessary.
In applying the Ottawa Pea Tenderometer test, a decrease in the force required is expected due the structural degradation of the organic material and softening of the cell wall induced by PEF treatment when compared to untreated samples.

As discussed, an increase in permeability and porosity of treated samples is also expected (Kumar et al. 2011). In this study, permeability was assessed by examining the uptake of red dye by both untreated and treated samples of switchgrass and woodchips at various exposure parameters. It was concluded that PEF treatment had a positive effect on increasing permeability.

![Figure 1](image_path)

**Figure 1.** Neutral red dye uptake experiments for untreated and treated wood chip samples 10kV/cm field strength

This should in turn encourage the release of cellular material and fluid when centrifuged, therefore an increase in the volume of fluid released would be expected.

**Conclusions**

This study aims to examine the potential for Pulsed Electric Field treatment as an effective method for pre-treating anaerobic digestion feedstock high lignocellulosic material. A decrease in crude fibre content would be suggestive of improved digestibility within an AD system as the initial breakdown of these components is a significant hindrance to the system efficiency, increasing retention times. A decrease in force required in the Ottawa Pea Tenderometer test would also be suggestive of a breakdown of lignocellulosic material as this would soften the material easing its compression. Increased permeability/porosity as examined through centrifugation of the treated material would also be suggestive of a
breakdown of the cell wall. The subsequent release or easier access to more readily digestible compounds resulting from this would also be suggestive of improved digestibility.

References

Abstract

Fat, oil and grease (FOG) is a by-product of food production. FOG enters the drainage network in solution as a result of poor practices when performing washing activities in both domestic and commercial kitchens. FOG may fall out of solution, accumulate and form a hardened solid in sewer infrastructure, as a result of physical and chemical property changes, leading to a loss of serviceability in the pipeline. This paper is a brief outline of a proposed, novel, dynamic risk assessment method to be developed and utilised in conjunction with GIS software to generate FOG Risk Maps. It is proposed to link the static risk arising from the installed sewer infrastructure with the dynamic risk of applied FOG loading generated by food service establishments using the mapping software. The FOG Risk Maps shall be generated as part of an overall project to assess the efficacy of Dublin City Council’s FOG Programme and to investigate the potential for the implementation of similar programmes in Ireland.

Introduction

Sewer overflow is a primary cause of urban flooding. Sewerage derived flooding is broadly categorised by causation as either: flooding as a result of hydraulic overloading; or flooding as a result of all other causes (Arthur et al. 2009, Arthur et al. 2008). While major flooding events tend to be the result of hydraulic overloading, i.e. as a result of storm or tidal flows, 84% of sewerage derived flooding incidents (>26,000) in England and Wales per year are derived from “other causes” (Arthur et al. 2008a). It is estimated that greater than 90%, approximately 24,750 events per year, are the result of in line blockages (Arthur et al. 2008), of which an estimated 50-75% are caused by fat, oil and grease (FOG) blockages (Keener et al. 2008). FOG accumulates in sewer systems in the form of hardened solids (Iasmin et al. 2014, Keener et al. 2008) leading to sewer blockages and potential sewer overflow. He et al. (2013) suggest four major components contribute to FOG deposit formation in sewer pipes: calcium, free fatty acids, FOG (or oil), and water. It has been further suggested that concrete corrosion combined with low flow velocity pipelines are contributing factors (He et al. 2013). Sewer overflows as a result of FOG blockages can potentially release high concentrations of pathogens, nutrients, and solids that impose a risk to public health and the environment (He et al. 2013).

In 2008 Dublin City Council (DCC) introduced its “FOG Prevention Programme” to address the recurring FOG related blockages in the drainage network. Now in its seventh year, the programme monitors the trade effluent discharge of over 2000 licenced food service establishments within the DCC functional area. It is hoped that by promoting behavioural change, the DCC FOG Programme can significantly reduce the quantity of FOG entering the drainage network.

The objective of this project is to utilise GIS to evaluate the efficacy of Dublin City Council’s FOG Programme in reducing the risk of causing blockages posed by food service establishments to the drainage network, to investigate the environmental benefits of such programmes and to examine the potential to implement similar initiatives nationally and internationally.
Materials and Methods

Data Acquisition
A desk study will be performed to establish the pre-FOG Programme state of the chosen catchment. A review of historic environmental inspection notes, performed in the initial stages of the FOG Programme combined with DCC Drainage Division maintenance records will provide a description of the state of the pre-FOG Programme catchment.

A desk study of the DCC drainage map for the chosen catchment will be performed in order to determine the extent and condition of the in-situ sewer infrastructure. On-site surveying, in the form of environmental inspections performed by the researcher in the catchment and recent DCC Drainage Division maintenance records will describe the current state of the catchment.

The combined data sources will be analysed to provide information on “blockage hotspots” and evaluate the environmental benefits of the DCC FOG Programme.

Data Mapping
GIS software will be utilised to give a spatial representation of the factors influencing FOG risk in the urban catchment under review to link food service establishment (FSE) distribution and density in relation to the underlying drainage network. This data shall include:

- FSE data, including: location; compliance with trade effluent discharge licence; and nature of business.
- Drainage network data, including: pipe length; pipe material; pipe gradient; number of connections; and blockage history.

Risk Analysis
A novel dynamic risk assessment model specific to FOG blockage management will be developed and applied to the below ground infrastructure (static risk) and above ground FOG loading (dynamic risk). A FOG Risk map will be generated by assessing each risk component individually, and combining using the GIS software to layer and weight the components to achieve a true representation of the actual risk posed by FSEs.

Results and Discussion
This project is in the early stages of development and results will be published later. However, it is projected that through the development of the pre- and post-FOG Programme, the risk reduction during the FOG Programme will be significant.

The FOG Risk Maps will provide a robust method of scheduling environmental inspection and preventative maintenance frequency in order to protect drainage infrastructure and will allow programme coordinators to streamline inspection frequency and pin-point at-risk areas. Currently, FOG inspection frequency is determined on the “FOG Risk Category” as determined during the previous Environmental Inspection. FSEs are assessed on their compliance with the 15 conditions of their trade effluent licences and placed in the relevant FOG Risk Category. The categories are defined in accordance with Table 1, below. Inspection frequency is dependent on this compliance, as outlined in Figure 1, below. Licencing fees are then set according to this FOG Risk Category.

It is proposed that following the development of the FOG Risk Maps, inspection frequency may be determined based upon the applied FOG Risk posed by the FSE to the drainage network, leading to a more focused inspection programme. This risk rating will account for the size and nature of the food service establishment, the existing in-situ risk from the drainage infrastructure and the history of blockages in the area.
Table 1. Defining the FOG Risk Category

<table>
<thead>
<tr>
<th>Category 1 – Unacceptable</th>
<th>Premises has failed to apply for a trade effluent licence within the given timeframe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Category 2 – High Risk</td>
<td>Premises has no grease trapping equipment installed</td>
</tr>
<tr>
<td></td>
<td>Premises has undersized/unsuitable grease trapping equipment installed</td>
</tr>
<tr>
<td></td>
<td>Installed grease trapping equipment is in poor condition as a result of a failure to meet the required maintenance standards</td>
</tr>
<tr>
<td></td>
<td>Grab sample taken of trade effluent has a FOG concentration of greater than 300% the allowable concentration of 100 mg/L</td>
</tr>
<tr>
<td>Category 3 – Medium Risk</td>
<td>Grease trapping equipment is overdue, but not in serious breach of minimum maintenance requirements</td>
</tr>
<tr>
<td></td>
<td>Paperwork, including FOG disposal records, is not available for inspection, incomplete, or inaccurate</td>
</tr>
<tr>
<td></td>
<td>Poor management practices in the kitchen area of FSE</td>
</tr>
<tr>
<td></td>
<td>Absence of sampling location on grease trapping equipment</td>
</tr>
<tr>
<td></td>
<td>Grab sample taken of trade effluent has a FOG concentration greater than allowable concentration of 100 mg/L but less than 300% allowable concentration</td>
</tr>
<tr>
<td>Category 4 – Low Risk</td>
<td>Grease trapping equipment is in good condition and all pertinent information is available and up to date</td>
</tr>
</tbody>
</table>

Figure 1. Pie chart representing the current level of compliance and inspection frequency for 145 food service establishments (FSE) within an urban catchment in Dublin City Council’s operational area
Conclusion

This project will provide water service providers with a robust method of scheduling environmental inspection and preventative maintenance frequency in order to protect drainage infrastructure. By maintaining a high level of serviceability in the drainage infrastructure, water service providers can reduce the likelihood of blockage and sewer overspill events occurring, thus reducing the associated environmental concerns associate with such events. This project is a part of a larger project to assess the efficacy of Dublin City Council’s FOG Programme and to investigate the potential for the implementation of similar programmes in Ireland.

Acknowledgements

This project is funded by the Irish Research Council and Noonan Services Group as part of the Employment Based Postgraduate Research Programme. The authors would like to thank both parties for their support.

The authors would also like to thank Dublin City Council and Irish Water for their support of the project.

References


Abstract

The presence of detectable levels of contaminants in biosolids has led to concerns that land applications may translocate through the food chain. In order to prioritise the contaminants of concern (metals and PPCPs), a quantitative risk ranking approach was developed. Risk ranking results revealed that the metals Cu, Pb and Ni and the PPCP triclocarban are of importance. Sensitivity analyses based on rank order correlation revealed that partition coefficient (Kd) was the most important parameter with regards to metals (correlation coefficient 0.69 and -0.43 for Zn and Ni respectively), whereas percentage recovery in soil was the most important parameter for PPCPs (correlation coefficient -0.65 and -0.60 for triclocarban and triclosan, respectively).

Introduction

Biosolids that originate from wastewater treatment plants are a rich source of organic materials as well as nitrogen and phosphorus. These elements make biosolids an ideal substrate in which to fertilize agricultural land. However, despite advances in sewage treatment, most of the organic and inorganic contaminants remain in the sludge after treatment and are subsequently applied to agricultural land. Contamination, mainly linked to the consumption of pharmaceuticals and other inorganic compounds and their subsequent excretion in wastewater, is the source of diffuse and continuous pollution into surface water. The fact that certain substances are persistent in the environment along with the inefficiencies of wastewater treatment plants to eradicate these substances has intensified the situation. When sludge is applied to agricultural land, contaminants will tend to accumulate in the cultivated layer of topsoil and following repeated applications of sludge, contaminants could theoretically accumulate to toxic concentrations that might adversely affect, for example, crop growth and quality, soil fertility and food chain (Code of Practice 1996). To assess the potential risk to human health from the application of biosolids to agricultural land, it is imperative to implement a quantitative risk assessment method. In order to prioritize the contaminants of concern, a quantitative risk ranking approach can be adopted.

The objective of this study is to (1) rank metals and pharmaceuticals and personal care products (PPCPs) detected in Irish biosolids, and to identify those posing the greatest risk to surface water and human health; (2) to develop a quantitative risk ranking model to compare the potential risk of soil contamination and subsequent health risks resulting from the land spreading of biosolids.

Materials and Methods

With regards to metals and PPCPs, there are concerns with the levels being released into the environment, the bioavailability of the released contaminants and the potential human toxicity. The aforementioned variables can be implemented to develop a risk ranking model to rank the human health risk from land spreading of biosolids on agricultural land. Risk ranking can be used to prioritize substances for focused risk management (Labite and Cummins, 2012). A preliminary risk ranking exercise (Fig 2) was conducted in EXCEL 2007 to refine the contaminants of concern based on the occurrence of the contaminants detected in European biosolids. Input data was collated from existing scientific literature and threshold parameters for persistence, bioavailability and toxicity (PBT) were obtained from the Environmental Protection Agency United States (USEPA) PBT profiler. The results were analysed, and the contaminants of concern in Ireland were chosen to be further analysed using sensitivity analysis.
Input data that was collated from existing scientific literature was used to create a simulation model of probable events in EXCEL 2007 (with the @Risk 6 add-on) to calculate the biosolid levels detected in biosolids (BL), the partition coefficient \( K_d \) (\( K_{ow} \) PPCPs only), solubility, bioavailability fractions (exchangeable, reducible, oxidisable, residual), percent recovery and toxicity (LD50 oral Rat) and to characterise the risk of the contaminants to human health. Data was collected for the metals; cadmium (Cd), copper (Cu), nickel (Ni), lead (Pb), zinc (Zn), chromium (Cr), and PPCPs; carbamazepine (CBZ), triclosan (TCL) and triclocarban (TCC). A description of the risk ranking calculations to evaluate rank scores for metals is presented in Table 1. Each of the above variables was assigned a parametric distribution. Each distribution was sampled 5000 times (iterations) to determine possible scenarios that follow the set distribution shape. The Monte Carlo simulation resulted in a probability distribution for each metal and PPCP. The equations in Table 1 were used to rank the contaminants of concern by implementing a qualitative approach to the risk values of low, moderate and high.

### Table 1. Description of risk ranking calculations to evaluate rank levels for metals

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Input</th>
<th>Risk level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biosolid levels</td>
<td>BL</td>
<td>RBL,x</td>
<td></td>
</tr>
<tr>
<td>Partition coefficient</td>
<td>( K_d )</td>
<td>RK_{d,x}</td>
<td></td>
</tr>
<tr>
<td>Solubility</td>
<td>( S_{ol} )</td>
<td>RS_{ol,x}</td>
<td></td>
</tr>
<tr>
<td>Exchangeable fraction</td>
<td>EF</td>
<td>REF,X</td>
<td></td>
</tr>
<tr>
<td>Reducible fraction</td>
<td>RF</td>
<td>RRF,X</td>
<td></td>
</tr>
<tr>
<td>Oxidisable fraction</td>
<td>OF</td>
<td>ROF,X</td>
<td></td>
</tr>
<tr>
<td>Residual fraction</td>
<td>( R_{es}F )</td>
<td>RResF,X</td>
<td></td>
</tr>
<tr>
<td>Toxicity</td>
<td>( T_{ox} )</td>
<td>RTOX,X</td>
<td></td>
</tr>
</tbody>
</table>

Output risk scores were calculated as follows; \( \text{Rank} = BL,x + K_d,x + S_{ol},x + EF,x + RF,x + OF,x + R_{es}F,X + T_{ox},x \), where \( x \) denotes the relevant contaminant.

### Results and discussion

Preliminary risk ranking results revealed that the class of contaminant of greatest concern in Ireland are the pharmaceutical and personal care products (PPCPs) carbamazepine, triclosan and triclocarban. These contaminants were further analysed using Monte Carlo simulation to assess the effect of uncertainty and variability in the model input parameters. Risk ranking results for PPCPs reveal that triclocarban ranked the highest score based on parameter values. Sensitivity analysis based on the rank order correlation coefficient revealed that the most important parameter with regards to PPCPs is percent recovery in soil with correlation coefficient of -0.65 triclocarban and -0.60 triclosan (Figs. 1 & 2).

Risk ranking results for metals in biosolids revealed that Cu, Pb and Ni ranked the highest (Fig 3). Sensitivity analysis has shown that the partition coefficient \( K_d \) was the most important parameter (with correlation coefficient values 0.60 and -0.43 for Zn and Ni, respectively). The solubility and soil-water partition coefficients \( K_{ow} \) of heavy metals are of paramount importance to predict the behaviour and mobility of metals within the soil compartment and the extent of their transfer to surface water (Carlon et al. 2004). Figure 4 show Spearman rank order correlation for Zn in biosolids.

Despite advances in wastewater treatment, biosolids still continue to harbour contaminants. Although present in the µg/L-mg/L levels, their continuous entry to the environment is problematic. In Ireland, the release of metals to the environment via biosolids is subject to stringent conditions such as pH of soil (must be <5) or clay content less than 10 % (Code of Good Practice 1996). Metal levels detected in Irish biosolids are all below the permissible limits set by the Sewage Directive (86/278/CEE). The same cannot be said for PPCPs which have not been regulated or hold conditions for land spreading. The continuous
introduction of PPCPs and their bioactive metabolites into the environment may lead to high, long-term concentrations and promote continual but unnoticed adverse effects on aquatic and terrestrial organisms (Barceló and Petrovic, 2007)

**Figure 1.** Sensitivity analysis for triclocarban in biosolids

**Figure 2.** Sensitivity analysis for triclosan in biosolids

**Figure 3.** Risk ranking scores for metals in biosolids including 5th and 95th percentiles.
Conclusion

The risk ranking methodology developed has revealed that the metals in biosolids of most importance with regards to human health risks are Cu, Pb and Ni, whereas the top ranking PPCP was triclocarban. Sensitivity analysis for metals has revealed that the partition coefficient (K_d) of metals in soil, Zn and Ni are of importance due to its propensity to be more soluble and hence more mobile in the soil. With regards to bioavailability fractions, the fraction of most importance was the residual fraction and the metal Cd. Sensitivity analyses for PPCPs reveal that the recovery and toxicity parameter was of most importance with regard to TCC, TCS and CBZ, indicting the ubiquitous nature of these contaminants in biosolids and the ensuing environment. This study highlights the need to view contaminants individually as potential risk from each contaminant will be influenced by different inputs.

Acknowledgements

The authors acknowledge the Irish EPA for the funding of this project under the STRIVE Programme (2007-2013). Project partners include Teagasc and NUI Galway

References


Figure 4. Sensitivity analysis for Zn in biosolids.
THE STRATEGIC ASSESSMENT OF ATMOSPHERIC AMMONIA FROM INTENSIVE AGRICULTURE – EARLY STAGE SCREENING

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\textsuperscript{b}University of the West of England, Bristol, United Kingdom.

Abstract

Intensive pig and poultry farming has been shown to influence its environs by the release of ammonia into the atmosphere. While Food Harvest 2020 aims to increase productivity of these two sectors, any existing impact on the environment is also likely to increase. In order to comply with the Habitats Directive (92/43/EEC), and subsequent devolved National European Communities (Birds and Natural Habitats) Regulations 2011 (SI 477/2011) it is necessary to prove beyond any reasonable doubt that the intensive agriculture units in Ireland have no significant impact on Natura 2000 (N2K) sites. This project adopted the United Kingdom’s Environment Agency threshold distances in order to identify priority areas for assessment within the N2K network. Following geospatial analysis, it was found that 0.5%, 2.5%, 4.4% and 4.1% of the N2K network fell within 1km, 5km, 10km and 15km respectively of intensive poultry units; where 0.5%, 2.3%, 6.4% and 9.3% of the N2K network fell within 1km, 5km, 10km and 15km respectively of intensive pig units. Though this level of screening can be used to identify the potential risk areas, it does not provide any indication of actual impact.

Introduction

Ireland has a strong tradition of both pig and poultry production, with plans under Food Harvest 2020 to increase their industry value of €330 million and €254 million by 50% and 10% respectively. As a member of the European Union (EU), Ireland has obligations to ensure that it achieves this growth while taking cognisance of the potential risks to the environment, particularly sites which are protected under EU law.

