

Attenuated-Total-Reflection Fourier-transformed spectroscopy as a rapid tool to reveal the molecular structure of insect powders as ingredients for animal feed


Jordi Ortuno[1],Katerina Theodoridou[1]

[1]*Institute of Global Food Security, Queen's University Belfast, Belfast, UK.*

k.theodoridou@qub.ac.uk

QUEEN'S UNIVERSITY BELFAST | IGFS THE INSTITUTE FOR GLOBAL FOOD SECURITY

EAAP • WAAP • INTERBULL • 2023 • LYON • FRANCE 74th

Food security

80% of feed protein is imported from outside EU

Almost 30% of fisheries are overexploited

80% of global arable land is dedicated to livestock

GMO-feeds social concern

Environment

98% of water used in farming is due to irrigation of feed crops

71% of South American rainforest conversion for farming → loss of biodiversity

High GHG emissions linked to fertilization, pesticides and transport

Protein Feed Source of the future

ıs Asia Australia Middle East Africa Inequality Cities Global developmen

Amazon rainforest's final frontier under threat from oil and soya

MailOnline

Home | News | U.S. | Sport | TV&Showbiz | Australia | Femail | Health | Science | Mon

Latest Headlines | Royal Family | News | World News | Arts | Headlines | France | Pictures | Most read |

Waitrose ends use of GM animal feed on its farms: Critics hail decision as 'beginning of the end' for use of the crops in the UK

- Waitrose meat, milk and eggs will not come from animals on GM feed

The Telegraph

Home Video News World Sport Business Money Comment Cultu

Politics | Investigations | Obits | Education | Science | Earth | Weather | Heal

HOME » NEWS » UK NEWS

All seafood will run out in 2050, say scientists

BBC Sign in News Sport Weather iPlayer TV Rac

NEWS

Home | UK | World | Business | Politics | Tech | Science | Health | Family & Education

The bean at the heart of America's trade war

By Reality Check team
BBC News

2 August 2018

Share

BBC Sign in News Sport Weather iPlayer TV Radi

NEWS

Home | UK | World | Business | Politics | Tech | Science | Health | Family & Education

US & Canada

Monsanto ordered to pay $289m damages in Roundup cancer trial

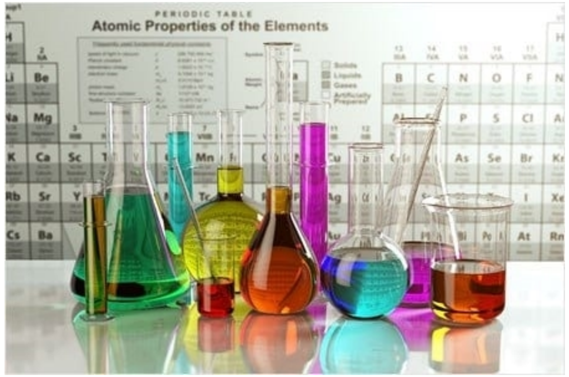
11 August 2018

Share

INSECTS ARE A COMMON INGREDIENT IN THE DIET OF MONOGASTRIC ANIMALS

Traditional ‘wet’ analytical chemistry

- ✓ Usually looks for a specific known component through homogenisation of the tissue.
- ✓ Information about the spatial origin and distribution of the component of interest is lost.
- ✓ Rely heavily on the use of harsh chemicals altering the native feed structures and possibly generating artifacts.
- ✓ Require reasonable amounts of feed material.
- ✓ Time consuming, expensive and prone to errors within and between laboratories.
- ➢ Studying the secondary structure of proteins leads to an understanding of the components that make up a whole protein.
- ➢ Often vital to understanding its digestive behaviour, nutritive quality, utilisation and availability in animals.