Environmental conservation within the European Union (EU) is built upon the foundation of both the Habitats Directive (Council Directive 1992/43/EC) and the Birds Directive (Council Directive 2009/147/EC). Combined, these directives result in both the designation of protected sites, collectively known as the Natura 2000 (N2K) Network; and the subsequent protection of designated features within these sites. The N2K network is extensive both in Europe and in Ireland, with sites designated for the protection of a large range of habitats, mammals, birds, fish and invertebrates.

Pig and poultry production account for 6% and 2% respectively of Ireland’s atmospheric ammonia emissions, with cattle producing the majority of 82%, with the remaining 9.7% being produced by sheep, conserved grassland, maize and tillage crops (Dowling 2012). Atmospheric ammonia poses a significant direct effect to habitats and species accustomed to low nutrient environments, such as bogs, heathlands, sand dunes, etc. (Pitcairn, 1998; Erisman et al 2007; Hicks et al 2011). Whereas, protected species could also be at risk of secondary impacts through both eutrophication and acidification, such as the depletion of food resources (lichens) for the Kerry slug.

Countries have developed a range of threshold screening distances in order to identify high risk receptor areas for atmospheric ammonia. Threshold distances provide a useful tool during the screening of Intensive Agriculture Units, as it easily excludes the sites where there is no potential overlap between pollutants and receptors. The United Kingdom’s Environment Agency’s screening distances have been adopted within this project to identify the priority areas within the N2K network potentially exposed to excess ammonia levels and loads. Four tiers of priority are employed as part of this screening exercise, corresponding to N2K sites that occur within 1km, 5km, 10km and 15km of an intensive agriculture unit.

The objective of this exercise was to identify intensive pig and poultry units within the threshold distances 1km, 5km, 10km and 15km in order to screen N2K sites against intensive agriculture in Ireland, and establish priority areas for assessment.
Materials and Methods

Only poultry units where places exceed 40,000 birds; or where pig units exceed 2,000 places for production pigs or 750 places for sows require licensing under the Integrated Pollution Prevention and Control Directive (IPPC) (2008/01/EC), and as such were the only units considered an appropriate scale to be included as part of this assessment. Locations of IPPC licensed facilities within the Republic of Ireland (ROI) were obtained from the EPA Envision mapviewer website (EPA 2014), while the location of units within Northern Ireland (NI) were obtained by request from the Northern Ireland Environment Agency (NIEA). These locations were used to generate point shapefiles in ArcMap 10.3. N2K site boundary shapefiles were downloaded for both the ROI and NI, from the National Parks and Wildlife Services (NPWS 2013) and NIEA (NIEA 2014) websites, respectively. ArcMap was subsequently used to generate “halos”, or “buffers” using the adopted UK Environment Agency threshold distances, i.e. 1km, 5km, 10km and 15km. It was subsequently possible to extract the N2K sites which fell within range of the threshold distances; these were mapped as priority areas for consideration of impacts arising from atmospheric ammonia. The areas occupied by the four tiered priority areas were calculated using ArcMap 10.1.

Results

In total, between the ROI and NI there are 263 poultry units and 129 pig units (Figure 1) that are regulated under IPPC licensing. Of these licensed units, there are approximately 12 Priority 1 Areas within vicinity of poultry units, and 14 for pig units (Figure 2); these are the areas of N2K sites that fall within 1km of a licensed pig or poultry unit. Table 1 details the actual area occupied by N2K sites (as presented in figure 2) within each distance threshold of pig and poultry units. Of the total area covered by the N2K network, 0.05% falls within 1km of a poultry unit, while 0.05% of the N2K network also falls within 1km of pig units. While poultry units are concentrated in the North East, pig units are more evenly spread through the ROI, and as such have the potential to be proximal to a higher number of N2K sites. This only becomes apparent when considering sites between 5km and 15km from the units; where 8.45% of the N2K network overlaps with the distance thresholds of the poultry units, and 15.68% of the N2K network overlaps with the distance thresholds of the pig units.

**Figure 1.** Distribution of IPPC licensed intensive agriculture units and N2K network.
Figure 2. Priority N2K areas for assessment against intensive agriculture unit emissions.

Table 1. Summary of N2K coverage within EA distance thresholds of intensive agriculture units, and the total coverage of N2K sites from the ROI and NI. *The area of the full N2K network is calculated based on the actual area covered and excludes any overlap of Special Areas of Conservation and Special Protection Areas.

<table>
<thead>
<tr>
<th>EA Distance Threshold</th>
<th>Area</th>
<th>Poultry Units</th>
<th>Pig Units</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>ha</td>
<td>% of Total N2K</td>
</tr>
<tr>
<td>1km</td>
<td></td>
<td>841.4</td>
<td>0.05</td>
</tr>
<tr>
<td>5km</td>
<td></td>
<td>39540.2</td>
<td>2.5</td>
</tr>
<tr>
<td>10km</td>
<td></td>
<td>71133.4</td>
<td>4.4</td>
</tr>
<tr>
<td>15km</td>
<td></td>
<td>65477.9</td>
<td>4.1</td>
</tr>
<tr>
<td>Full N2K Network*</td>
<td></td>
<td>1615437</td>
<td>100</td>
</tr>
</tbody>
</table>

Discussion

This level of screening serves to highlight the potential risk areas where further assessment is required; it does not present the most heavily impacted areas. More detailed future assessment will give full consideration to the type of unit, ventilation systems in place, stocking density, etc. The full extent of the impact can only be assessed once emission monitoring takes place on a range of farms, and reliable ammonia emission factors are established. After this stage, the footprint of the emissions from a source needs to be cross referenced with the critical loads and critical levels of designated features that lie within the priority N2K areas.
Early screening assessment of sensitive areas using distance thresholds is wholly dependent on the distances used. The four tiered levels of proximity used within this project are based upon distances used by the UK Environment Agency; where they use 10km as the standard screening distance for N2K sites. There is some evidence however to suggest this may be overly cautious compared to similar international methods, where in the Netherlands a threshold of 3km is applied for N2K sites (Hicks et al 2011).

The diversity of N2K sites also needs to be given cognisance when viewing the priority areas identified in Figure 2. As there is a huge diversity of sites protecting an array of species and habitats, it follows that not all N2K sites will be sensitive to atmospheric ammonia; and in some cases may be beneficial to the designated features of a site. There are numerous mechanisms by which atmospheric ammonia can influence a N2K site, though the majority of these are the result of either eutrophication or acidification, more complex secondary or multi-trophic mechanisms also occur. Botanical diversity is directly impacted within 50-300m of as a result of emitted atmospheric ammonia (Pitcairn et al 1998).

Despite the measures in place under the Habitats Directive, emissions to N2K sites are often under considered or even excluded from the appropriate assessment process in practice. Article 3 of the Environmental Impact Assessment Directive (EIA) (85/337/EEC) identifies nine facets of the environment to be assessed; including human beings, flora and fauna, soil, water, air, etc. Though environmental assessment under the Habitats Directive is designed to assess impacts only on the designated features of a site (a subset of the flora and fauna facet); no assessment should be considered appropriate until it fully considers all potential impacts capable of arising from the listed environmental facets on the site’s designated features.

Acknowledgements

The authors acknowledge funding for this project by STRIVE as administered by the Environmental Protection Agency. The authors would also like to thank both the EPA and the Northern Ireland Environment Agency Staff for information and support provided. Further details of the project are available at http://ssu.ie/research/ammonian2k/

References:

TRUCK TRACKING SYSTEMS TO OPTIMISE THE IRISH FOREST ENERGY SUPPLY CHAIN

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Abstract
Industrial biomass energy accounted for 69% of all thermal renewable energy used in 2011, which corresponds to 2.9% of all thermal energy used in Ireland. Forestry is the largest biomass resource, with over 744,000 hectares which equates to 10.6% of Ireland's land area, and a further 17% expansion of forest cover is planned by 2030. The major barrier to the forest biomass expansion is the complex and expensive supply chain element; with transportation counting for a major portion of the overall supply chain costs. This study presents the use of GPS tracking systems to optimise transportation routes. The aim of this study is to optimise forest energy supply chain costs in Ireland by incorporating these routes into the following two decision support systems: one tactical that optimises the biomass supply, and another operational that deals with trucks daily scheduling.

Introduction
There is currently strong demand for wood from sawmills, panel mills and from the emerging wood energy sector in Ireland. It is forecasted that by 2020 the demand for biomass for energy will be 53 MGj, with forest biomass delivering about 9 MGJ (Clancy and Scheer 2011). It is estimated that there will be a supply gap of 1.252 million cubic metres (Irish Forestry and Forest Products Association 2012). This scenario will create a tight supply/demand situation. If demand for wood is to be met by 2020, the balance of supply is likely to comprise imported biomass, or it will require a significant investment in the sectoral supply chain, either way this will increase the competition for wood fibre (Irish Forestry and Forest Products Association 2012).

Under this situation it is important that wood biomass resources are used as efficiently and cost effectively as possible. Woody biomass is a relatively new assortment in Ireland, with economic barriers to the widespread utilisation of it, and a lot of knowledge remains to be gained in order to supply the market properly. The Irish Forest Energy Programme has been researching and designing cost-effective wood fuel supply chains Kent et al. (2011). As part of this programme the development of new systems to improve transportation costs on the forest energy supply chains are being studied.

Minimising transportation costs is considered an essential aspect on supply chain optimisation (Eriksson and Bjoerheden 1989), as transportation costs can be responsible for 20% to 40% of the supply chain costs (Weintraub et al 1996). In Ireland road transportation is the main method for distributing wood to the processing plants. This will remain as the most important mode of transport, forming a substantial part of the industry's raw material cost and having a major influence on the sector's overall economic performance and competitiveness (Devlin et al 2008).

The aim of this study was to analyse the road-truck-driver interactions, select the "best" routes for wood biomass transportation, and incorporate this information into two decision support systems that optimises the forest biomass supply chain in Ireland.
Materials and Methods

The study consisted of three stages:

Stage 1- Best route selection: Travel data was gathered using a fleet management system built into a range of trucks with different number of axles, configuration, payload and volume capacity. The GPS was set to record its position every one minute along the routes travelled; other information gathered consisted on average speed, trip time, distance, loading and unloading time, and payloads. The information gathered was linked to ArcGIS 10.1 to analyse each trip and to create a GIS-based Irish road transportation network that provides travel distances, by road type, for a user defined route. The road network was analysed with ArcGIS extension Network Analyst in order to determine the best routes under cost, weight and speed restrictions.

Stage 2- Supply chain optimisation: Optimal routes generated through Network Analyst populate the second stage of the study which consists of the development of a spatial model that optimises forest biomass supply in Ireland. The linear programming model developed on MS Excel® plans harvesting, storage, chipping and transporting operations over a two year period using the wood moisture content (MC) as determining factor (Figure 1). Some of the parameters and conversion factors required to populate the model are presented in Table 1.

![Drying curves](image)

**Figure 1:** MC of biomass felled at different months and stored throughout the two year planning period.

<table>
<thead>
<tr>
<th>Parameters and conversion factors</th>
<th>SCI</th>
<th>SCII</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net Calorific Value at 0% MC (GJ/t)</td>
<td>19.10</td>
<td>19.20</td>
</tr>
<tr>
<td>Basic density (kg/m³)</td>
<td>377</td>
<td>377</td>
</tr>
<tr>
<td>Bulk density (kg/m³)</td>
<td>275.86</td>
<td>287.38</td>
</tr>
<tr>
<td>Bulk/solid volume conversion factor</td>
<td>2.90</td>
<td>2.90</td>
</tr>
<tr>
<td>Truck maximum legal payload 5 axle (kg)</td>
<td>23,000</td>
<td>23,000</td>
</tr>
<tr>
<td>Truck maximum loose volume capacity (m³)</td>
<td>95</td>
<td>95</td>
</tr>
<tr>
<td>Truck maximum legal payload 6 axle (kg)</td>
<td>27,000</td>
<td>27,000</td>
</tr>
<tr>
<td>Truck maximum loose volume capacity (m³)</td>
<td>95</td>
<td>95</td>
</tr>
<tr>
<td>Material loss rate (kg m⁻³ year⁻¹)</td>
<td>0.059</td>
<td>0.059</td>
</tr>
<tr>
<td>Interest rate %/month</td>
<td>0.49</td>
<td>0.49</td>
</tr>
</tbody>
</table>

Restrictions of the model:
- Moisture content of the biomass received at the plant.
- Energy demand at the plants.
- Even volume production through the planning period.
Stage 3- Truck scheduling: This Excel based scheduling uses a meta heuristic method called Simulated Annealing with the aim of maximising the productivity of truck transport while minimising the transportation costs and waiting times under technical, policy, and labour constraints. The scheduling model is Windows based under Visual Basic.Net programming, and it will also be linked to an ArcGIS Engine application.

Scheduling model information required
Depots:
- Number of depots.
- Opening hours.
Trucks:
- Number of trucks.
- Maximum legal payload per truck configuration (kg)
- Daily fixed costs.
- Idling costs.
- Unloaded travelling costs.
- Loaded travelling costs.
Forest:
- Number of forest.
- Type of truck configuration that can access each forest.
- Forest opening time for collection.
- Need of chipper.
- Productivity rate of chipper.
- Loading time.
- Products from each forest.
Customer:
- Number of plants.
- Opening hours.
- Type of products demanded, tonne of product demanded, GJ/tonne demanded.
- Unloading time at the plant

Results and Discussion
Experimental work is ongoing, but Figure 2 shows how the information from the GPS tracking system helps to determine the average speed, times and distances travelled by trucks on the Irish road network.
It is expected that route selection, truck configuration and wood moisture content will be key variables for the forest biomass supply chain optimisation model. This model will deliver a series of matrices containing information related to:

- Volume of biomass material to be harvested each month,
- Loose volume of wood chips produced at roadside or at the plant for each period,
- Storage periods,
- Number of truckloads delivered to the plant,
- Energy content of the material being supplied, and
- Total supply chain costs (harvesting, chipping, storing, transportation costs).

The truck scheduling model will report:

- Daily total transportation costs,
- Total volume to be hauled,
- Optimal (or near optimal) schedules indicating trips assigned to each truck,
- Travelling times and distances,
- Waiting times,
- Loading and unloading times.

**Conclusions**
Incorporating decision support tools that allow for the assessment of key fuel quality attributes and their effect on supply chain costs will help to remove one of the barriers to economic forest biomass development by minimising biomass transportation costs and therefore optimising the supply chain.

**Acknowledgements**
This study was funded by COFORD (National Council for Forest Research and Development in Ireland), and under the Charles Parsons Energy Research Program (Grant Number Grant Number 6C/CP/E001) of Science Foundation Ireland (SFI).

**References**


THE INFLUENCE OF ARTIFICIAL DRAINAGE ON LIFE CYCLE ANALYSIS OF IRISH DAIRY FARMS

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Abstract

Life cycle comparison analysis demonstrates the difference in environmental impact between Irish dairy farms with or without artificial drainage. A system simulation model based on Dairy_sim and LCA modelling are investigated to evaluate the impact of artificial drainage of heavy wet soils on the productivity and environmental impacts of dairy farms.

Introduction

In Ireland, dairy production systems are based on grazing (Fitzgerald et al., 2009). The main components of a grass-based dairy production system are: the herd, grass/land, housing. The system properties of a dairy production system can be identified into inputs and outputs. Ireland has regional differences in climate (temperature and precipitation). The interaction between regional climate and soil type influences the system of dairy production as far as the management system used, production and seasonal distribution of herbage (Fitzgerald et al., 2008; 2005). Soil can be classified according to drainage into poorly, moderately and well drained (Fitzgerald et al., 2008). Dairy farms are found on both well- and poorly drained soils in most parts of Ireland (Fitzgerald et al., 2009). Dairy production systems on well- and poorly drained soils differ in system properties and/or their management. Compared to well drained soils, poorly drained soils have been found to be lower in stocking rate, herbage production, main silage cuts, days of grazing, grazed herbage intake but, higher in baled silage cut and silage intake (Fitzgerald et al., 2008).

The objective of this study is to create a comparison Life Cycle Assessment for Irish dairy farms with or without artificial drainage.
Farm system properties are interlinked. For example, stocking rate is an important determinant of herbage demand and increased grass growth can lead to higher stocking rates (Fitzgerald et al., 2005). Increases in stocking rate can lead to a higher requirement of silage for feed and concentrate input (Fitzgerald et al., 2009; Casey and Holden, 2005a; 2005b). Concentrate feed facilitates milk output per cow (Yan et al., 2013a). Fertiliser is used for grazing application and silage ground, influencing total grass herbage production (Casey and Holden, 2005b). In pasture-based grazing systems, high concentrate feeding generally implies a deficit of on-farm feed supply due to high stocking rate or poor grass growth (Yan et al., 2013a).

Farm efficiency is the most important factor in terms of the balance of output per cow and feed supply. Excess water availability, water-logging or water stress can limit herbage growth (Fitzgerald et al., 2008). Wet soil conditions have been identified as the most important factor limiting the utilization of grazed grass on Irish farms (Creighton et al., 2011). Furthermore, trafficability and access of these soils are the most problematic factors that limit production rather than grass availability (Fitzgerald et al., 2009). The amount of water lost from the topsoil through either percolation or overland flow is referred to collectively as drainage (Fitzgerald et al., 2008). Generally, drainage is applied to increase or improve productivity (milk output) by directly encouraging grass growth, soil trafficability and accessibility (for animals and machinery) (Tuohy et al., 2013).

Life Cycle Analysis is used to understand the environmental impact of milk production (Yan et al., 2013b). It indicates the environmental burden throughout the life cycle of a product, i.e. from raw material extraction and production to end-of-life and waste management (Yan et al., 2011), (ISO 2006). It consists of four methodology stages (goal and scope definition, life cycle inventory, life cycle impact assessment (LCIA), and results interpretation) (Yan et al., 2013a). There are different approaches for LCA goal and scope definition, depending on the specific question under investigation, and ultimately depending on the decision that has to be supported by an LCA study (Rebitzer et al., 2004). There are specific stage parameters: production system, functional unit (FU), system boundary, allocation procedures for goal and scope definition (ISO, 2006a); impact categories and characterisation factor for the LCIA and emission factor. Life Cycle Analysis only addresses the environmental aspects of the production system, not economic or social aspects (Yan et al., 2011; ISO, 2006). Functional unit, system boundary and allocation procedures are defined, depending on the subject and intended use of the study. Energy Corrected Milk (ECM) or fat and protein content can be used as FU (Yan et al., 2011). Examples of FU are milk mass (1 tonne), 1000 L of milk (1.5%
fat), modified milk mass or 1 kg ECM, 1 kg of ECM delivered at the farm gate in 1 yr or 1 tonne ECM. The system boundary determines the processes associated with the delivery of the FU (ISO, 2006). In the allocation procedures inputs and outputs are partitioned (Yan et al., 2011). Examples of allocation are agricultural machines allocated by hectares of use (Yan et al., 2011), division of impact between the dairy unit and other enterprises e.g. liveweight export (economic allocation) (Yan et al., 2013a). For the LCI, data relating to the input and output of each process are collected (Yan et al., 2011). The aim of the LCI is to calculate the quantities of different resources required and emissions and waste generated per FU. The LCIA assesses the inventory data in terms of contributions to environmental impacts (Rebitzer et al., 2004). Impact categories of milk production are acidification and eutrophication. Impact categories like soil function and land use can make LCA more appropriate for agriculture (Yan et al., 2011). When the LCIA phase is excluded a study is referred to as an LCI (Yan et al., 2011). Interpretation of LCIA (ISO, 2006b) consists of identifying significant issues, evaluation of the model, sensitivity evaluation, assessment of data quality and making conclusions. It includes identification of the main causes of impacts and recommendation of mitigation measures. The selection of mitigation options is an example for a goal of an LCA (Yan et al., 2011; 2013a). Decisions in the design/development phase highly influence the environmental impacts in the other life cycle stages (Rebitzer et al., 2004). Drainage can be considered as design phase of a dairy production system in Ireland.