JOURNAL OF AGRICULTURAL AND FOOD CHEMISTRY
Article
pubs.acs.org/JAFC

Application Potential of ATR-FT/IR Molecular Spectroscopy in Animal Nutrition: Revelation of Protein Molecular Structures of Canola Meal and Presscake, As Affected by Heat-Processing Methods, in Relationship with Their Protein Digestive Behavior and Utilization for Dairy Cattle

Katerina Theodoridou and Peiqiang Yu*

College of Agricultural and Bioresources, Department of Animal and Poultry Science, University of Saskatchewan, 51 Campus Drive, Saskatoon, SK S7N 5A8 Canada

Contents lists available at ScienceDirect
Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy
journal homepage: www.elsevier.com/locate/saa
ELSEVIER
SPECTROCHIMICA ACTA

Explore protein molecular structure in endosperm tissues in newly developed black and yellow type canola seeds by using synchrotron-based Fourier transform infrared microspectroscopy

CrossMark

Katerina Theodoridou [a], Sally Vail [b], Peiqiang Yu [a,c,*]

Journal of Agricultural Science, Page 1 of 13.
doi:10.1017/S0021859613000452

ANIMAL RESEARCH PAPER

Ruminal dry matter and nitrogen degradation in relation to condensed tannin and protein molecular structures in sainfoin (*Onobrychis viciifolia*) and lucerne (*Medicago sativa*)

Article
FOOD CHEMISTRY
pubs.acs.org/JAFC

Synchrotron-Based Microspectroscopic Study on the Effects of Heat Treatments on Cotyledon Tissues in Yellow-Type Canola (*Brassica*) Seeds

Peiqiang Yu,*[,†,‡] Katerina Theodoridou,[‡] Hangshu Xin,[‡] Pei-Yu Huang,[§] Yao-Chang Lee,[§] and Bayden R. Wood[||]

JOURNAL OF AGRICULTURAL AND FOOD CHEMISTRY
Article
pubs.acs.org/JA

Magnitude Differences in Bioactive Compounds, Chemical Functional Groups, Fatty Acid Profiles, Nutrient Degradation and Digestion, Molecular Structure, and Metabolic Characteristics of Protein in Newly Developed Yellow-Seeded and Black-Seeded Canola Lines

Katerina Theodoridou,[†,⊥] Xuewei Zhang,[†,§] Sally Vail,[#] and Peiqiang Yu*[,†,§]

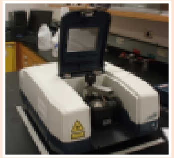
RESEARCH Open Access

CrossMark

Using vibrational infrared biomolecular spectroscopy to detect heat-induced changes of molecular structure in relation to nutrient availability of prairie whole oat grains on a molecular basis

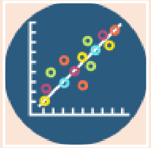
M. D. Mostafizar Rahman[1,2], Katerina Theodoridou[1,3] and Peiqiang Yu[1*]

Objectives of the study



Assess the potential of FTIR to reveal the nutrient molecular profile of four insect species (allowed to include in animal feed)

Explore the chemical profile and digestibility of those insect species



Study the relationship between the molecular structure and the nutritive value of those insect species