![Schematic representation of the life cycle of milk production](image)

**Figure 2.** Schematic representation of the life cycle of milk production (derived from principles defined in Sonnemann et al., 2003), defining the production phase to farm gate, value added processing and eventual waste management (Yan et al., 2011).

**Results and Discussion**

There is little research focus on the implications of drainage to the LCA of a dairy production system. In addition, the system properties of a dairy production systems vary and do we start from an average systems, one on well-drained soil. There is always some uncertainty as to how representative the average dairy farm can be (Yan et al., 2013).

**Conclusions**

This paper presents interim farm considerations to compare alternative land use options in order to establish the feasibility of increasing milk production on farms with heavy wet soil to meet Food Harvest 2020 targets for greater output with little or no increase in environmental impact and integrate dairy LCA modelling and data resources.

**Acknowledgements**

This research has been undertaken with the financial support of Science Foundation Ireland under Grant Number 06/CP/E001 and IRCSET under the Empower fellowship scheme. Improving the productivity of heavy wet grassland for delivery of Food Harvest 2020

The authors also acknowledge the assistance of Dr James Humphreys at Teagasc Crops Research Centre, Cork.
References


Improving Farm Management Using Information and Communication Technology for Lameness Detection on Dairy Farms

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Abstract
Livestock farming contributes around 18% of global Green House Gas emissions. As a major sector, dairy farming has the potential to improve its production efficiency by using information and communication technology (ICT) systems, which can provide farmers with real time information about animal welfare by lameness detection and derived decision support. This paper investigates the potential of ICT applications on dairy farms for lameness detection and management. The effect of the applied ICT system will be assessed by life cycle assessment and life cycle costing analysis. The expected result would be improvement of dairy production efficiency and economic profit.

Introduction
There is a growing demand for dairy products due to the expansion of population and the change of dietary habits. The dairy industry plays a significant role in Irish agriculture and the food industry is expected to grow as a consequence of the predicted expansion in dairy production following abolition of the EU milk quota system in 2015 (Ashfield et al., 2013). In order to improve the production efficiency of dairy farming, key influencing factors like animal welfare must be studied. Lameness is defined as a deviation in gait resulting from pain or discomfort from hoof or leg injuries and disease (Flower and Weary, 2009). Lameness is a major health and welfare issue in modern intensive dairy farming (Cha et al., 2010), which can lead to important economic losses. For example, lame cows may reduce the efficiency of automated milking systems (AMS) if less willing to visit the milking unit voluntarily (Borderas et al., 2008). Milk yield can also be significantly affected, according to Green et al., (2002) the estimated reduction in milk yield per 305-d lactation was approximately 360 kg.

On-farm detection of lameness is difficult. Currently, the most common methods used are visual locomotion scoring systems for monitoring animal gait (Flower and Weary, 2006). Some similar visual scoring systems like stall lameness scores (SLS) that monitor cow behavior when standing (weight shifting, standing on the edge of the stall, uneven weight bearing while standing, and uneven weight bearing while moving from side to side (Gibbons et al., 2014) are also used. Some systems measure the weight applied to each leg. A 4-balance system for measuring the leg load distribution of dairy cows during milking to detect lameness was developed by Pastell and Kujala, (2007). In addition, Alsaaad et al. (2012) developed electronic measurement using ALT-pedometer to monitor activity and lying behavior to recognize different behavior patterns between non-lame and lame cows. However, these methods all have problems such as validity, reliability, and sensitivity. Carrying out these assessments can be time-consuming and costly for farm management.

ICT systems can automatically sense lameness for early diagnoses by providing real time data information. Connecting to national databases via the Internet has the potential to explore the relationship between factors not previously considered because of the need for real time applications. With daily or even hourly updates, online information can create new possibilities to foresee and possibly prevent certain events. The objective of this project is to investigate the potential of ICT applications on a dairy farm for lameness detection and its implications for management.
Materials and Methods

Life cycle analysis
The environmental impacts of Dairy farming can be characterized by a life-cycle assessment (LCA) approach. LCA offers a comprehensive methodology for examining the net environmental performance of products and services across a suite of environmental metrics that includes all important interactions with human and natural systems (ISO, 2006a). When coupled with life-cycle cost analysis (LCCA), farmers are able to better ascertain the total impacts of their dairy farm and balance between environmental benefit and economic profits.

ICT integrated dairy farming system
The framework of ICT integrated dairy farming system is shown in Figure 1 (Rutten et al., 2013). It describes the steps from sensor system to farm management decisions. This study will use the sensor information from Level III to model foundation LCA model and integrates economic information to produce advice for the farmers.

![Diagram of dairy farm management system](image)

**Figure 1:** Framework of the use of sensor information in dairy farm management.

Because lameness can severely reduce dairy production, it is very important for farmers to know at which stage a cow is lame. The life stage of a cow can be divided into 5 parts: Calf, Growing heifer, Heifer, Lactating cow and Dry cow. According to previous studies, lameness is likely to happen during lactation. Figure 2 and Figure 3 (Green et al., 2002) show the incidence of first episode of lameness peaked 3 months after calving and high yielding cows were more likely to be lame with high milk production throughout lactation than cows that were never lame.

![Graph of number of cows lame by month](image)

**Figure 2:** Number of cows lame by month in milk
**Figure 3:** Mean lactation curves for cows that were ever lame versus those that were never lame. X axis = repeated measures of test day yield, Y axis = estimated kg of milk per day

The body condition scoring systems (five-point scoring system) can be applied for lameness detection in the ICT system. Each condition score is assessed by certain criteria simplified in Table.1 (Edmondson. et al., 1989). The parts of cow considered are the thoracic and lumbar regions of the vertebral column (chine, loin and rump), spinous processes (loin), tuber sacrale (hooks), tuber ischii (pin bones), and anterior coccygeal vertebrae (tail head) which are shown in figure 4.

**Figure 4:** The areas considered when scoring the body condition of a cow

<table>
<thead>
<tr>
<th>Body condition score</th>
<th>Vertebrae at the middle of the back</th>
<th>Rear view (cross section) of the hook bones</th>
<th>Side view of the line between the hook and pin bones</th>
<th>Cavity between tail head and pin bone Rear view and angled view</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Severe under-conditioning</td>
<td><img src="image1" alt="Image" /></td>
<td><img src="image2" alt="Image" /></td>
<td><img src="image3" alt="Image" /></td>
<td><img src="image4" alt="Image" /></td>
</tr>
<tr>
<td>2. Frame obvious</td>
<td><img src="image5" alt="Image" /></td>
<td><img src="image6" alt="Image" /></td>
<td><img src="image7" alt="Image" /></td>
<td><img src="image8" alt="Image" /></td>
</tr>
<tr>
<td>3. Frame and covering well</td>
<td><img src="image9" alt="Image" /></td>
<td><img src="image10" alt="Image" /></td>
<td><img src="image11" alt="Image" /></td>
<td><img src="image12" alt="Image" /></td>
</tr>
<tr>
<td>4. Frame not as visible as covering</td>
<td><img src="image13" alt="Image" /></td>
<td><img src="image14" alt="Image" /></td>
<td><img src="image15" alt="Image" /></td>
<td><img src="image16" alt="Image" /></td>
</tr>
<tr>
<td>5. Severe over-conditioning</td>
<td><img src="image17" alt="Image" /></td>
<td><img src="image18" alt="Image" /></td>
<td><img src="image19" alt="Image" /></td>
<td><img src="image20" alt="Image" /></td>
</tr>
</tbody>
</table>
Results and Discussion

As this research is in its early stage and there is little research focus on the Level III (Figure 1) integration of sensor information with other information, it is very difficult to predict the result of this study. However, as future farming tends to be precision agriculture and internet based information management, it is expected that the newly developed ICT will help livestock farmers to improve production efficiency with economic balance.

Conclusions

This study will evaluate the application of ICT systems on a dairy farm with integration of economic information with “cloud” data. This ICT integrated model will be build based on the Irish livestock system, the farm scale LCA model suitable for farm platform decision will be developed for European livestock production system.

Acknowledgements

This work is funded by Smart Integrated Livestock Farming (SILF) project, under ERA-NET scheme “ICT-AGRI”.

References


SUSTAINABLE DAIRY PRODUCTS: THE PROCESSING STAGE IN PRODUCT LIFE CYCLES

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Abstract

Dairy production and the dairy industry is one of the pillars of the agricultural and national economy of Ireland. There is an increasing demand for dairy products around the world, which is a great opportunity to develop the overseas market for the Irish dairy industry. Both consumers and regulators are becoming focused on the sustainability of food products and dairy is no exception. This paper examines the use of LCA as a tool to establish indicators of sustainability for the Irish dairy industry. The approach can ensure a holistic view that encompasses environmental and economic dimensions of sustainability.

Introduction

The world’s population is expected to grow to 10.85 billion by 2100 (United Nations Population Division, 2012) while the population was only about 7.16 billion in 2013. As the result of population growth and changes to diet structure, especially in developing countries, the demand for dairy production is expected to rise. ‘Additional production combined with the value added at processing level is likely to be worth in excess of 1 billion Euros’ (Food Harvest 2020), thus Ireland will grasp this opportunity to develop an overseas dairy product market. While population grows so do environmental threats, thus a new production concept – sustainable processing – is emerging. Sustainable processing ‘meet[s] the needs of the present without compromising the ability of future generations to meet their own need’ (the United Nation’s Brundtland Commission, 1987). Most research on dairy products in Europe has focused on the environmental impact up to the farm gate and little on the processing phase. Dairy farm sustainability has been modelled by Van Calker et al (2008) and a number of other groups. This research will focus on the processing part – from the ‘farm gate to the factory gate’. Meeting strict requirements for sustainability in the dairy industry will require that the volume of wastewater, energy resources and greenhouse gas emissions should be calculated carefully and plans implemented for their reduction. Life Cycle Assessment (LCA) (based on the ISO 14040) is a suitable tool to analyse the environmental impact of each unit process and the whole process chain.

The objective of this paper was to specify how LCA methods can be used to assess the role of processing in contributing to the environmental impact of Irish dairy products.
Materials and Methods

A sequential approach was defined:
1. Review of the dairy product process, especially in Ireland to identify the most important unit processes and their combination for specific products.
2. Definition of attribution LCA models for each dairy process using liquid milk processing as the first example (based on ISO 14040 family).
3. A consequential LCA of the process dairy market analysis based on the Food Harvest 2020 targets and optimising the combination of unit process sub-models.
4. Develop an Environmental Product Declaration type report, with a proposal for product category rules, for Irish dairy products and assessment of competing eco-labels as promotion tools for the Irish dairy industry.

Results and Discussion

The most important unit processes are defined in Table 1. From Table 1 it can be seen that a wide range of unit operations are important. However, only a few are necessary for all dairy products, such as pasteurization, thermalization, cooling, packaging and Cleaning-In-Place (CIP). These are likely to be the most important operations for the environment footprint.

<table>
<thead>
<tr>
<th>Table 1. Necessary unit processes of different dairy products</th>
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</thead>
<tbody>
<tr>
<td><strong>Unit process</strong></td>
</tr>
<tr>
<td>Thermalization</td>
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<tr>
<td>Pasteurization</td>
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<tr>
<td>Concentration</td>
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<tr>
<td>Drying</td>
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<tr>
<td>Evaporation</td>
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<tr>
<td>Sterilization</td>
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<tr>
<td>Fractionation</td>
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<tr>
<td>Heating</td>
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<tr>
<td>CIP</td>
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<tr>
<td>Ripening</td>
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<tr>
<td>Fermentation</td>
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<tr>
<td>Sowing</td>
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<tr>
<td>Cooling</td>
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<tr>
<td>Storage</td>
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<tr>
<td>Packaging</td>
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<tr>
<td>Separation</td>
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<tr>
<td>Mixing</td>
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<tr>
<td>Homogenization</td>
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<tr>
<td>Chilling</td>
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<tr>
<td>Dewatering</td>
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<tr>
<td>Crud separation</td>
</tr>
<tr>
<td>Crud washing</td>
</tr>
<tr>
<td>Scalding</td>
</tr>
<tr>
<td>Salting</td>
</tr>
<tr>
<td>Pressing</td>
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</tbody>
</table>

The goal and scope in each case will depend on the scale (process or system) and the functional unit will depend on the product (e.g. milk, in kg at 4% fat; butter in kg at X% fat). The overall system boundary for liquid milk (Figure 1) is largely restricted to the processing plant.
Until the attribution LCA is completed progress to the latter stages of the research will not be possible.

Conclusion

The purpose of this study is to conduct an LCA analysis of dairy processing for the Irish dairy industry to evaluate the consequences of reaching the target of the Food Harvest 2020. By reducing the total environmental footprint, an appropriate eco-labelling for global marketing for Irish dairy industry can be made.

Acknowledgement

The author is working under the foundation of CSC-UCD Scholarship Scheme.

References


DIRECT WATER USE ON IRISH DAIRY FARMS

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Abstract

With the abolition of milk quotas in 2015 throughout Europe and government strategies such as Food Harvest 2020 that targets a 50% increase in milk production through sustainable expansion, there will probably be increased pressure on freshwater resources on both a national and international scale. Quantifying the volumes of water used in the production of agricultural products is an important metric of the sustainability of food production. The water used on a farm to facilitate milk production is poorly understood or not measured at all, and varies from farm to farm due to differences in management practices. This study quantified the total water used for milk production on 25 farms from cradle-to-farmgate. An average of 6.4 litres of water was used per litre of milk produced. An overall range of 1,115,000 L – 7,041,310 L of water was used over the 25 farms. Understanding this water use and the processes responsible for the greatest water demand is the first step in quantifying and managing the water footprint of Irish milk production.

Introduction

Freshwater resources have come under increased pressure from a growing global population, climate change and increased food production. 70% of global fresh water use is attributed to the agricultural sector (UNEP 2007). With increased production there will be a great need to develop and promote sustainable Irish dairy production, Ireland already has a competitive advantage as the dairy industry has the lowest carbon footprint in Europe (Leip et al. 2010). Assessing water use by water footprint will be an important way in which makes Ireland’s dairy exports can be made more attractive to consumers on the global market.

Freshwater availability could become the main global economic growth limit (UNEP 2007). One of the major challenges in agricultural development today is to maintain food security and alleviate poverty without further depleting water resources and damaging ecosystems (Rosegrant et al. 2002). Quantifying the volumes of water used in agricultural production is an important metric of the sustainability of food production. From an Irish perspective, the main concerns are the cost of supplying water on farms, microbial or other contaminants of water and the negative impact of poor water management on the environment. A water footprint is a quantitative indicator of freshwater use referring to the total volume of water consumed over the lifecycle of a product as defined by the Water Footprint Network (Hoekstra 2011) The water footprint is made up of three quantitative indicators. The blue water footprint refers to consumption of surface and groundwater along the supply chain of a product. The green water footprint refers to consumption of soil moisture (rainwater in so far as it does not become run-off). The grey water footprint is an indicator of the amount of freshwater pollution that can be associated with an activity. ‘Consumption’ refers to loss of water from the available ground-surface water body in a catchment area. Losses occur when water evaporates, returns to another catchment area or the sea or is incorporated into a product. The total water used over a supply chain can also be regarded as direct and indirect water use. In the case of milk production, indirect water use includes evapotranpiration of growing grass and crops and water used in producing energy, fertilizers and concentrates. Direct water use is the water used on site to facilitate the milk production process such as drinking water for livestock, washing the milking machine, bulk tank and milking parlour and milk pre-cooling.

The objective of this study was to quantify the direct water use of milk production from cradle-to-farm-gate from 25 farms in Ireland as a first step to completing a water footprint of milk production.
Material and Methods

Water meters were installed on 25 Irish commercial dairy farms in 2012. Farms were selected from a database of advisory clients within Teagasc. Selection criteria included availability of farm data and an ability and willingness of the farmer to collect and maintain accurate data. Data were collected from May 2012 to April 2013. Up to eight water meters were installed on each farm to record total direct water use including water used in the milking parlour and water consumed by livestock. Domestic water use was measured where necessary and subtracted from total water supply to give water supply to farm only. A combination of wireless data transfer and manual recording was used. Water meter data (m³) were recorded on a monthly basis via an electronic survey which included data on farm imports such as concentrate feed, artificial fertiliser and fuel consumption. All data were analysed in spreadsheets and summed by water use. The water meter data were categorised from the supply (source) into parlour and other uses. Parlour readings were further categorised to include the water heater, plate cooler and wash-down readings. ‘Other’ consists of livestock drinking water and miscellaneous water use on the farm. Milk production data was sourced from the Irish Cattle Breeding Federation (ICBF) records. The data on farm imports such as concentrate feed, artificial fertiliser and fuel consumption will be used to compute the indirect water use in future work.

Results and Discussion

Average herd size was 104 dairy cows, and ranged from 45 to 194. Herd size was calculated as the average number of cows milked from June to October; this represents the average number of cows milked over the peak milk production period. Average milk production per farm was 519,324 litres (range 275,409 to 875,267 L). Greater than national average milk production (316,000 L) and herd size (66) is indicative of future commercial farm sizes, a result of farm expansion in preparation for quota abolition in 2015. The average volume of water used for the production of milk per farm was 3,121,242 L, and ranged from 1,115,000 L – 7,041,310 L. The average volume of water required for each farm process (Table 1) resulted in an average total volume of water consumed per litre of milk produced of 6.40 L.