QUEEN'S UNIVERSITY BELFAST | IGFS THE INSTITUTE FOR GLOBAL FOOD SECURITY

Experimental Design

 FC — Field Crickets

 BC — Banded Crickets

 MW — Mealworm

 BSF — Black Soldier Fly Larvae

3 batches of 4 insect species live

↓

sieved-remove frass and litter

↓

fasted for 12h at room temperature

↓

Washed and freeze-dried

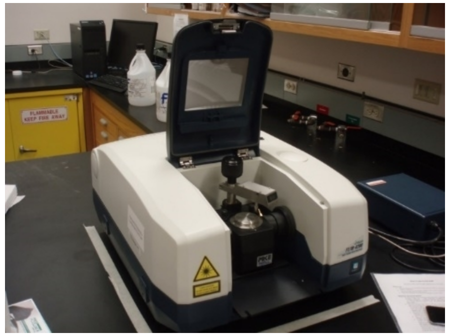
↓

Milled and sieved <1mm

↓

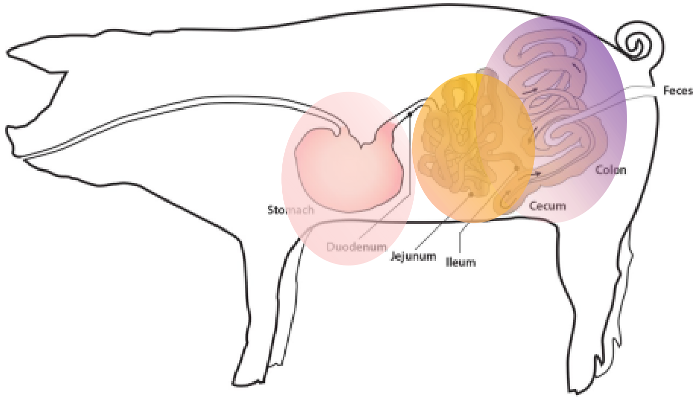
Stored -20^{0}C

- Chemical profile
- *In vitro* DM Digestibility
- Nutrient molecular structure



QUEEN'S UNIVERSITY BELFAST | IGFS THE INSTITUTE FOR GLOBAL FOOD SECURITY

In vitro DM digestibilty



Insect Samples

- **Stomach**: ••**Pepsin:** pH 2, 2h, 39°C
- **Small intestine**: ••**Pancreatin:** pH 6.8, 4h, **39°C**
- **Large intestine**: ••**Viscozyme:** pH 4.8, 18h, **39°C**

Adapted and modified from Boisen and Fernandez 1997

QUEEN'S UNIVERSITY BELFAST | IGFS THE INSTITUTE FOR GLOBAL FOOD SECURITY

Statistical Analysis

- One-way ANOVA was performed for the chemical composition molecular structure and digestibility using the statistical package SPSS 25.
- Significance was declared at $P<0.10$

- Correlation between the molecular structure profile and wet chemistry analysis in the insect samples were analyzed using Pearson's correlations
- The normality test of the residual data was conducted using the Shapiro-Wilk method

Chemical profile

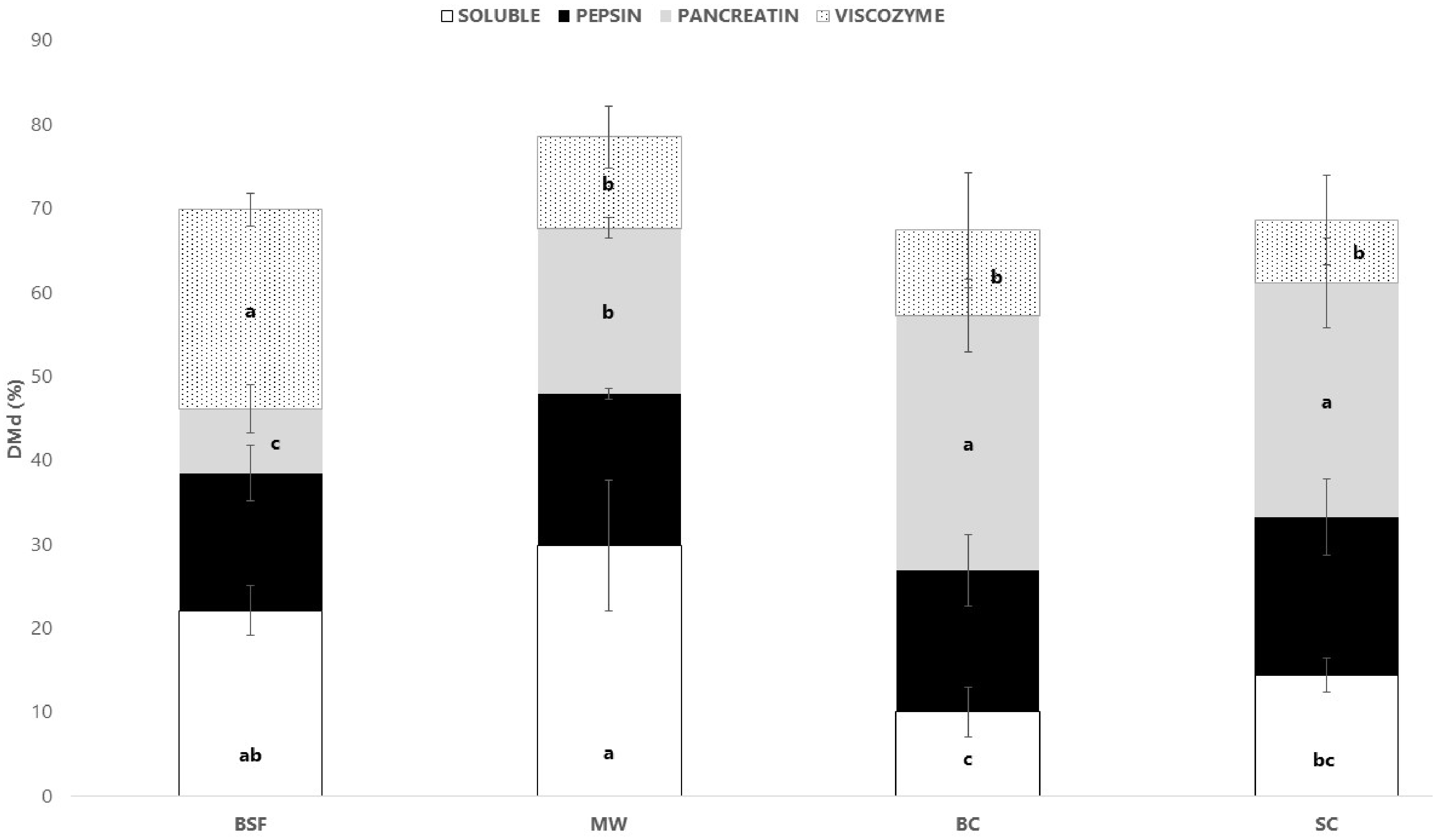
No significant differences for CP, chitin, NDF/ADF, between cricket species. MW has a higher CP content compared to the rest species (P < 0.0001).