Consumption by livestock and other miscellaneous use accounted for two thirds of water use on farms. The second largest use was the plate cooler (1.69 L/L). The recommended optimum ratio of water:milk in the plate cooler from an energy consumption perspective is 2:1 (Upton, 2011). Finding efficient recycling strategies for this plate cooler water will be key to reducing the direct water footprint of dairy farms while maintaining energy efficiency. The result of 6.40 L/L is similar to the direct water use of 5.40 L/L in the study of De Boer (2013) which examined water use on a single farm. A study carried out on Irish dairy farms by Bord Bia and Cranfield University found that between 7.2-8.6 L of water / L of milk is required for direct uses which includes bulk tank and machine washing, milk cooling via a plate cooler and wash-down post milking. These figures were not directly measured on-farm and were calculated from assumptions regarding the water requirements for livestock drinking and cleaning services on farms. Assumptions regarding the volume of water required for each process can lead to over or under estimations of the volume required. Our approach of measuring each process individually and over a range of farms gives a more accurate account of water demands for milk production from the cradle-to-farmgate.

Conclusions

The direct water use of milk production from 25 farms was quantified as 6.40 litres of water per litre of milk. This detailed approach will give an understanding of how and where water is utilised on both monthly and seasonal time horizons. Assessments of water use which rely on spatially and temporally specific data provide more relevant results relating to local water scarcity and identifying ‘hot-spots’ in production. Not all production systems are alike, and the variability in water use between different farms systems will be explored in future research. This study is the first step in quantifying the water footprint associated with Irish milk production. The indirect water use in the production of milk will be quantified in 2014. The results of this study will give strategic insights that might enable the Irish dairy sector to reduce its burden on freshwater systems. This water footprint will be incorporated into an overall sustainability model of Irish
dairy systems being developed by Teagasc, ensuring that production strategies will consider all of
the relevant environmental impacts as well as other social and economic concerns.

<table>
<thead>
<tr>
<th>Process</th>
<th>Total Water Use (L)</th>
<th>Specific Water Use (L/L) (Range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply</td>
<td>3,121,242</td>
<td>6.40 (1.16 – 12.01)</td>
</tr>
<tr>
<td>Livestock &amp; miscellaneous c</td>
<td>2,090,783</td>
<td>4.38 (1.18 - 9.51)</td>
</tr>
<tr>
<td>Parlour</td>
<td>1,030,459</td>
<td>2.02 (0.2 - 4.59)</td>
</tr>
<tr>
<td>Plate Cooler</td>
<td>918,469</td>
<td>1.69 (0.0 - 4.36)</td>
</tr>
<tr>
<td>Water Heater</td>
<td>91,045</td>
<td>0.17 (0.0 - 0.42)</td>
</tr>
<tr>
<td>Wash-down</td>
<td>685,103</td>
<td>1.28 (0.2 - 3.02)</td>
</tr>
</tbody>
</table>

Acknowledgements
The authors acknowledge funding from the Teagasc Walsh Fellowship Scheme and the support of
the Carbery Greener Dairy Farms project.

References
LIFE CYCLE ANALYSIS OF BIOMASS PRODUCTION IN IRELAND – A FOCUS ON TRANSPORTATION

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Abstract
The demand for wood for energy production in Ireland is predicted to double from 1.5 million m³ over bark (OB) in 2011 to 3 million m³ OB by 2020, in line with fulfilment of EU renewable energy targets. Understanding the environmental impacts of timber production and processing is important in determining efficient methods for wood energy production. The results of previous analysis on wood energy supply chains highlights transport as the most energy and greenhouse gas (GHG) emissions intensive step in the life cycle. The aim of this study is to build on this research by examining the effects of changes in certain parameters on overall greenhouse gas emissions and energy use. The parameters investigated include; transport distance, percentage of biodiesel in fuel blend, and legal maximum payload (LMP) of the truck. This finding illustrates importance of localised production and use of forest biomass. Reducing transport distance from 200 km to 100 km, results in a reduction of 29% in GHG emissions. Implementation of a 10% biodiesel-conventional diesel blend decreases GHG emissions by 2%, however energy use increases by 2%, as biodiesel production is an energy intensive process. Loading the haulage vehicle to the legal maximum payload will decrease greenhouse gas emissions from the system by between 2.5 to 7%.

Introduction
In Ireland, there is an increasing awareness of the need to reduce greenhouse gas (GHG) emissions and to develop alternative energy sources to reduce dependence on finite fossil fuel resources. The Irish government has adopted the European Union’s (EU) Renewable Energy Directive (RED) target of 20% of overall gross energy consumption by renewables by 2020, further driving the need to develop bioenergy resources (European Commission 2009). The production and utilisation of the woody biomass such as wood chip and forest residues in Ireland is seen as a viable route to reducing greenhouse gas emissions from energy production while helping to realise EU targets.
Transportation of biomass is seen to be one of the key issues in creating environmentally viable and sustainable biomass supply chains. Heinimann (2012) states approximately 60% of the overall environmental burdens of forestry production can be caused by road construction and maintenance, along with long-distance transport. As such, excluding these elements of the production chain from the system boundary could result in significantly underestimating the environmental impacts of wood energy systems. Increasing biomass demand created by the EU renewable energy targets will result in larger areas dedicated to bioenergy cultivation, and as such increased transport distances. The use of transport systems however, means increased energy input to the bioenergy system, resulting in larger emissions.
In Ireland, transport is a major source of energy demand in Ireland, consuming approximately 30% of all energy. Road freight accounts for 16% of this with an energy demand of about 0.8 Mtoe per year. Road freight energy demand has risen by over 119% since 1990 (Howley, Dennehy et al. 2011). In addition to this, by 2007, the road freight transport sector in Ireland had the highest increase in CO₂ emissions across all sectors, at 182% above 1990 levels (Howley, O Gallachoir et al. 2008). As such, it is vital to ensure that any potential environmental benefits from the utilisation of bioenergy are not significantly reduced by increased energy demand in transport. The aim of this paper is to evaluate the energy demand and greenhouse gas emissions related to the production of 1 oven dried tonne (odt) of biomass from forestry in Ireland.

Materials and Methods
Goal and scope
The aim of this study is to further investigate and compare the impact of different road transportation systems on the energy balance and greenhouse gas emissions associated with biomass supply chains in Ireland. Sitka spruce production chains have been modelled for Irish conditions (Murphy et al., 2014). The effects of different legal maximum payload weights on overall greenhouse gas emissions are analysed. The effects of varying transport distances will also be examined. A further variable is the biodiesel content of the fuel, increasing in line with EU renewable energy requirements.
The reference functional unit is 1 oven dry tonne of biomass delivered. All of the energy, mass and greenhouse gas flows in the system are normalised to this unit. The boundaries of the system are illustrated in Figure 1.

![Figure 1: System diagram](image)

Life cycle inventory
The LCA was conducted in Simapro 7.3 (PRé Consultants bv, the Netherlands) and uses data from Irish forestry operations and trials (Lyons, 2012, Brennan, 2012, Neri, 2010, Coates et al., 2013, Kent et al., 2011). In case of gaps in the availability of data specific to Ireland, other published data are used (Ecoinvent, 2007, Aldentun, 2002, Whittaker et al., 2011).

Life cycle impact assessment
Two categories are considered in this LCA; global warming potential (GWP) and cumulative energy demand (CED). A further method of assessing advantages of renewable energy systems may be to evaluate the pure energy ratio of the system. The term “energy ratio” is used to characterise relations between the energy input and output. Energy ratio is a ratio between the energy output and energy input (Klvac, 2011).

Results and Discussion
Fig. 2 outlines the contribution of each stage in the life cycle to the overall greenhouse emissions and energy demand on a hectare basis. The results show that transportation is the most energy intensive stage in the life cycle, accounting for 56% of overall GHG emissions and 55% of overall energy requirements.
By reducing the transportation of forest biomass from 200 km to 100 km, greenhouse gas emissions can be reduced by approximately 29%. As such, ideally biomass demand centres could be located close to the source areas to maximise emissions reduction from biomass utilisation.

The Irish Government has committed to achieving 10% of road and rail transport energy from renewable sources by 2020. The results of this study show that if this target is reached by increasing the proportion of rape methyl ester (RME) in the fuel blend to 10% by volume it will result in a reduction in greenhouse gas emissions of 2.11%. However, this increase in RME will increase overall energy demand by 2% as cultivation of rapeseed is an energy intensive process.

Haulage vehicles travelling with payloads lower than the maximum they are allowed results in inefficient biomass transport. The results show that loading the haulage vehicle to the legal maximum payload will decrease greenhouse gas emissions from the system by between 2.5 to
7%. In Ireland, there is instrumentation of the biomass haulage fleet with on-board weighing systems is being actively pursued in the haulage industry. This will enable optimum payloads in line with maximum legal payload limits to be achieved, thus reducing greenhouse gas emissions in biomass transportation.

![Figure 5: Effect of transportation at legal maximum payload](image)

**Conclusions**

The results of this LCA study illustrate the benefits of localised use of biomass energy sources as a means of keeping transport distances low. The results highlight the benefits of on-board weighing devices in maximising payloads in relation to the legal maximum payload limit in reducing greenhouse gas emissions from transportation. The effects of the implementation of the biofuels obligation scheme on the sustainable transport of biomass in Ireland is shown.

**Acknowledgements**

This publication has emanated from research conducted with the financial support of Science Foundation Ireland under Grant Number 06/CP/E001. (www.sfi.ie)

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Aldentun, Y. (2002). "Life cycle inventory of forest seedling production — from seed to regeneration site". *Journal of Cleaner Production*, 10, 47-55.

Brennan, A. (2012). "RE: Forestry operations". Type to MURPHY, F.


THE AMOUNT AND VALUE OF NUTRIENTS IN BIOLOGICAL WASTE STREAMS IN IRELAND

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Abstract

The recovery of nutrients from organic waste resources has the potential to reduce the impact of farming and the food system. This work identified five organic waste streams commonly found in Ireland and quantified their embedded nutrient content. The subsequent nutrient availability of each stream once processed through three alternate technologies was assessed and valued to be between €15M and €307M depending on the stream / technology combination.

Introduction

The natural cycles of Nitrogen (N) and Phosphorus (P) production have been disturbed by farming practices and human actions resulting in a decline in their availability in soils on a global scale (Tilman et al, 2002). The recycling of organic wastes from food, gardens, wood, crops and animals is one potential solution for resolving this issue by the recycling of the nutrients Nitrogen, Phosphorus and Potassium (K) back into agricultural production. Such an approach has the potential to be more sustainable from an economic, social and environmental perspective by creating jobs, reducing the use of imported mineral fertiliser and by minimising waste being sent to landfill which could result in a number of reductions in environmental impacts. The objective of this study was to calculate the potential economic value of five waste streams processed through three nutrient recovery technologies.

Materials and Methods

A number of studies (referenced below with the results) have identified waste generated in Ireland, amounts of nutrient found in organic waste streams, efficiency factors of nutrient recovery technologies and nutrient availability following processing by recovery technology. This desktop study combined the results of these earlier publications to calculate the magnitude and value of nutrients embodied in organic waste flows in Ireland. Three recovery technologies were considered: composting and anaerobic digestion (operational in Ireland) and pyrolysis (not operational in Ireland). The efficiency of the system is critical in identifying the technology most suitable for each feedstock. Factors such as energy balance, capital costs, processing time and emissions are equally important but were not included in this study. The efficiency factors used were 0.5 for AD, 0.35 for Pyrolysis and 0.7 for composting (except for food waste which was 0.2) based on review of literature.

Results

The quantity of five biological waste streams found in Ireland (Table 1) indicated that manures were most important followed by food waste. These five waste streams account for 99.4% (mass) of organic waste streams (human faeces, meat and bone meal and tallow represent 0.6%)

<table>
<thead>
<tr>
<th>Waste Stream</th>
<th>Quantity (tonnes)</th>
<th>Mean (tonnes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food waste</td>
<td>1,051,000</td>
<td>1,051,000</td>
</tr>
<tr>
<td>Green (or garden) waste</td>
<td>229,000 to 297,000</td>
<td>263,000</td>
</tr>
<tr>
<td>Wood residual</td>
<td>106,687 to 320,062</td>
<td>213,375</td>
</tr>
<tr>
<td>Crop residual</td>
<td>106,117 to 70,785</td>
<td>88,482</td>
</tr>
<tr>
<td>Manure (cattle, pig, sheep, poultry)</td>
<td>46,357,345</td>
<td>46,357,345</td>
</tr>
</tbody>
</table>

†Figures are based on the year 2010.
1Based on residual waste of 10% for wood production.
2Based on residual waste of 25% for crop production.
380% Slurry, 20% Manure
The amount of embedded NPK for each organic waste stream and potential quantity found in Ireland is presented (Table 2). Crop residues were found to have a relatively large nutrient content in Ireland given the relatively small mass generated each year. The recovery and subsequent utilisation of the nutrients depends on the nutrient recovery technology chosen. The estimated yield (Table 3) indicated that anaerobic digestion was most suitable for food waste and manure, and composting for green (or garden), wood and crop wastes. Pyrolysis always yielded the least nutrients.

### Table 2. Embedded nutrient content of five waste streams and amount in Ireland.

<table>
<thead>
<tr>
<th>Waste stream</th>
<th>Embedded NPK value</th>
<th>Embedded quantity in Ireland</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N (kg/t)</td>
<td>N-IE (t)</td>
</tr>
<tr>
<td>Food waste</td>
<td>1-7^cd</td>
<td>4,204</td>
</tr>
<tr>
<td>Garden waste</td>
<td>1-3^b</td>
<td>526</td>
</tr>
<tr>
<td>Wood residual</td>
<td>0.1-3^ab</td>
<td>26</td>
</tr>
<tr>
<td>Crop residual</td>
<td>3-8^ab</td>
<td>491</td>
</tr>
<tr>
<td>Manure/slurry</td>
<td>1.0-5^c</td>
<td>115,893</td>
</tr>
</tbody>
</table>

**Table 3. Potential quantity of product that could be produced**

<table>
<thead>
<tr>
<th>Waste Stream</th>
<th>Tonnes of product</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Compost Digestate Biochar</td>
</tr>
<tr>
<td>Food waste</td>
<td>210,200 525,500 367,850</td>
</tr>
<tr>
<td>Green</td>
<td>184,100 131,500 92,050</td>
</tr>
<tr>
<td>Wood residual</td>
<td>149,362 106,687 74,681</td>
</tr>
<tr>
<td>Crop residual</td>
<td>61,937 44,241 30,968</td>
</tr>
<tr>
<td>Manure</td>
<td>12,291,628 23,178,672 6,145,814</td>
</tr>
</tbody>
</table>

**Discussion**

The total nutrient content is not an appropriate indicator of the availability of nutrients, as only a fraction of the total nutrient content is available (Keeney, 1982). The amount of available NPK found in each of the five waste streams (Table 4) indicated that there was great variation based on the limited and, unfortunately incomplete data available. The most prominent feature was the great variation in NPK values which was due to large variation of nutrients found in waste streams. When availability was considered, biochar from pyrolysis seemed to become a more attractive means of nutrient recovery.

### Table 4.0 Nutrient (NPK) content and availability (kg/tonne of product); T=Total A=Available.

<table>
<thead>
<tr>
<th>Waste stream</th>
<th>Compost</th>
<th>Digestate</th>
<th>Biochar</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>P</td>
<td>K</td>
</tr>
<tr>
<td>Food waste</td>
<td>T</td>
<td>11^g</td>
<td>3.8^a</td>
</tr>
<tr>
<td></td>
<td>A</td>
<td>0.6-1.7^g</td>
<td>1.9^g</td>
</tr>
<tr>
<td>Green</td>
<td>T</td>
<td>7.5-9^k</td>
<td>3-4^i</td>
</tr>
<tr>
<td></td>
<td>A</td>
<td>0.2-2^o</td>
<td>1.5-3^o</td>
</tr>
<tr>
<td>Wood residual</td>
<td>T</td>
<td>7.5^o</td>
<td>3.0^o</td>
</tr>
<tr>
<td></td>
<td>A</td>
<td>0.2^o</td>
<td>1.5^o</td>
</tr>
<tr>
<td>Crop residual</td>
<td>T</td>
<td>10-15^y</td>
<td>2-5^i</td>
</tr>
<tr>
<td></td>
<td>A</td>
<td>1.0-7.5^y</td>
<td>1.8-3^i</td>
</tr>
<tr>
<td>Manure/slurry</td>
<td>T</td>
<td>1.5-3.7^k</td>
<td>2.1-5.4^i</td>
</tr>
<tr>
<td></td>
<td>A</td>
<td>0.6-1.5^k</td>
<td>1.7-4^k</td>
</tr>
</tbody>
</table>

---


1No data found, nominal amount given.
Assuming the price of chemical fertiliser in Ireland was approximately $N = €1.27, P = €1.72 and $K = €1.00$ Per Kg (Lalor, 2011), the economic value (Table 5. Note the shaded values identify the greatest recovery rate for a specific nutrient in a waste stream) ranged from €15M to €157M depending on processing technology. When placed in the context of current spend on mineral fertiliser (Table 6) it is clear that nutrient recovery from waste streams should be as much a priority as carbon and energy considerations (Table 7).

<table>
<thead>
<tr>
<th>Waste Stream</th>
<th>Compost (t)</th>
<th>Digestate (t)</th>
<th>Biochar (t)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>P</td>
<td>K</td>
</tr>
<tr>
<td>Food waste</td>
<td>126</td>
<td>399</td>
<td>1,345</td>
</tr>
<tr>
<td></td>
<td>€160</td>
<td>€687</td>
<td>€1,345</td>
</tr>
<tr>
<td>Green waste</td>
<td>37</td>
<td>276</td>
<td>736</td>
</tr>
<tr>
<td></td>
<td>€47</td>
<td>€475</td>
<td>€736</td>
</tr>
<tr>
<td>Wood residual</td>
<td>30</td>
<td>224</td>
<td>597</td>
</tr>
<tr>
<td></td>
<td>€38</td>
<td>€385</td>
<td>€597</td>
</tr>
<tr>
<td>Crop residual</td>
<td>62</td>
<td>111</td>
<td>495</td>
</tr>
<tr>
<td></td>
<td>€79</td>
<td>€192</td>
<td>€495</td>
</tr>
<tr>
<td>Manure/slurry</td>
<td>7,375</td>
<td>20,896</td>
<td>73,750</td>
</tr>
<tr>
<td></td>
<td>€9,366</td>
<td>€35,941</td>
<td>€73,750</td>
</tr>
<tr>
<td>Total</td>
<td>€9,690</td>
<td>€37,680</td>
<td>€76,924</td>
</tr>
</tbody>
</table>

Table 5. NPK availability and value (using minimum number from table 4.0)*

*Euro figures are in thousands

<table>
<thead>
<tr>
<th>WASTE STREAM</th>
<th>N</th>
<th>P</th>
<th>K</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food waste</td>
<td>126</td>
<td>399</td>
<td>1,345</td>
</tr>
<tr>
<td>Green waste</td>
<td>37</td>
<td>276</td>
<td>736</td>
</tr>
<tr>
<td>Wood residual</td>
<td>30</td>
<td>224</td>
<td>597</td>
</tr>
<tr>
<td>Crop residual</td>
<td>62</td>
<td>111</td>
<td>495</td>
</tr>
<tr>
<td>Manure/slurry</td>
<td>7,375</td>
<td>20,896</td>
<td>73,750</td>
</tr>
<tr>
<td>Total</td>
<td>€9,690</td>
<td>€37,680</td>
<td>€76,924</td>
</tr>
</tbody>
</table>

Table 6. Amount of synthetic fertiliser consumed in Ireland (CSO, 2012).

The percentage of mineral fertiliser that each product could replace is presented in Table 7.0.

<table>
<thead>
<tr>
<th>% Reduction</th>
<th>Compost</th>
<th>Anaerobic Digestion</th>
<th>Pyrolysis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>24.5%</td>
<td>31%</td>
<td>3%</td>
</tr>
</tbody>
</table>

Table 7. Per cent of mineral fertiliser that each product could replace.

Conclusions and recommendations

This study showed that the use of organic waste for nutrient recovery has a significant economic value, up to approximately €157 Million a year, and should therefore be treated as a valuable resource and not a waste. No one technology was identified as having the best recovery rate for all waste streams. To further validate this analysis a full data set ensuring consistency of feedstock should be gathered.

Acknowledgements

This research is funded by the Irish Research Council under the Government of Ireland scheme.

References


INDEXING SOIL QUALITY UNDER AGRICULTURAL MANAGEMENT SYSTEMS IN IRELAND

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Abstract

Quantifying soil quality to evaluate the effects of agricultural management systems on grassland and arable is of particular interest because of the expanding global demand for agricultural products and soil security. Soil quality assessment can provide a practical approach for early detection of adverse influences of management practices. The aims of this study were to determine appropriate soil properties for assessing soil quality, and to develop soil quality indices under agricultural management. The study was conducted using 40 sites in Ireland under arable and grassland management systems. At each site five subplots was selected for soil sampling and twenty one chemical, biological and physical properties were measured using standard methods as indicators of soil quality. The visual evaluation of soil structure (VESS) was performed to evaluate and classify soil quality. Key indicators were selected by significant differentiating among VESS classes and management treatments as total data set, and a minimum data set was identify for each land use by using principal component analysis. Eight indices of soil quality for pasture and four indices for arable were calculated. Soil organic carbon (SOC), total nitrogen (TN), aggregate size distribution (ASD), bulk density (BD), bulk density of ≤ 2 mm fraction, extractable potassium and carbon nitrogen ratio (CN) were selected as important indicators under pasture, and BD, TN, CN, ASD, magnesium, penetration resistance, and soil respiration were key indicators under arable. The management intensification is tending towards an adverse impact on soil quality under pasture systems. The indices under arable indicated the positive influences of minimum tillage with crop rotation on soil quality. The indexing approach in this study can provide a practical and reliable method for quantitative evaluation of soil quality under agricultural management in Ireland.

Introduction

Rapid, precise and quantitative assessment of soil quality is crucial for sustainable evaluation and monitoring the effects of management practices on soil resource under agricultural systems (Zhang et al., 2012; Bone et al., 2012). Inappropriate management practices can influence soil quality resulting in soil degradation and adverse effects on soil productivity (Batey and McKenzie, 2006; Munkholm et al., 2013). Evaluation of soil quality is usually done by combining physical and biochemical indicators (Doran and Parkin, 1994). Therefore, choosing the appropriate indicators is the main step to an accurate assessment of soil quality (Doran and Jones, 1996). Principal component analysis (PCA) is commonly used to reduce data redundancy among properties for identifying a minimum data set (MDS) (Andrews et al., 2002; Rezaei et al., 2006). Indexing soil quality which integrates selected soil properties into a single index is the most used and multidisciplinary approach for quantitative assessment of soil quality (Karlen and Stott, 1994). SQ indices (SQI) have been successfully applied at many scales and locations (e.g. Andrews et al., 2002; Masto et al., 2008). An integrated SQI is commonly developed using a three-step process: indicator selection, indicator scoring, and integration of scores into an index (Andrews et al., 2002 and 2004).

The objectives of this study were to determine key indicators for assessing soil quality and to develop integrative indices of soil quality under Irish agricultural management systems.
Materials and Methods

Experimental design

The study was conducted on 40 sites under different agricultural management systems in Ireland. Twenty sites were selected on arable and twenty on pasture between latitude 52° 8' N and 53° 54’ 20” N and longitude 6° 22’ W and 8° 19’ W. Field sampling was conducted in a 30 m² plot laid out at an uniform part of each site, with random orientation. At each plot, five sub-plots 2 m² were selected based on walking a ‘W’ between the end points of the main plot for sampling and field measurements. Soil samples (n=200) were taken from the top 10 cm of soil, sealed and stored in cool, dark conditions prior to laboratory analysis. Soil chemical, physical and biological properties which were considered as potential indicators of soil quality based on literature review were measured, including; near-surface penetration resistance, sorptivity, bulk density (BD), the bulk density of the 2 mm fraction (BD_2mm), total porosity, soil water content, particle size distribution, aggregate size distribution, microbial, total nitrogen (TN) and total carbon (TC), soil organic carbon, extractable calcium (Ca), magnesium (Mg), potassium (K) and phosphate (P), cation exchange capacity (CEC) and pH. For each sub pot, visual evaluation of soil structure (Guimaraes et al., 2011; Ball et al., 2007) was performed to evaluate soil structural quality. The VESS method was explained in detail by Askari et al (2013) as deployed for this study. Arable sites were categorized into conventional tillage system with mono-cropping (CO), conventional tillage system with crop rotation (CR), minimum tillage with mono-cropping (MO), and minimum tillage system with crop rotation (MR). K-means clustering analysis was used to identify three major classes of management intensity (low, medium and high) on pasture.

Indexing soil quality

Of the potential soil quality indicators in arable soil, those that were significantly different (P<0.05) by management practices were considered for further analyses as appropriate and responsive indicators to management practices. PCA was performed on the remaining soil properties to identify a minimum data set (MDS) according to the method explained by Andrews et al. (2002) and Rezaei et al. (2006). For pasture soils, measured soil properties were allocated to either a calibration set (70%) or a validation set (30%) for developing soil quality indices (SQI) and validating them, respectively. VESS on calibration data set was used to identify the indicators associated with soil quality in the study area and the properties that were significantly different (P<0.05) by soil quality classes were selected as a total data set (TDS) for developing the indices. PCA was also employed on the standardized data matrix of the TDS on pasture to reduce data redundancy and identify the most appropriate indicators for assessing soil quality. Four indices were calculated for arable soils (SQIa) using MDS and eight indices were developed for pasture soil (SQIp) using both TDS and MDS, and by using linear and non-linear scoring functions.

Results and Discussion

VESS on arable indicated 27 % of samples were categorized into “good” (VSq < 2), 55 % into “fair” (VSq between 2 and <3) and 18 % in “poor” (VSq ≥ 3), and on pasture, 45 % of sites had “good” soil structural quality, 45 % “fair” and 10 % “poor” soil quality. Data redundancy was appropriately reduced, and the most relevant soil quality indicators were identified as a MDS using principal component analysis, this approach was confirmed to be effective in similar studies (Andrews et al. 2002; Rezaei et al., 2006). MDS on arable were, aggregate size distribution, penetration resistance, soil respiration, bulk, extractable magnesium, total nitrogen and CN ratio. Under pasture, the calibration data set was used to select the indicators that were significantly different by soil structural quality class (P < 0.05) as a TDS containing bulk density, bulk density of ≤ 2 mm fraction, SOC, aggregate size
distribution, extractable potassium, CN ratio and total nitrogen. Of TDS, SOC, bulk density (≤ 2mm) and CN ratio were selected as a MDS for evaluating soil quality under temperate maritime grassland management using PCA. The range of measured soil indicators was in consistent with previous studies in Ireland (e.g. Kurz et al., 2006; Fay et al, 2007), which indicated that the study sites were representative of dominant soils under agricultural systems in Ireland. All selected soil parameters under arable (MDS) and pasture (TDS and MDS) were reported as important indicators for evaluating soil quality and identifying the impact of agricultural managements practices (Karlen and Stott, 1994; Doran and Parkin, 1994; Doran and Jones, 1996; Creamer et al. 2014). All four SQIa on arable and eight SQlp on pasture could differentiate soil quality classes and their average values were similar on arable and pasture. Indexing soil quality by integrating the most important indicators can be used for precise and multidimensional assessment of agricultural systems (Andrews et al. 2002).

Conclusions

key indicators for assessing soil quality under different management practices were identified as SOC, TN, CN, BD, BD\textsubscript{2mm}, ASD and K for pasture soils and as BD, Mg, TN, CN, penetration resistance, ASD and soil respiration for arable soils. All integrated indices of soil quality developed for arable and pasture systems were able to differentiate between visual soil quality classes and proved to be an effective multi-aspect tool for quantitative evaluation of soil quality in agricultural soils of a temperate maritime climate. The study indicated that the role of crop rotation on sustainability of soil productivity, and suggested the incorporation of minimum tillage with crop rotation as an appropriate management treatment on arable systems in Ireland. The data from pasture soils suggested that management intensification was having an adverse impact on soil quality under Irish pasture management.

References

INVESTIGATION OF THE POTENTIAL OF INFRARED SPECTROSCOPY FOR MEASURING ALGAL QUALITY PARAMETERS

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Abstract

Microalgae cultivation is becoming a potential candidate for energy purposes due to high yields and numerous other advantages. However, current analysis methods have certain drawbacks, such as being time costly and sample destructive, that need to be addressed. Measured infrared spectra of the samples showed definite, repeatable peaks whose wavelengths correspond to several organic compounds, as reported in other studies. These wavelengths, spectra or spectra regions could potentially be used to predict calorific value and carbon content, among others parameters, if significant correlations can be shown.

Introduction

The cultivation of microalgae for energy production is a developing area which could potentially meet the challenges of a secure, reliable and environmentally friendly supply (Brennan & Owende, 2010). Microalgae have a high growth rate with higher biomass productivity and oil yield than other energy crops, demonstrating its potential for production for energy purposes. Other advantages microalgal systems offer include the ability to treat wastewaters through the removal of unwanted nutrients and thus could be used for remediation purposes (Rawat et al., 2011). Thus there are a growing number of studies focusing on microalgae for energy purposes, to reduce reliance on fossil fuels and to mitigate carbon dioxide emissions (Rawat et al., 2011). Dunaliella species are one group of particular interest as up to 50% of its dry weight can be from glycerol, under the appropriate conditions (Raja et al., 2007).

However, due to a number of factors such as light and nutrient availability, CO₂ levels, temporal (i.e. day/night and seasonal) fluctuations and biomass density can all affect growth rates (Torres et al., 2013). Thus, with a highly dynamic system monitoring and analysis is essential to produce optimal product yields (Chen et al., 2004). To monitor the microalgal growth cycle several quality parameters such as calorific value and carbon content can be examined. Through photosynthesis, microalgae can incorporate inorganic carbon, primarily in the form of CO₂, which can be used as a measure of the biomass growth as well as the CO₂ mitigation potential (Bernard, 2011). As an energy source, the calorific value of microalgae is a very important factor. Under normal growth conditions typical calorific values of microalgae are between 18 and 21 MJ kg⁻¹, which is only half that of diesel at 43 MJ kg⁻¹ (Illman et al., 2000). However, under specific conditions to increase lipid content, a study looking at Chlorella emersonii has achieved a calorific value of 29 MJ kg⁻¹ (Illman et al., 2000).

One method of determining these parameters of a microalgal culture is through the use of infrared technology. Near- and mid-infrared spectroscopy has been used in a variety of sectors already including the food, agricultural and pharmaceutical industries for control, analysis and monitoring operations (Fagan et al., 2007). The resulting spectra of samples can reveal information pertaining to the molecular bonds present and hence provide details of its molecular structure. Hence, infrared spectroscopy may therefore be used in both the qualitative and quantitative analysis of a product or process (Tura et al., 2007).

The aim of this study was to propose a method for the determination of carbon content and calorific value of D. tertiolecta using mid-infrared spectroscopy.
Materials & Methods

Experimental Design & Sample Preparation

The green alga (Chlorophyceae) *Dunaliella tertiolecta* Butcher (1959) (CCAP 19/27), selected for its known high carbon sequestration (Farrelly, 2013), was obtained from the Culture Collection of Algae and Protozoa (CCAP), Dunstaffnage Marine Laboratory, Oban, Scotland. The stock culture was maintained by bi-weekly sub-culturing in f/2 medium at 20 °C, 24:0 (light:dark) cycle and 100 µmol s⁻¹ m⁻². Inoculum of the *D. tertiolecta* was acclimatized to the experimental conditions, including carbon dioxide by maintaining them for 3 days under air mixed with carbon dioxide to the specified % (v/v).

The experiments were conducted in seven 1.2 L Roux bottles with a working volume of 1000 ml. Each glass culture flask then contained 700 ml of the f/2 medium which was then inoculated with 300 ml of concentrated algae. The flasks were operated in a culture growth cabinet (Binder APT.lineTM KBWF, Binder GmbH, Tuttingen, Germany) that allowed for the control of both temperature and illumination intensity. The chamber was maintained at a constant temperature of 23°C for all the trials, with a light/dark period of 18:6 hour intervals from fluorescent light tubes present in the growth chamber, placed at an approximate distance of 5 cm from the culture flasks and at a light intensity of approximately 200 µmol m⁻² s⁻¹, during the light period. Aeration, at 2% CO₂ concentration, was supplied using a pneumatic compressor and gas mixer (WITT KM60-2ME, Witt-Gasetechnik GmbH & Co KG, Witten, Germany). The flow rate was set by a MR3000 flow meter at a rate of 0.5 L min⁻¹ L⁻¹ media. The air was filtered to 5µm by sterile air filter units. The cultures were monitored by taking daily samples of 10ml from each replicate to determine cell density, optical density, pH and biomass.

Cell density, pH, optical density and biomass analysis

Direct microscopic counts of microalgal cells were taken aseptically every 24 hours over the trial period and cell counts were determined by use of a TS100 Nikon Eclipse microscope (Micron Optical, Wexford, Ireland) and haemocytometer (Hausser Scientific, Horsham, PA, USA). From the 10ml sample of each replicate, pH was measured with a calibrated Thermo Scientific Orion 5-Star Plus pH meter and the result taken when a steady value was reached. Optical density was measured from a 3ml sample from each replicate in a cuvette using a UV-Vis spectrophotometer (UV-3100PC, VWR International) with absorbance values taken at 680 nm. f/2 medium was used as a blank to eliminate background noise. A sample (5ml) from each replicate was placed in a 15ml centrifuge tube and dewatered at 4000 rpm during 5 minute runs. The separated cell pellets were then re-suspended in distilled water and centrifuged at 4000 rpm for 5 minutes, and the process was repeated twice to remove any residual salts in the media. The dewatered centrifuge tubes were transferred to dried, weighed aluminium dishes and further dried in an oven at 70 °C until there was no weight change, with the resulting weight, minus the dish, giving the biomass weight per 5ml of wet sample.

Harvesting

The culture was harvested at maximum cell density and subsequently centrifuged at 4000 rpm for 5 minutes. The separated cell pellets were then re-suspended in distilled water and centrifuged at 4000 rpm for 5 minutes, and the process was repeated twice to remove any residual salts in the media. The dewatered replicates were then transferred to dried, weighed aluminium dishes and further dried in an oven at 70 °C until there was no weight change. The weights of the replicates were recorded before being stored for further analysis.

Carbon Analysis & Calorific Value

Total carbon content on a dry basis was determined from 80mg of each replicate using a carbon analyser (PrimacsSLC TOC Analyser, Model CS22, Skalar Analytical B.V., 4800 DE Breda, The Netherlands). High range analysis (1 – 40mg) was carried out using oxalic as a standard (ISO11464, ISO11465), having a known carbon content of 19.05%. Results were analysed and displayed with the software TOC4WIN (v1.4) in accordance with the methods in the Skalar analyser manual.
Calorific values were determined in a bomb calorimeter (6400, Parr Instruments, Moline, Illinois, USA). Pellets for calorific value determination were formed from 0.5g of the dried algae using a pellet press. The pellets were accurately weighed (±0.001g) in the sample cup and then placed in the bomb calorimeter for analysis.

**Infrared Analysis**

Infrared analysis was carried out using a Bio-Rad Excalibur FTS3100 mid-infrared spectrometer (Bio-Rad, Philadelphia, USA). Data was taken in the spectral range 2,500 nm – 25,000 nm. Duplicate scans of each sample were taken. Analysis of the spectral data was carried out with The Unscrambler software package (v.10, Camo, Norway). Spectral ranges were cut to a useful range of 2,500 – 19,000 nm.

**Results and Discussion**

The measured calorific values, shown in Figure 1, ranged from 17.96 MJ kg\(^{-1}\) to 19.55 MJ kg\(^{-1}\), which lie well within the observed range in other studies for microalgae under normal conditions (18 MJ kg\(^{-1}\) to 21 MJ kg\(^{-1}\)) (Illman et al., 2000). However, certain studies whose goal was to maximise the algal oil content for energy purposes have achieved higher values, with up to 36 MJ kg\(^{-1}\) for *D. tertiolecta* being reported. With such a wide range of calorific values recorded the potential energy output from algae can also vary greatly. The measured carbon content (Fig 1) for each of the replicates ranged from 41.67% to 45.74%. In systems with flue gas-fed cultures, the complex and potentially variable nature of the gas input can lead to different levels of carbon uptake over a period of time. Thus in instances such as this the carbon content of algae will be more variable and its measurement will be more necessary.