g/100g DM	Insect species								SEM	P
	BSF		MW		FC		BC			
DM (g/100g)	35.2	a	38.5	a	28.6	b	26.9	b	1.59	**
EE	31.3	ab	35.0	a	21.8	c	25.3	bc	1.82	*
CP (Nx6.25)	38.9	c	50.1	b	66.8	a	62.0	a	3.38	***
ASH	13.0	a	4.69	c	8.58	b	7.06	b	1.050	**
NDF	13.2	b	11.7	b	35.2	a	32.3	a	3.31	***
ADF	9.33	bc	8.36	c	15.6	a	12.1	ab	0.954	**
ADICP	4.06	b	4.38	b	9.81	a	5.75	ab	0.338	**
ADL (sa)	1.17		1.44		1.50		1.16		0.104	NS
Chitin	5.83	b	4.86	b	7.70	a	7.41	a	0.506	*

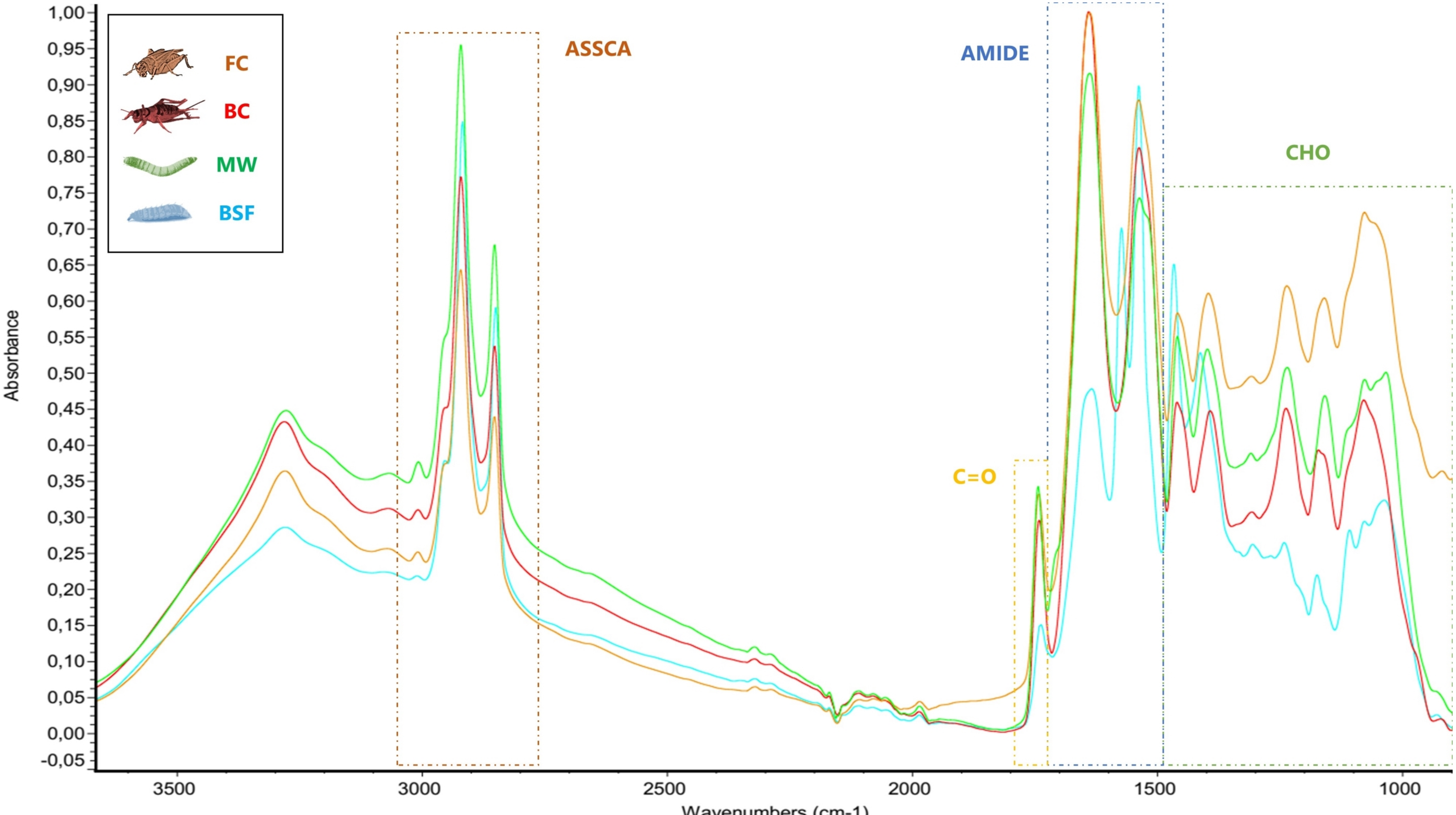
* P < 0.05
** P < 0.001
*** P < 0.0001

In vitro DM digestibilty

MW showed the highest ($P<0.05$) DMd compared to other species. Pancreatin DMd was higher in both cricket species compared to MW or BSF.

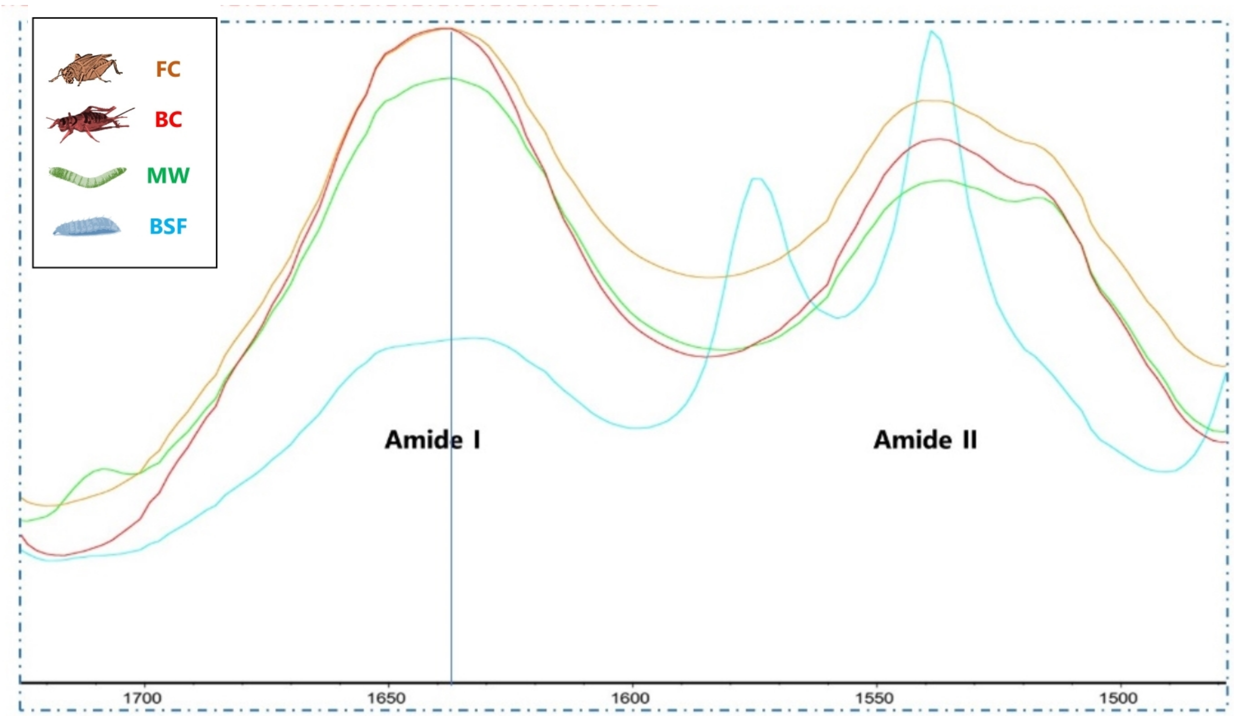


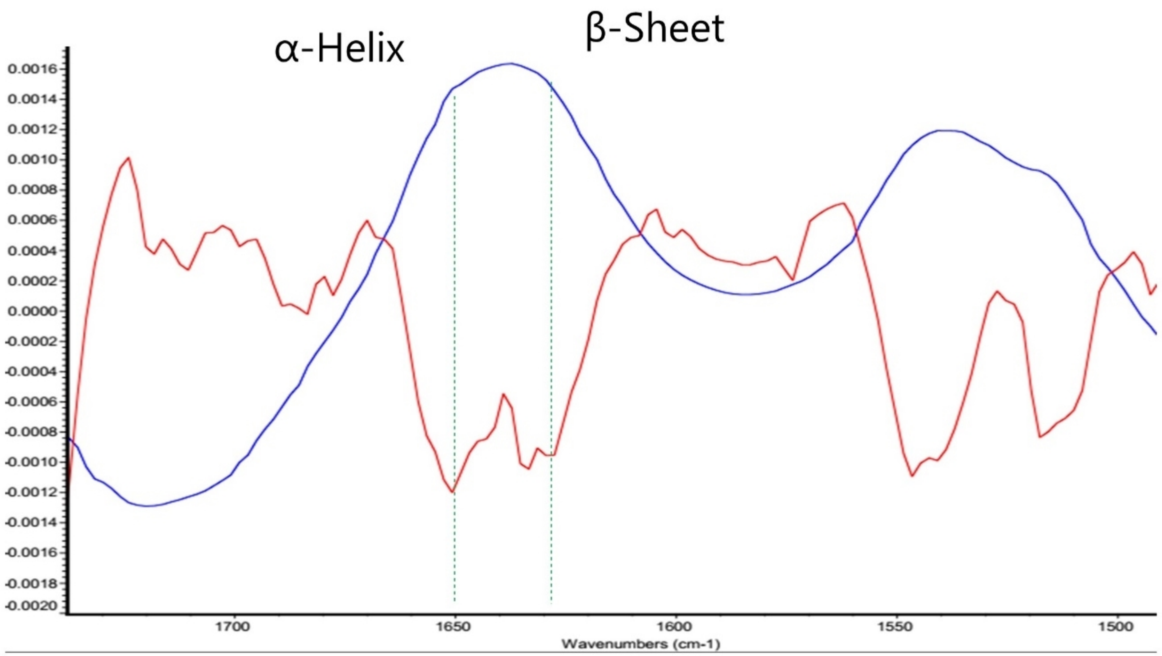
Mid-infrared spectra (3600-900 cm^{-1})