![Figure 1](image)

**Figure 1.** Measured calorific values and carbon contents of the seven *Dunaliella tertiolecta* replicates

The recorded spectra show numerous peaks corresponding to the presence of organic compounds relevant to the quality parameters of the studied algae. Peaks at 2950 to 3075 nm and 6243 nm are related to the functional group amine, which in turn are attributed to the presence of proteins. The peaks between 3300 and 3500 nm can be attributed to the asymmetric and symmetric stretching vibrations of CH\(_3\) and CH\(_2\) groups of the fatty acid acyl chains which make up the lipids present in the algae (Patel et al., 2008). The region from 8500 to 11000 nm can largely be attributed to a sequence of bands of C-O, C-C, C-O-C and C-O-P stretching vibrations of polysaccharide carbohydrates. These peaks and the compounds they correspond to are summarised in Table 1. The carbohydrate, protein and lipid content contribute to the calorific value of biomass and so all of the peaks are relevant to determining the relationship between the observed spectra and our bomb calorimeter-derived calorific value for each sample. Similarly, the compounds we have identified from our spectra are all organic and so contribute to the total carbon content of the measured biomass.
Table 1. Summary of the identified peaks of the measured infrared spectra of the alga *D. tertiolecta*

<table>
<thead>
<tr>
<th>Wavelength (nm)</th>
<th>Bond</th>
<th>Functional Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>2950 - 3075</td>
<td>N-H stretch</td>
<td>Amines</td>
</tr>
<tr>
<td>3300 - 3500</td>
<td>C-H bands</td>
<td>Acyl chains</td>
</tr>
<tr>
<td>4200 - 4545</td>
<td>C≡N stretch</td>
<td>Nitriles, alkynes</td>
</tr>
<tr>
<td></td>
<td>C≡C stretch</td>
<td></td>
</tr>
<tr>
<td>6243</td>
<td>N-H bend</td>
<td>Primary amines</td>
</tr>
<tr>
<td>8500 - 11000</td>
<td>C-O, C-C, C-O-C and C-O-P</td>
<td>polysaccharides</td>
</tr>
</tbody>
</table>

Conclusion

From these measured parameters of the final, dried product it is evident the methods applied to their analysis give repeatable results with low variability. This gives the basis for the development of models that could potentially predict the algal quality parameters from the infrared spectral data. The next step therefore is to measure these parameters under changing variables (CO₂ concentrations, light regime, nutrient levels etc.) and to attempt to correlate these with the spectral data so that the spectra or spectral regions can be used to predict multiple parameters in a quicker, more cost effective system that may then lead to continuous online measurements for more robust process control.

References


THE RELATIONSHIP BETWEEN ENZYME ACTIVITY, SOIL STRUCTURE AND GRASSLAND MANAGEMENT

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Abstract
Grassland management is important to both soil quality and productivity for sustainable land use. Mismanagement can cause a cycle of soil quality deterioration and reduced productivity. This study estimated soil structural quality and enzyme activities related to soil carbon (C) cycle in relation to grassland management including sward reseeding, nitrogen fertilizer application and animal stocking rate. Seven soils were sampled to 20 cm from farms representing most of the range of grassland management in Ireland. Visual evaluation of soil structure (providing a Sq score), soil organic C, microbial biomass C and enzyme activity (CM-cellulase, β-glucosidase) were measured. Sq score was strongly negatively correlated with enzyme activity, indicating a decline of enzyme activity with poorer soil structural quality. Frequent reseeding had a significant benefit for enzyme activity down to 20 cm. Increased stocking rate significantly increased enzyme activity from 10-20 cm. The relationship between soil structural quality and enzyme activity as regulated by management indicated a strong interaction between soil structure and enzyme activity.

Introduction
Since agriculture production systems intensification has implications for soil quality, mismanaged intensification will lead to soil quality degradation (Kerebel and Holden 2013). Grassland management plays an key role in soil C turnover, aggregate formation and microbial abundance (Lagomarsino et al. 2009). CM-cellulase and β-glucosidase (β-G) are key C-enzymes by regulating organic C decomposition. As they are vulnerable to management changes, quantifying specific enzymes in the context of soil structural quality and management should help the understanding the interaction of soil quality, microbial function and land management.

The objective of this research was to evaluate the influence of the grassland management on soil structure and C-enzyme activity in order to better understand how management intensification might affect soil processes related to productivity and C cycle processes.

Material and Methods
Soil samples at depths of 0-10 cm and 10-20 cm from 7 grassland fields with a range of management intensity defined by stocking rate, N fertilizer rate and reseeding frequency were chosen. All soils were loam texture with clay content ranging from 18 to 27%. Selected soil properties were measured by methods listed in Table 1. All statistical analysis was completed using SPSS statistic v. 20. Soil structural quality (indicated by Sq) was evaluated by visual evaluation of soil structure (VESS) (Guimarães et al. 2011). Management classification was as listed in Cui et al. (2014).
<table>
<thead>
<tr>
<th>Soil property</th>
<th>Reference method</th>
<th>Soil property</th>
<th>Reference method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic C</td>
<td>dry combustion</td>
<td>Respiration</td>
<td>Anderson (1982)</td>
</tr>
<tr>
<td>MBC</td>
<td>Brookes et al. (1985)</td>
<td>CM-cellulase</td>
<td>Schinner and von Mersi (1990)</td>
</tr>
</tbody>
</table>

**Results and Discussion**

*Grassland management and soil properties*

Sq ranged from 1.07 to 2.60 indicating all sites had good soil structural quality and appear to be subject to management that is not adversely impacting soil structure (Table 2). In general the chemical and biological properties analyzed showed a significant decrease with depth ($p<0.05$) (Table 3). By time since last reseed, there was significantly less organic C, and soil respiration at both depths in the 10 to 20 yr group, significantly more MBC at both depths in the >20 yr group. By N fertilizer input rate, there was no significant difference or very small differences in organic C at both depths, soil respiration was greater at both depths with larger N input, MBC was lower with less N input. By stocking rate, organic C, total N and soil respiration increased significantly with increased stocking rate at both depths, while MBC had a mixed pattern.

**Table 2.** Characteristics of field management and soil properties (top 20 cm soil) of the seven fields used in this study.

<table>
<thead>
<tr>
<th>Soil</th>
<th>Years since last reseed</th>
<th>Stocking rate class</th>
<th>N fertilizer input class</th>
<th>Moisture (g 100g⁻¹)</th>
<th>pH</th>
<th>Bulk density (0-10cm) (g cm⁻³)</th>
<th>Porosity (0-10cm) (%)</th>
<th>Clay (%)</th>
<th>Sq score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>21.5</td>
<td>6.2</td>
<td>0.85</td>
<td>56</td>
<td>18</td>
<td>2.60</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>18.4</td>
<td>6.7</td>
<td>0.85</td>
<td>57</td>
<td>19</td>
<td>1.07</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>72.9</td>
<td>6.1</td>
<td>0.75</td>
<td>65</td>
<td>25</td>
<td>1.60</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>56.0</td>
<td>5.7</td>
<td>0.73</td>
<td>63</td>
<td>24</td>
<td>2.70</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>61.9</td>
<td>5.6</td>
<td>0.84</td>
<td>65</td>
<td>27</td>
<td>1.77</td>
</tr>
<tr>
<td>6</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>58.3</td>
<td>5.3</td>
<td>0.81</td>
<td>65</td>
<td>25</td>
<td>1.44</td>
</tr>
<tr>
<td>7</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>56.4</td>
<td>4.9</td>
<td>0.72</td>
<td>65</td>
<td>26</td>
<td>1.95</td>
</tr>
</tbody>
</table>

*Grassland management and enzyme activity*

Enzyme activity significantly decreased with depth ($p<0.05$) (Table 3). There were significant differences in enzyme activity with time since last reseed with the 10-20 yr group having the lowest CM-cellulose and β-G activity at both depths. The greater effect of sward age on C-related enzyme activity at depth compared to the surface indicated the influence of residue and litter turnover, indicating the necessity of reseeding as suggested from both economic and soil quality perspectives. β-G had significantly greater activity at high N input rates at depth of 0-10 cm soil. In the 10-20 cm layer, CM-cellulase was more active with greater N input and β-G indicated a mixed response. Stocking rate had little effect on CM-cellulase and a mixed effect on β-G. The significant effect of stocking rate on C-related enzyme activity was indicative of more microbial activity in the 10-20 cm soil layer. Higher stocking rates are also usually
associated with more frequent reseeding and greater fertilizer input to elevate grass productivity for feed as silage or grazing. The associated root mats can promote microbial activity, while at the same time, animal trampling, which will be more pronounced under intensive grazing, can cause a mixing of material from the surface to deeper layers. This movement of soil can trigger and accelerate C processes by re-locating soil nutrients.

**Table 3.** Soil properties by sward age (years since last reseeding), N fertilizer application rate and stocking rate (by column, the letter indicates a significant difference at \( p < 0.05 \) by management class).

<table>
<thead>
<tr>
<th>Management</th>
<th>Organic C (g C 100g(^{-1}))</th>
<th>Respiration (( \mu g ) g(^{-1}) h(^{-1}))</th>
<th>MBC (mg kg(^{-1}))</th>
<th>CM-cellulase (ug glucose g(^{-1}) h(^{-1}))</th>
<th>( \beta )-G (ug ( p )-nitrophenol g(^{-1}) soil h(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sward age (years)</td>
<td>0-10 cm</td>
<td>10-20 cm</td>
<td>&gt; 20</td>
<td>0 - 43</td>
<td>&gt; 43</td>
</tr>
<tr>
<td>1-9</td>
<td>5.43(0.12)b</td>
<td>3.58(0.24)a</td>
<td>4.94(0.15)b</td>
<td>4.85(0.33)</td>
<td>4.91(0.12)</td>
</tr>
<tr>
<td>10-20</td>
<td>6.2(0.3)c</td>
<td>2.7(0.1)a</td>
<td>3.9(0.3)b</td>
<td>3.1(0.1)a</td>
<td>2.6(0.2)a</td>
</tr>
<tr>
<td>&gt; 20</td>
<td>2813(195)b</td>
<td>1029(42)a</td>
<td>1040(42)a</td>
<td>1299(115)a</td>
<td>3443(138)c</td>
</tr>
<tr>
<td>N fertilizer (kg ha(^{-1}))</td>
<td>0-43</td>
<td>&gt; 43</td>
<td>&gt; 129</td>
<td>1.5 - 2.5</td>
<td>&gt; 2.5</td>
</tr>
<tr>
<td>0.1</td>
<td>7.34(0.16)b</td>
<td>5.78(0.13)a</td>
<td>8.08(0.31)b</td>
<td>7.36(0.61)</td>
<td>184.83(4.41)a</td>
</tr>
<tr>
<td>0</td>
<td>258.94(16.66)b</td>
<td>173.08(5.13)a</td>
<td>224.03(8.11)ab</td>
<td>199.51(8.13)a</td>
<td></td>
</tr>
<tr>
<td>Stocking rate (LSU ha(^{1}))</td>
<td>1-9</td>
<td>10-20</td>
<td>&gt; 20</td>
<td>0 - 43</td>
<td>&gt; 43</td>
</tr>
<tr>
<td>1.5 - 2.5</td>
<td>4.39(0.22)b</td>
<td>4.8(0.2)c</td>
<td>4.5(0.3)b</td>
<td>2.77(0.04)a</td>
<td>3.87(0.20)b</td>
</tr>
<tr>
<td>&gt; 2.5</td>
<td>4.8(0.2)c</td>
<td>2.7(0.1)a</td>
<td>2.7(0.1)a</td>
<td>5.01(0.15)</td>
<td>5.01(0.15)</td>
</tr>
</tbody>
</table>

**Soil structure and enzyme activity**

Sq score was significantly negatively correlated with CM-cellulase \((p < 0.01)\) and \( \beta \)-G activity \((p < 0.05)\), which indicates that as structural quality increased (Sq score decreases) enzyme activity increased. This finding was associated with better soil structural quality was consistent with the view that good structure contain more effective porosity, more organic matter and better soil aggregation (Guimarães et al. 2013), that organic matter input/return to soil by management improves soil structure resulting in a greater C content in macro aggregates, that good soil structure will support soil enzyme activity and greater organic matter content supports soil enzyme activity by increasing available nutrients (Bowles et al. 2014). The consistent pattern of soil C related to soil structure (indicated by Sq score) and enzyme activity regulated
by management indicates that soil organic matter (representing significant soil C pool) is an important ‘bridge’ between soil structure and enzyme activity. Further research is required for a better understanding of these interactions.

Conclusion
This study found that grassland management influences soil structure by regulating soil organic C, which further regulates soil enzyme activity. The data indicated a strong interaction between soil structure and soil enzyme activity, both of which were influenced by management. Soil organic C seemed to contribute to this interaction, acting as a ‘bridge’ between structure and enzyme activity. Management that increases soil organic C is useful to both soil structure and enzyme activity, but if linked with intensive grazing might have a strong influence on soil C processes, especially in the 10-20 cm layer, by increasing microbial activity triggered by nutrient relocation to this depth from the surface.

References
MONITORING OF SLURRY APPLICATION USING REMOTE SENSING

Ross Donnelly-Swift and Nicholas Holden
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Abstract
Remote sensing offers a solution to monitoring slurry spreading on grasslands. Monitoring farmlands can be difficult and not always feasible. Imagery obtained from SPOT satellites has been used to locate and detect slurry spreading events that have been cross referenced with data obtained from farms about the location and date of these events. The pixel value of grasslands sprayed with slurry is different from that of grasslands with no slurry present. This can enable remote sensing to help aid the monitoring process.

Introduction
Over 50% of Ireland is covered in Grassland (Bossard et al., 2000). The majority of which is for agriculture (Crowley, 2008). Cattle are the dominant livestock in Ireland with over 80% of total livestock in the country (Commission et al., 2012). Agriculture is a valuable part of the Irish economy however it also has an impact on the environment. If slurry contaminates water it will cause eutrophication and acidification due to the high amounts of ammonia (NH3) present in it (Rodhe and Etana, 2005). This has led to the introduction of both national and international legislation on the protection of the environment. One such piece of legislation is the Nitrates directive (91/676/EEC) which came into effect in 1991 and concerns the protection of waters against pollution caused by nitrates from agricultural sources (Commission, 2000). In Ireland N can be applied in the form of artificial and natural fertilizer (Hutchings et al., 2007). Slurry is a semi liquid organic fertilizer made primarily from livestock faeces. Mineral fertilizers replaced slurry as they were more reliable in their ability to deliver nutrients and were easier to transport. This lead to slurry been viewed as a waste product that had to be disposed of but due to tighter regulations it is now a valuable resource which a farm can recycle (Van Kessel and Reeves III, 2000). Grass has a greater potential to absorb excess nitrogen as it has a longer growing season and it requires more nitrogen to initiate growth (McGechan and Wu, 1998). Ireland is divided into three zones. Each zone has different regulations on storage capacity and the closed periods when slurry spreading cannot be spread. In each zone all spreading must stop by the 1st of November and can commence again on different dates in January depending on the zone. Applying N outside of the growing season for grass leads to higher loss to both the atmosphere and leaching to the soil (Laidlaw et al., 2000). Slurry spreading and housing of cattle account for 40% of total Nitrates emissions (Hyde et al., 2003). Cattle on dairy and beef farms need to be housed indoors during the winter due to the slow to dormant growth in grass pastures (McGechan and Lewis, 2000). Lack of storage for slurry is the main cause of spreading slurry when conditions are unsuitable (Holden et al., 2004). There are different methods of spreading slurry with some leading to greater amounts of N lost to the environment (Schellberg and Lock, 2009). Splash plate spreads the slurry over the surface of the grass and soil. It is an easy way of applying slurry but also has more wastage involved. Injection of slurry decreases the loss of slurry due to evaporation but is more costly and is not beneficial in economic terms if done on a small scale (McGechan and Wu, 1998). Slurry that is very thick is sticky and will remain on vegetation were as thin slurry has properties like water and can easily move towards the base of the vegetation (Rodhe, 2003). In order to monitor slurry spreading it’s not always possible or feasible to visit every farm to make sure that slurry spreading does not occur in breach of the Nitrates Directive. For this reason it is important to find different methods of monitoring grasslands. Remote sensing can help aid in this monitoring process.

The objective of this project was to develop a low cost remote sensing tool for reliable, rapid, spatially extensive quantification of the presence of slurry applied to fields.
Materials and Methods

Field Sites

Three field sites have been chosen for this project. Two are Teagasc research centres located in Moorepark, Fermoy Co. Cork, Latitude 52° 30.420'N, Longitude 8° 12.149’W and Grange Beef Research Centre, Dunsany, Co. Meath Latitude 53° 31.125’N, Longitude 6° 39.553’W. The third site is the Agri-Food and Biosciences Institute (AFBI) and is located in Hillsborough, Co Down, Northern Ireland, Latitude 54° 27.200’N, Longitude 6° 4.603’W. The farms selected are used for dairy and/or beef production and have grasslands for grazing. Each farm was able to provide dates of slurry spreading events and in which fields. Mean average rainfall for Ireland is between 750 and 1000mm. The wettest months in all areas are between December and January. The mean annual rainfall between 1981 – 2010 for each site is as follows: Grange 800 – 1000 mm, Hillsborough 800 – 1000 mm, Solohead 1000- 1200 mm. (Met Éireann, 2013). Slurry is spread from the end of January to the start of November with certain flexibility around the starting and finishing dates depending on the location of the farm. Heavy precipitation is also a restriction on slurry spreading.

Satellite Imagery

Imagery was obtained from the Système Pour l’Observation de la Terre (SPOT) utilizing SPOT 2, 4 & 5. SPOT 2 has three bands centred at green, red and near infrared with a resolution of 20 metres. SPOT 4 & 5 have the same bands as SPOT 2 but with an extra band centered at short-wave infrared. SPOT 4 has a resolution of 20 metres while SPOT 5 has a resolution of 10 metres. The imagery obtained has been radiometrically corrected for distortions in the viewing instrument and geometrically corrected for systematic effects. Internal distortions of the image are corrected for measuring distances, angles and surface areas. It was important to select imagery that captured a recent slurry spreading event in each of the field sites. A cloud free image from SPOTs database was then matched to a slurry spreading event that occurred within the first week. Slurry spreading events over a week were also captured alongside the primary events for testing.

Table 1. Farm Data

<table>
<thead>
<tr>
<th>Field Site</th>
<th>Date Image Taken</th>
<th>No. of days since spreading</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grange</td>
<td>07/08/2005</td>
<td>Day 5</td>
</tr>
<tr>
<td>Grange</td>
<td>07/02/2007</td>
<td>Days 1, 2, 5</td>
</tr>
<tr>
<td>Grange</td>
<td>12/02/2008</td>
<td>Days 1, 16</td>
</tr>
<tr>
<td>Grange</td>
<td>02/02/2007</td>
<td>Day 5</td>
</tr>
<tr>
<td>Grange</td>
<td>17/02/2009</td>
<td>Days 1, 5</td>
</tr>
<tr>
<td>Solohead</td>
<td>08/08/2003</td>
<td>Days 3, 7, 24</td>
</tr>
<tr>
<td>Solohead</td>
<td>09/06/2005</td>
<td>Day 5</td>
</tr>
<tr>
<td>Solohead</td>
<td>02/02/2007</td>
<td>Day 6</td>
</tr>
<tr>
<td>Solohead</td>
<td>11/02/2009</td>
<td>Day 2</td>
</tr>
<tr>
<td>Hillsborough</td>
<td>14/04/2008</td>
<td>Days 4, 32</td>
</tr>
<tr>
<td>Hillsborough</td>
<td>16/03/2011</td>
<td>Days 8, 13</td>
</tr>
</tbody>
</table>
**Satellite assessment**

Erdas Imagine Software was used to analyse the images obtained. This software is a remote sensing application which allows for the processing of geospatial raster data.

**Results and Discussion**

After analysis of the imagery obtained it was possible to detect the presence of slurry when comparing it to the data provided from the farms. Knowing the exact field and date when slurry has been spread allows for accurate detection. The presence of slurry gives the pixel values a noticeable difference from the surrounding grasslands that didn’t receive any slurry.