Primary protein structure:
Amide I and Amide II

Secondary protein structure:
α-helix and β-sheet





Amide I band was lower ($P < 0.0001$) for BSF compared to the other species. Amide region of BSF presented an extra peak.

Pattern of α-helix and β-sheet: FC>BC> MW>BSF ($P < 0.0001$)

Correlations between spectra parameters and nutrition profiles

	AmideA	AM I	AM II	AM III	AmI/AmII	aH	bS	aH/bS
CP	**0.96**	**0.95**	**-0.62**	**0.65**	**0.82**	**0.96**	**0.95**	0.51
NDF	**0.79**	**0.72**	-0.28	0.29	0.52	**0.73**	**0.72**	0.40
ADF	0.70	0.65	-0.16	0.30	0.41	**0.68**	**0.66**	0.51
CHITIN	0.46	0.42	-0.10	0.12	0.26	0.46	0.42	**0.58**
PancDMd	**0.88**	**0.91**	**-0.69**	**0.68**	**0.85**	**0.91**	**0.90**	0.46
ViscDMd	**-0.71**	**-0.76**	**0.75**	**-0.67**	**-0.80**	**-0.75**	**-0.74**	-0.26

Strong positive correlation ($r>0.95$; $P<0.001$) was found between the height of the AmI, αH, βS , AmideA with the CP content.
No correlation ($P>0.05$) was found with the chitin content.
PancDMd positively correlated ($P<0.01$) with CP ($r=0.91$) and NDF ($r=0.80$), which was reflected in the significant correlations found between these chemical constituents and spectral features, especially AmI, αH, βS.

*Take home message

- ✓ Application of FTIR demonstrated the potential to identify nutrient molecular structural differences between insect species rapidly.
- ✓ Correlations between chemical constituents and spectral features, revealing the possibility of using FTIR for the proximal composition profiling of insect powders.
- ✓ FTIR is a rapid technique to predict the chemical composition and quality of insect powders intended to be included in animal feed formulations, as well as to prevent fraud and adulterations.
- ✓ Further analysis focusing on the effect of the insect's life stage, species, feed substrate, and rearing conditions would maximize the possibilities of ATR-FITR applicability.

QUEEN'S UNIVERSITY BELFAST | IGFS THE INSTITUTE FOR GLOBAL FOOD SECURITY

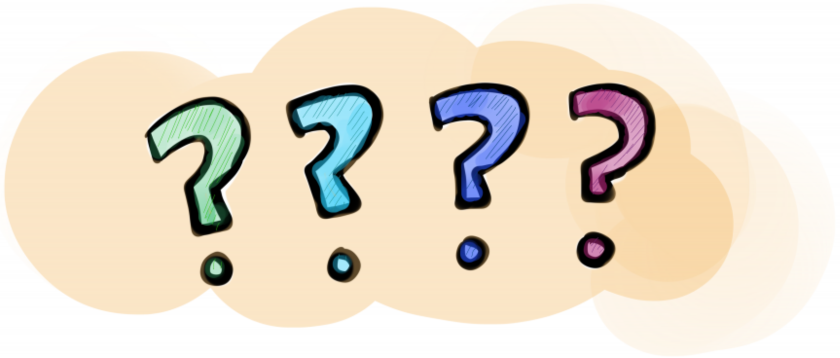
Future work: 4-year project starts October 2023

'Insects for sustainable animal feed: Livestock farming in a climate change challenged world'

FoodBio Systems DTP

UKRI Biotechnology and Biological Sciences Research Council

Thank you for your attention



Funded by Agri-Food Quest Competence Centre programme (INI Agri-Food QUEST-11-12-17-004–AFQCC)