**Figure 1.** A SPOT image taken in February with fields that are darker in appearance having been sprayed with slurry within two days.

Slurry sticks to the grass and masks the reflectance of the green vegetation enabling detection of the slurry to be achieved. The green band (number 1) of the SPOT image has a higher mean value for pixels taken from a field where no slurry spreading has occurred. This shows there is now a noticeable difference in the fields which can be detected using remote sensing.

**Figure 2.** Plot of pixels with slurry  
**Figure 3.** Plot of pixels with no slurry
Conclusion

Using the data collected from this study it will now be possible to look at imagery in the winter months and compare the spectral signature of grasslands to see if any suspected slurry spreading has occurred. This will allow for remote sensing to provide help with more traditional methods of monitoring the environment.

Acknowledgements

The authors are very grateful for the financial support from the EPA under the STRIVE program. We would also like to thank both Teagasc centers Grange Beef Research Centre, Moorepark research centre and the Agri-Food and Biosciences Institute in Hillsborough for providing valuable data for the research to be carried out.

References


THE ROLE OF ALLOCATION IN THE CARBON FOOTPRINTING OF DAIRY AND BEEF SYSTEMS

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Abstract

It is predicted that global human population will increase to over 9 billion by 2050 leading to an increase in global demand for animal products. As livestock systems will meet some of this demand, strategies to reduce the GHG intensity (kg of GHG/unit of food) of animal products are required. Lifecycle Analysis (LCA) is an internationally standardised tool, commonly used to assess GHG emissions of agricultural commodities such as milk and meat. A major methodological issue is allocation where a system or process produces more than one output. The objective of this study was to better understand the impact of allocation methodology on the carbon footprint of dairy and beef systems.

Introduction

It is predicted that global human population will increase to over 9 billion by 2050 (United Nations, 2007) leading to an increase in global demand for animal products (FAO, 2009), currently responsible for 18% of global GHG emissions (Steinfeld et al., 2006). Without the deployment of abatement technologies, agricultural GHG emissions are anticipated to increase. It is necessary to identify strategies to reduce the GHG intensity (kg of GHG/unit of food) of agricultural produce. Lifecycle Analysis (LCA) is an internationally standardised tool (ISO, 2006a) used to assess the GHG emissions of agricultural commodities such as milk and meat (IDF, 2010). It adopts a holistic systems approach to quantifying GHG emissions generated throughout the life cycle from raw-material acquisition through production, use, recycling and final disposal (ISO, 2006). A single impact LCA focused on global warming potential is commonly referred to as a carbon footprint. A major methodological issue is allocation. When a system (such as a dairy farm) or process (such as a cow) produces more than one output, the impact has to be allocated in some proportion to the multiple outputs (such as milk and meat).

The objective of this work was to better understand the impact of allocation methodology on the carbon footprint of dairy and beef systems.

Materials and methods

This will use a carbon footprint model for Irish livestock farms (O’Brien et al., 2011), with activity data from the “National Farm Survey” for 2012 (Hennessey et al., 2013). The allocation of products derived from the cow process (milk, meat, hide, tallow, other materials) will be assigned using: (i) mass; (ii) economic value; (iii) protein; (iv) biochemical energy; and (v) emergy. Mass values will be derived from survey data, economic values from 2012 market prices, protein values from market reports from the food industry, biochemical energy based on typical published values from the literature. A technical and methodological evaluation of how emergy can be used in this context will also be undertaken. Emergy (units of solar emjoules, seJ) is defined as the available energy (exergy) that is used in transformations directly and indirectly to make a product or service (Odum, 1996). The fundamental assumption of emergy analysis is that the contribution of a resource is proportional to the available energy of one kind required to produce the resource (Brown and Herendeen, 1996). The amount of input energy (expressed as solar emergy) per unit output energy is termed, solar transformity and to convert material and energy into seJ, a conversion transformity factor is used (Odum, 1996). Each input flow in the system is multiplied by its specific transformity to calculate its emergy content and emergy inputs into the system are added together to calculate total emergy input. Transformity represents the emergy efficiency of production (Brown and Ulgiati, 2004) where higher
values indicate greater need for environmental resources or product. The transformity calculation is based on an allocation of total emergy among the different products of the system according to their energy contents (Bastianoni and Marchettini, 2000). It is thus theoretically possible to calculate the emergy for meat, milk and other products from livestock, and thus allocate based on emergy proportions.

Results and Discussion

The method of allocation has a known effect on the emissions per kg of meat and to a lesser degree on the emissions per kg of milk (Figure 1). The reason for this is because meat production within specialised dairy systems is a small contributor to the total output. It is not clear whether there is an objective function that properly reflects allocation, but economic allocation only reflects market value and mass is not necessarily in proportion to impact (think of diamonds vs rock from a diamond mine). Protein and biochemical energy (biological in Figure 1) suggest a different picture, but both are subject to wide variability depending on management and biological factors. Minor changes in the allocation of emissions to meat can have a strong effect (Figure 2).

Figure 1. Effect of allocation techniques on partitioning of GHG emissions between milk and meat

Figure 2. Sensitivity analysis: effect of protein based allocation rule on the partitioning of GHG emissions between milk and meat.

The use of the emergy concept is envisaged to be a credible alternative means of allocation because it should be independent and objective.

Conclusion

It is envisaged that using the emergy concept will prove to be an objective and robust alternative method of allocation to improve on the current methods used for the LCA of dairy and beef production systems. It is also envisaged that the ‘emergy’ concept will tie in the various ‘functions’ of the food (nutrition; textural; cultural) products (milk/meat) albeit while not specifically addressing each and every ‘function’ individually, but encapsulated with the transformity.
References

THE EFFECTIVENESS OF MOLE DRAINAGE ON A CLAY-LOAM SOIL

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²Livestock Systems Research Department, AGRIC, Teagasc, Moorepark, Fermoy, Co. Cork.
³Environment Research Centre, Teagasc, Johnstown Castle, Co. Wexford.

Abstract
In Ireland, many farms are located in areas where high rainfall, underlying geology and landscape position have given rise to low permeability soils, which makes grazing and trafficability difficult at certain times of the year. At the same time precipitation ranges from 750-1400 mm year⁻¹ (excluding mountainous areas) while evapotranspiration ranges from 390 to 570 mm, therefore large amounts of excess water need to be drained. Where very low permeability soils are encountered, conventional piped systems are cost prohibitive at the spacings required for adequate watertable control, and as such it is necessary employ soil disruption techniques to improve hydraulic conductivity. The usefulness of these techniques (mole and gravel mole drainage) as means of draining low permeability soil warrants investigation in order to provide guidelines on their limitations and overall effectiveness.

Introduction
Where soils are impermeable to depths of >2.5 m, the cost of a conventional drainage system to control the watertable is generally prohibitive because of the very close drain spacing needed (Galvin, 1983; Rodgers et al., 2003). As such it is necessary to use drainage methods that incorporate soil disruption techniques (Burke et al., 1974). The aim of these techniques (which include mole and gravel mole drainage) is to provide very closely spaced drainage channels and to alter the structure of the subsoil, improving its saturated hydraulic conductivity and reducing its water holding capacity (Rodgers et al., 2003). The major advantage of mole drainage is its low cost (€125 - 300/ha), provided there is a suitable outlet.

The success of mole drainage on fine textured soils, with high silt and clay content can be very variable (Rycroft & Thorburn, 1974; Galvin, 1983). The stability and long term effectiveness of mole drainage depends upon the soil texture, stability of the soil aggregates to wetting and soil moisture status at the time of installation (Mulqueen, 1985; Spoor, 1985). As the conditions required for the long term stability of a mole channel are quite rare in Irish soil and climactic conditions, an alternative disruption method has been developed. Gravel mole drainage was developed by Mulqueen (1985). Gravel filled mole drains are required where an ordinary mole channel cannot be formed or will not remain stable for a sufficiently long period to provide effective drainage. This technique is more expensive (€1500-2800/ha).

Traditionally mole drainage has been successful in the north and north east of Ireland (Galvin, 1969), where both the soils higher clay content and less intense rainfall regime are conducive to the creation of a stable mole channel. Mole drainage is not used widely in the south of Ireland, due to the soils perceived unsuitability and limitations imposed by the wetter climate. Naturally, farmers on impermeable soils in this region are as much in need of an effective drainage system as their counterparts in the north. The aim of this study was to compare the effectiveness of mole and gravel mole drainage in removing excess water and controlling the watertable position from a soil with 35-45% clay content in the south of Ireland.

The main objective was to investigate and account for temporal and spatial changes in flow volumes from overland and subsurface drain flow from four treatments; (A) no intervention, (B) mole drainage installed in January 2011, (C) mole drainage installed in July 2011 and (D) gravel mole drainage installed in July 2011, on a clay-loam to clay soil across 12 rainfall events.

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Materials and Methods

Site Description
The study was conducted at Solohead Research Farm in the south of Ireland (52°30’N, 08°12’W) from 2011 to 2013. Average annual rainfall (10 years) on site is 1070 mm, with potential evapotranspiration of approximately 510 mm annually. The general soil types on the farm are poorly drained gleys (90%) and grey brown podzolics (10%). More specifically soil test pits elucidated some textural and saturated conductivity data from the study site, which is presented in Table 1. Quaternary till overlying Devonian Sandstone bedrock contains a perched watertable (depth of 0 to 2.2 m below ground level, BGL), (Necpalova et al., 2012).

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>&gt; 2 mm (%)</th>
<th>&lt; 2 mm USDA textural class</th>
<th>Hydraulic conductivity* (m/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 25</td>
<td>11.5</td>
<td>41.3</td>
<td>Clay loam</td>
</tr>
<tr>
<td>25 - 80</td>
<td>25.5</td>
<td>30.9</td>
<td>Clay</td>
</tr>
<tr>
<td>80 - 130</td>
<td>28.3</td>
<td>34.2</td>
<td>Clay</td>
</tr>
<tr>
<td>130 - 200</td>
<td>1.0</td>
<td>5.9</td>
<td>Clay</td>
</tr>
</tbody>
</table>

*Estimated using the hydraulic properties calculator by Saxton and Rawls (2006).

Drainage Design
There was no evidence of any high transmissivity soil layer at the study site (Table 1) which would allow for conventional field drains to be installed (Mulqueen & Hendricks 1986). The required drain spacing at 0.6 m depth was estimated as 0.75–1.5 m using nomographs developed by Toksöz and Kirkham (1971a, 1971b) assuming a drainage discharge value of 12 mm/day (Collins et al., 2004) and desired minimum watertable depth of 0.45 m. Field drains are not economically feasible at this spacing. As such it was decided to employ mole drainage (and variations thereof) as the most practical drainage solution for the site.

Experimental treatments and design
In August 2010, all internal fences were removed and the area was demarcated. Along the southern end of the site a large trench up to 2 m BGL was excavated to act as a collection drain. The site was then graded using a bulldozer to remove any surface irregularities ensuring an even gradient. The area was surrounded by a 1 m deep trench filled with stone aggregate. The purpose of this trench was to hydrologically isolate the area, preventing any interference from adjacent land areas.

In January 2011 the area was divided into four blocks, each 60 m wide and 100 m long. Each block was sub-divided into four plots each 15m wide and 100m long. One of the four treatments was imposed in each plot in a randomized complete block design. The four treatments were (A) no intervention, (B) mole drainage installed in January 2011, (C) mole drainage installed in July 2011 and (D) gravel mole drainage installed in July 2011. The mole plough (M. Tighe Engineering, Navan, Co. Meath, Ireland) had a 0.075 m diameter foot, an 0.08 m diameter expander plug. Mole drainage was installed at a depth of 0.55 m and spacing of 1.20 m. The gravel mole plough (O’ Keeffe Engineering, Listowel, Co. Kerry, Ireland) had a 0.08 m wide foot. It was adjusted to install a 0.20 m high column of gravel in the channel. Gravel mole drainage was installed at a depth of 0.40 m and spacing of 1.2m.

Experimental measurements
An automated weather-station (Campbell Scientific Ltd. Loughborough, UK) was situated on site. This provided input parameters for the estimation of soil moisture deficit (SMD) using the model of Schulte et al. (2005). In three plots from each treatment overland and subsurface drain flow (collection tanks, v-notch weirs and Sigma area/velocity sensors connected to Sigma 920 flowmeters (HACH Company, Maryland, USA)) were measured continuously.
while groundwater recharge was estimated by subtraction. Watertable depth was measured weekly. The response of treatments to rainfall was analysed for 12 events from June 2012 to March 2013. Data were analysed using ANOVA with treatment as a fixed effect.

Results and Discussion
Total overland flow and ratio of overland flow to effective drainage varied little between treatments. Event mean total overland flow in treatments was 5.5 – 6.7 mm accounting for 0.24 – 0.30 of event mean effective drainage. Mean total subsurface drain flow during events was greater (P<0.05, s.e. 0.62 mm) in treatment D (7.4 mm) than either B (3.7 mm) or C (4.0 mm). The mean ratio of subsurface drain flow to event effective drainage was also significantly higher (P<0.01, s.e. 0.022) in treatment D (0.36) than B (0.18) or C (0.20).

The relative flow response from the subsurface drains was seen to reduce with time. For events 1-4 mean (standard deviation) total overland flow was 0.47 (0.08) of the total subsurface drain flow. For events 5-12 mean total overland flow was 2.02 (0.41) of the total subsurface drain flow. During Event 1 (02/06/12) all drains performed well with high ratios of drain flow to effective drainage, as defined by Schulte et al. (2005), (Fig. 1a). From event 5 there was an increase in total overland flow relative to drain flow. In event 6 (14/08/12) ratios of overland flow to effective drainage in treatments B, C and D were 50, 41 and 41%, respectively (s.e. 5.9 %, NS), while the ratio of drain flow to effective drainage in the treatments were 4, 11 and 40% respectively, with treatment D outperforming both B and C (s.e. 6.5%, P<0.05). At event 10 (27/12/12) ratios of runoff to effective drainage remained high, while drain performance in all treatments was poor (Fig. 1b).

Figure 1.

Across replicates the watertable depth was consistently shallower in treatment A than in treatments B, C or D. Mean pre-event watertable depth was 65 cm BGL in treatment A relative to 80, 80 and 87 cm BGL for treatments B, C and D respectively, with post event means of 52, 71, 72 and 78 cm BGL for A, B, C and D respectively.

Conclusions
Both mole drainage and gravel mole drainage were found to be effective in the removal of excess water. Across replicates the watertable depth was consistently shallower in treatment A (undrained control) as such all drainage treatments brought about a level of watertable control. Drain performance varied widely within and between treatments and between events but some behavioural trends were evident. Treatment D (gravel mole drainage installed in July 2011) had consistently higher peak flow rates and greater total flows than in other treatments. The relative subsurface drain flow response decreased over time in all treatments with corresponding increases in overland flow.

The reliance of these drainage methods on flow through cracks in the soil limits their effectiveness in persistent wet weather as the cracks themselves are subject to the natural shrink/swell properties of the high clay content soil. Extreme periods of rainfall resulted in a poor drainage response and high levels of overland flow. Greater drainage efficiency and more consistency between like treatments could only be achieved at greater expense to the
landowner i.e. a supplementary field drain network acting as an outfall, and as such would
need careful consideration. In areas where suitable conditions for effective mole drainage
installation exist, the operation could be repeated frequently (2 – 3 years) to maintain
effective drainage at little cost. Gravel mole drainage is more effective in the short term, but
was also subject to deterioration during the study period. The method cannot be repeated
frequently due to its high cost and as such would need to be supplemented by a field drain
network to improve flow capacity if it was to be effective in the long term.

Acknowledgements
This publication has emanated from research conducted with the financial support of Interreg
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**Appendix 1**

(Research projects in progress which have not been included in the Research Review)


**O’Flynn M** and McDonnell. Influence of harvest traffic on soil compaction, crops response and biomass yield in Miscanthus (PhD). Science Foundation Ireland

**Tuffy K** and Holden N. Impact of artificial sub-surface drainage on pasture production, the length of the grazing season and the profitability of milk production on a heavy wet soil (PhD). Research Stimulus Fund as administered by the Department of Agriculture, Food and the Marine and Teagasc Walsh Fellowship.


**Zhao M** and O’Donnell C. Development of PAT tools for monitoring of dairy processes (PhD). Food Institutional Research Measure (FIRM) administered by the Irish Department of Agriculture, Food and the Marine.

**Doyle P** and F Butler. Utility of HACCP to minimise risk of pathogenic bacteria in farm milk (PhD).

**Hunt K, Jordan K and Butler F.** Coagulase-positive Enterotoxins of Staphylococcus aureus isolates from Milk used in Raw Milk Farmhouse Cheese (PhD). Food Institutional Research Measure (FIRM).

**Walsh J** and Ward S. Carbon trading and management (PhD). Science Foundation Ireland under Grant Number 6C/CP/E001.
Appendix 2

Profiles of Postdoctoral Research Scholars only includes: Drs Boots, Coffey, Everard, Devlin, Drummond, Esquerre, Jackman, Riccioli, Walsh, O’Brien, Zhihang Zhang

Bas Boots M.Sc. Ph.D.

Project title: µAQUA, Universal Microarrays for the Evaluation of Fresh-Water Quality Based on the Detection of Pathogens and their Toxins

Abstract
The threat of waterborne diseases is predicted to increase in the future. To avoid outbreaks, water quality needs to be monitored and a universal method for rapid and cost-efficient detection of waterborne pathogenic microbes has been sought after for many decades. Traditional methods are laborious, require high levels of expertise and typically focus on only one or a few organisms at once. µAQUA aims to develop a universal microarray chip equipped with species specific oligonucleotide probes targeting protozoa, bacteria, viruses and cyanobacteria. Bioindicators for water quality will also be incorporated. My contribution to the project is the designing and testing of probes that target pathogenic members of the protozoa Cryptosporidium, Giardia, Naegleria and Entamoeba in environmental water samples. The project also involves monitoring of three Irish rivers, draining agricultural intense and urbanised catchment areas. The objective is to produce a commercially viable, universally applicable method to test and monitor water quality.

Background, Skills & Qualifications
I graduated with a M.Sc. in Environmental Sciences (Soil, Water & Atmosphere) from Wageningen University, the Netherlands in 2006. I have done research on soil carbon sequestration under elevated levels of atmospheric CO\textsubscript{2} at the ETH Eschikon, Switzerland and the University of California, Davis, USA. I also explored how invasive earthworms interact with native animals and can alter soil carbon cycling within a forest at the University of Georgia, Athens, USA. I became intrigued by the world of microbes and pursued a Ph.D. in microbial ecology at the University College Dublin, from which I graduated in 2010. During this period I carried out several field experiments and used molecular techniques to study, amongst other topics, symbiotic relationships between ants and microbes. I have developed a great interest in tinkering with statistical methods, which has lead to a short post-doc to analyse large datasets obtained from experiments involving ruminants and mitigating enteric methane production. I then explored methanogenic processes and microbial ecology in marine sediments invaded by non-native oysters. Currently, I have joined the UCD School of Biosystems Engineering as a post-doctoral researcher to work with Professor Nick Holden on the EU FP7 project µAQUA.

Recent Publications

Boots B, Clipson N. (2013). ‘Linking ecosystem modification by the yellow meadow ant (Lasius flavus) to microbial assemblages in different soil environments’. European Journal of Soil Biology, 55, 100-106.

Rory Coffey, BAgrSc, MSc(Eng), PhD.

Project Title: Assessing the impacts of climate change on the fate and transport of microorganisms using catchment scale modelling.

Project Leader: Dr. Enda Cummins

Abstract
Despite advances in water treatment, outbreaks of waterborne diseases still occur in developed regions including the United States (US) and Europe Union (EU). Water quality impairments attributable to elevated concentrations of fecal indicator bacteria, and associated with health risk, are also very common. Research suggests that the impact of such microorganisms on public health may be intensified by the effects of climate change. At present, the major regulatory frameworks in these regions, i.e., the US Clean Water Act (CWA) and the EU Water Framework Directive (WFD), do not explicitly address risks posed by climate change. Comprehensive analysis of future climate and water quality scenarios may only be achievable through the use of catchment-scale models. The objective of my current research is to simulate and assess the impacts of climate change on microbial fate and transport using catchment scale models. Unless adaptation measures are generated and incorporated into water policy, the potential threat posed to humans from exposure to waterborne pathogens may be amplified. Such adaptation measures will assist in achieving the aims of the EU WFD and US CWA and minimise impacts of climate change on microbial water quality.

Background, Skills & Qualifications
I completed my undergraduate studies in 2003 with an honors degree in Agricultural Science (Engineering Technology) from UCD. Subsequently, I received a funded Research Masters scholarship from UCD Biosystems Engineering focussing on risk assessment in the food chain. Work involved the development of a Feed Chain Risk Assessment (FCRA) for bovine animals in Ireland and identification of measures to reduce human exposure to mycotoxins resulting from the consumption of food products of bovine origin. My PhD (at UCD Biosystems Engineering), funded by the Environmental Protection Agency, was awarded in 2010. The objective of this work was to assess, develop and apply a microbial model capable of predicting concentrations of pathogenic organisms in Irish drinking water catchments. Following my PhD I took up a postdoctoral position within UCD Biosystems Engineering as a teaching/research fellow and progressed research initiatives in the area watershed modelling. Currently I am funded as an EU FP7 Marie Curie International Outgoing Fellow in collaboration with the Centre for Watershed Studies, Department of Biological Systems Engineering, Virginia Tech, USA.

Sample Peer-reviewed Publications


Colm Everard, BE, PhD, Uni Cert Stats

Project Title: Spectral Imaging for Contaminant Detection on Fresh Food Produce

Project Leaders: Prof Shane Ward and Dr Moon Kim

Abstract
The objective of my current research is to develop and validate on-line, non-destructive hyperspectral imaging technologies to rapidly assess safety and quality of fresh foods. This will reduce food safety risks in pre-harvest and post-harvest production. Multitask inline hyperspectral imaging, macro-scale laser-induced fluorescence imaging, Raman hyperspectral imaging, and image-based portable handheld inspection devices will be developed for detection of food safety issues.

Background, Skills & Qualifications
I obtained a BE and PhD in Biosystems Engineering at UCD. I also obtained a University Certificate in Statistics at UCD.
I joined Teagasc (Moorepark Food Research Centre) as a Research Officer in 2005 working on the development to cheese syneresis control technologies for improved product consistency. In 2008, I was awarded an IRCSET fellowship through their EMPOWER scheme, hosted by UCD. Subsequently, I was employed as a post-doctoral researcher on the Charles Parsons Energy Research Award at UCD. During this period I was awarded a 5 month SFI - Short Term Travel Fund to develop mathematical models to predict heating in Irish indigenous biomass crop piles and my host was the Reactive Substances and Systems Division at BAM Federal Institute for Materials Research and Testing, Berlin, Germany.
I am currently an EC FP7 Marie Curie International Outgoing Fellow and my outgoing host is the Environmental Microbial and Food Safety Laboratory, US Department of Agriculture, Agricultural Research Service, MD, USA.

Recent Peer-reviewed Publications

Dr. Ger Devlin, BSc., PhD.


Project Leader: Dr. Kevin McDonnell

Abstract
The Irish government has undertaken to reduce national CO₂ emissions through a range of measures put out in their Biomass Action Plan and the National Renewable Energy Action Plan. The conversion of peat fired power plants to co-fire with renewable biomass is one of these. This work considers how the adoption of sweeping policies impact on other actors presently supplying or utilizing woody biomass resources for renewable electricity generation.

Background, Qualifications and Skills
Dr Ger Devlin obtained his primary degree in BSc. Applied Physics from Dublin City University (DCU) in 2001. He was awarded his PhD degree in Engineering from the Department of Biosystems Engineering, UCD in 2007. He is Ireland’s representative and management committee member on COST Action FP0902 - "Development and Harmonization of new operational research and assessment procedures for sustainable forest biomass supply (www.forestenergy.org)." He is also Ireland's first representative on the International Energy Association (IEA) Task 43 - "Biomass Feedstocks for Energy Markets." He currently has 56 publications that include 3 books, 1 book chapter, 1 Good Practice Guide in Timber Transport, 1 book Editor and 26 international peer review publications along with 3 technical report publications and 14 conference publications. He is reviewer for several peer review journals including Fuel Processing Technology, Transportation Research Part D, Journal of Transport Geography, International Journal of Forest Engineering, Journal of Forest Energy, Canadian Journal of Forest Research and ASABE to name a few. He is also the first Irish based Editorial board member on the International Journal of Forest Engineering.

Peer-reviewed Publications
Liana Drummond, BSc. Eng., MSc., PhD.

Project Title: MILD-DRY: Novel microwave assisted vacuum drying for heat sensitive foods

Project Leader: Prof. Da-Wen Sun

Abstract
Drying is a valuable large scale operation method for keeping solid foods safe for long periods of time. However, heat sensitive foods and products that possess excellent quality in terms of taste, aroma, texture, and appearance, pose a major challenge to dry. Cellular tissues containing gas-filled pores tend to collapse when subjected to dehydration, particularly noticeable with prolonged exposure to elevated drying temperatures, such as those used in convective drying. The Mild-Dry project aims to develop a variable frequency microwave vacuum-drying (MWVD) process that will bring together the advantages of these two effective drying methods: the speed of microwave drying and the quality preservation of vacuum drying. The system is expected to reduce drying time of conventional vacuum drying processes resulting in lower energy and running costs, increased product throughput, preservation of the nutritional value and improved quality of heat sensitive dried foods. The project will also plan for the commercial scale up of the Mild-Dry system and its subsequent market entry, aiming to improve the competitiveness of European Small and Medium Enterprises (SMEs) from the dried foods sector.

Background, Skills & Qualifications
Graduated in 1991 at the University of Rio de Janeiro, Brazil with a BSc. in Chemical Engineering and in 1997 from the South Bank University, London, UK, with a MSc. in Food Safety and Control. Worked as a Research Assistant in Delft University of Technology: TU Delft, The Netherlands, developing and testing new applications for a novel separation process (eutectic freeze crystallization). Awarded a PhD from the Biosystems Engineering Department in UCD, in 2008. The research work conducted was on an innovative combined cooking/cooling technology for cooked meat products – Immersion Vacuum Cooling. Subsequently appointed for a postdoctoral position in Biosystems Engineering School in UCD, working on the development of Immersion Vacuum Cooling for the cooked meat industry, aimed at European SMEs (Coolmeat – FP7 project), with the objective of a potential scale-up and commercial application of this technology. Currently works as a post-doctoral researcher on the FP7 project: Mild-Dry - Microwave assisted vacuum drying for heat sensitive foods.

Recent publications
Project title: Development of optical imaging technologies to rapidly assess safety and quality of cereals

Project Leaders: Prof Shane Ward and Dr Stephen Delwiche

Abstract

The overall goal of this project is to develop and validate on-line, non-destructive optical imaging technologies to rapidly assess safety and quality of cereals at critical processing stages post-harvest. This will reduce food safety risks and result in economic benefit to the cereal industry.

Background, skills & Qualifications

The objective of my PhD at UCD was to develop spectroscopy and hyperspectral methods for early detection of physical damage in mushrooms. During this study I developed skills and knowledge in the areas of NIR spectroscopy, NIR hyperspectral imaging and chemometrics. From that work I published 5 peer-reviewed journal papers and 7 conference papers as first author. Following the successful completion of my PhD I took up a position as Postdoctoral Researcher at UCD Biosystems Engineering (2010) where I focused on chemometric and sensor development for (i) seaweed characterisation and (ii) to facilitate the transfer of my PhD findings to the Irish mushroom industry. My current research is funded by the EC FP7 Marie Curie International Outgoing Fellowship programme. My outgoing host is the Food Quality Laboratory, U.S. Department of Agriculture, Agricultural Research Service, Beltsville Agricultural Research Center, MD, USA.

I have published 12 peer-reviewed papers in high impact journals and presented my research results at 20 international conferences to date. I also assisted in the supervision of PhD and MSc students. I was previously a lecturer in universities in Peru and Chile.

Recent publications


Esquerre, C., A.A. Gowen, G. Downey, and C. P. O'Donnell (2012). Wavelength selection for development of a near infrared imaging system for early detection of bruise damage in mushrooms (Agaricus bisporus), J. Near Infrared Spectrosc. 20, 4, 21-29

Patrick Jackman, B.E., M.Eng.Sc., PhD

**Project Title:** Application of wireless technologies to improve quality assurance in the poultry production chain

**Project Leader:** Prof. Shane Ward

**Abstract**
The monitoring of poultry production offers an opportunity to strengthen quality control assurances in pre-harvest. The quality and welfare of the crop are reduced by not tightly controlling the house environment, causing fluctuations and deviations in temperature, humidity and an accumulation of harmful gases such as CO₂ and NH₃. The house temperature is raised by turning on gas or diesel burners and cooled by heat exchange with the external atmosphere or by opening the air vents. The house humidity is reduced by opening the manual or automatic vents. Similarly gas concentrations can be reduced by opening the vents to refresh the air. The decision to open the vents and or switch on the burners is made by an environmental control system based on measured data; however the sensors providing the data are mounted on walls or support beams and thus not in the chickens’ own airspace. The “BOSCA” project has built wireless sensors to reside in the chickens’ own airspace to provide better data on air quality. As these sensors feed near real time data into a cloud server, they can disseminate process control decisions to farmers and to the environmental control system. Thus they lead to a more precise environmental control and hence better house productivity. Furthermore the data can be analysed over time for development of improved environmental control algorithms and for cross comparing house performances leading to a farmers league table.

**Background, Skills & Qualifications**
My PhD thesis was the automation of the United States Department of Agriculture (USDA) expert grading system for Beef carcasses (1997 edition) under Prof. Da-Wen Sun of UCD Biosystems Engineering and Dr. Paul Allen of Teagasc Ashtown. The task was to correlate visible imaging features of colour, marbling fat and muscle texture with instrumental, sensory panel and consumer panel determinations of palatability. My degree was awarded in December 2009 after an external examination by Prof. Yang Tao of the University of Maryland. I have a Masters of Engineering Science (Food) awarded by UCD and a Bachelor of Engineering (Chemical) awarded by UCD.

**Recent publications**


Cecilia Riccioli, BA, PhD

Project Title: Hyperspectral imaging technology for the quality inspection of fish products (SPECTRAFISH)

Project Leader: Dr. Da-Wen Sun

Abstract
In recent years, hyperspectral imaging (HSI) has gained a wide recognition as a non-destructive and fast quality and safety analysis and assessment method for a wide range of food products.

The SPECTRAFISH project aims to bridge the lack of a rapid and objective method of non-invasively inspecting based on quality and safety attributes of finfish products by integrating two conventional optical sensing technologies of computer vision and spectroscopy into unique imaging sensors, a hyperspectral imaging system that can provide not only spatial information but also spectral information for each pixel in an image.

The development of a hyperspectral imaging device for the automatic, rapid, objective and non-invasive measurement of quality and safety attributes of finfish fillets will be carried out throughout the project.

Background, Skills & Qualifications
I have more than six years of experience in the application of HSI to the inspection of the quality and safety agro-food products. I received my PhD from the Department of Animal Production at Universidad de Córdoba (Spain) in 2011. The thesis dissertation was “Detection and quantification of animal species in meat and bone meal using hyperspectral sensors”, supervised by Professor Ana Garrido Varo (current President of ICNIRS, http://icnirs.org/index.php/overview/executive). The PhD research period has led to an extensive training in multiple areas linked to Near Infrared Hyperspectral Image Analysis.

I obtained a BA in Science and Technology of Food from the University of Florence (Universita’ degli studi di Firenze, Italy) in 2005.

Recent publications


Eilín Walsh, BSc (Hons) MSc (Agr), PhD

Project Title: Sustainable Energy and Green Technologies

Project Leader: Dr. Kevin McDonnell

Introduction

The MSc in Sustainable Energy and Green Technologies programme offered by the School of Biosystems Engineering is underpinned by the best European practice by incorporating compatible EU policy drivers such as the Strategic Energy Technology Plan (SET Plan) for energy research, current R&D in green technologies through ongoing research initiatives under the Charles Parsons Energy Research programme, and collaboration with internationally acknowledged experts in the subject domains. One of the requirements of the Sustainable Energy and Green Technologies programme is that students conduct a research project focussed on a topic within the field which is presented as a minor dissertation. After the dissertations have been submitted I then assess each project for relevancy and novelty before using the students’ dissertation as a base to prepare an article for publication. Depending on the topic, the articles are prepared either for peer review or for a popular press publication. In this way, I have a significant responsibility for raising the profile of both the School of Biosystems Engineering and the Sustainable Energy and Green Technologies programme both nationally and internationally. I also work with the Charles Parsons Energy Research team on their activities in both peer review and popular press publications to highlight the research activities and outputs of this project.

Background, Qualifications and Skills

Joining the School of Biosystems Engineering was a natural choice for me. In 2005, having completed a Bachelor of Science degree in Environmental Biology in UCD, I joined the School of Biosystems Engineering to undertake a Masters of Science (Agriculture) before completing a PhD under the supervision of Dr. Kevin McDonnell. My PhD focussed on sustainable agriculture, specifically the use of industry-derived organic materials as an alternative to synthetic fertilisers to enhance soil fertility and productivity. It was during my PhD that my aptitude for technical and scientific writing became apparent and I am highly regarded amongst my peers for my writing, proofreading, and editing skills. Upon completion of my PhD research I followed an obvious progression to my current position.

Recent Publications


Niall O’Brien, BE, M.EngSc., PhD

Project Title: Integrating engineered nanomaterial (ENM) kinetics with environmental exposure modelling

Project Leader: Dr. Enda Cummins

Abstract
The “nanoADJUST” project aims to develop expertise in the application of techniques and tools used to characterise and analyse the behaviour of metallic engineered nanomaterials (ENMs) in natural aquatic media and integrate this expertise with environmental exposure modelling and risk management data requirements and processes. Data handling throughout the risk assessment (RA) process will be analysed and a statistical framework for the acquisition and management of nano-relevant data at all stages will be developed. Partitioning experiments in natural aquatic environmental matrices will be undertaken, generating data for use in exposure modelling and RA. Fit-for-purpose analytical methodology shall be developed for quantification of nanoparticle related elemental concentrations in model experiments and natural aquatic environmental matrices. Behavioural indicators or descriptors (i.e. partitioning likelihood distributions) shall also be developed for use in metallic ENM experimental analysis, exposure monitoring and risk assessment, and identification of organisms at risk of metallic ENM toxicity.

Background, Skills & Qualifications
My PhD thesis, concerning the development of a risk assessment methodology for evaluating ecological dispersion and human health risks from nanoparticles through environmental pathways, was completed in 2010 under the supervision of Dr. Enda Cummins. This involved developing techniques in environmental modelling, environmental risk assessment and benchmark dose modelling. I obtained a Masters in Engineering Science in the area of renewable fuel production in 2006 and a BE in Biosystems Engineering in 2004, both from UCD.

Recent Publications


Zhihang Zhang, BEng., PhD.

**Project Title**: Affordable variable frequency microwave assisted vacuum drying for heat sensitive foods

**Project Leaders**: Prof. Da-Wen Sun

**Abstract**

Food drying is a main food processing technology and a common method for food preservation, providing stable ingredients for a variety of foodstuffs. However, traditional drying (e.g., convective hot air drying) would often cause damage of many heat sensitive components like vitamin C, and deteriorate qualities (such as colour, texture and aroma) of many foods like herbs, spices and sea foods. Freeze-drying can provide great-quality dried foods. Freeze drying costs can be 200±500% higher than that of hot air drying in order to achieve the same final moisture content. The present project is to going to develop microwave vacuum drying, as an energy efficient drying method, combining advantages of microwave drying and vacuum drying, by reducing drying time, and drying temperature, to improve the conservation of many heat sensitive food components during drying process. Furthermore, with the aim of solving fixed-frequency microwave heating uniformity problems, variable-frequency microwave (VFM) heating will also be explored.

**Background, Skills & Qualifications**

I got my Bachelor degree in Food Engineering in Shanghai fisheries University. After graduation, I did research in School of Light Chemistry and Food Science in South China University of Technology, as a PhD student, for about 4 years. During the period, I was involved in many projects, like date exploitation, sugar manufacture, crystallization of an antibiotic, beer brewing, vinegar soft drink exploitation, and solution of sedimentation in soy sauce. Thereafter, I pursue a doctoral study in UCD. During the study, I carried out an EU project, about vacuum cooling of cooked ready-meal components, like meat (beef, pork and lamb), carbohydrate (rice, pasta and potato), vegetables (broccoli, carrot) and sauces. Between 2005 and 2008, I presented food safety training to food companies in Ireland, on behalf of FSAI. In 2008, I completed the PhD degree in Biosystems Engineering Department, UCD, with the thesis “Experimental and numerical study of vacuum cooling of cooked diced beef and rice”. Between 2008 and 2010, I worked as a postdoctoral researcher in UCD, on a project named MINICRYSTAL, which used power ultrasound to reduce freezing time of meat and improve quality of frozen meat. Between 2010 and 2012, I was involved in another EU project, COOLMEAT, in which immersion vacuum cooling of large ham was developed. I am currently working for the above mentioned project.

**Peer-reviewed Publications**


Appendix 3

UCD School of Biosystems Engineering: Postgraduates 2013/14 as photographed by Sean Kennedy
Appendix 4

UCD School of Biosystems Engineering : Staff and Post Docs
2013/14 as photographed by Sean Kennedy