Institution: University of Glasgow (UofG)		
Unit of Assessment: UoA12 General Engineering		
Title of case study: Sausage casing manufacturer's processes and practice revolutionised by collagen research		
Period when the underpinning research was undertaken: 2008–2010		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s):	**Role(s) (e.g. job title):**	**Period(s) employed by submitting HEI:**
Prof Huabing Yin Dr Shuying Cheng	Professor of Biomedical Engineering KTP associate	2005–present 2010–2012
Period when the claimed impact occurred: 2013–present		
Is this case study continued from a case study submitted in 2014? No		

1. Summary of the impact

Collagen, a protein, is the main component of many sausage casings; however, the variability in collagen quality can cause casings to burst, which is costly and wasteful. UofG research enabled multinational casings manufacturer Devro to identify the optimal properties of quality sausage casings and to adapt their processing methods to achieve higher-quality casings. The UofG research was also instrumental in Devro's decision to establish the company's first Research and Development Department. The research-based improvements in processing of collagen casings resulting from UofG research have facilitated entry to new markets, increased product yield while reducing wastage, and increased annual sales [text removed for publication].

2. Underpinning research

UofG research addressed collagen characterisation issues by developing ways of testing the physical, mechanical and chemical properties of collagen using atomic force microscopy (AFM) and Raman-microspectroscopic techniques. These methods were shared in a knowledge transfer partnership (KTP) and were used to create material databases outlining how the mechanical properties of collagen change during the industrial process of sausage case making. The databases were then exploited to develop improved procedures for Devro to achieve more uniform collagen consistency in the manufacturing process.

Prof Yin's research at UofG develops methods to study the physical, mechanical and chemical properties of cells and proteins including collagen [3.1–3.3]. This novel research made a significant contribution to the field of bioengineering, characterising for the first time the consistency and mechanical properties of collagen without the addition of chemical labels or damage to the collagen.

An understanding of the mechanical and physical properties of collagen was developed with the use of atomic force microscopy (AFM) to quantify those properties of cells and proteins including collagen [3.1]. AFM determines elastic and other physical properties through characterisation of the surface indentation of materials. In this research, Prof Yin systematically evaluated the operational factors of AFM, including the indentation depth and speed, to determine the best approach to systematically determine the elasticity of cells and matrices rich in collagen. This evaluation involved characterising a range of cells with varying collagen compositions and

demonstrated that it is possible to accurately determine the physical properties of materials with varying collagen composition using the AFM technique.

UofG research on Raman-microspectroscopy led to the development of further techniques that can characterise chemical changes in collagen [3.2, 3.3]. The primary aim of the research using this technique was to understand why collagen found in bones is different to that found in skin. The research led by Prof Yin used microfluidic chip devices to determine how factors such as pH and ion concentration, in fluid surrounding cells undergoing hardening through mineralisation, influences how the cells change [3.2]. The microfluidic chip allowed for a high-throughput approach, and a similarly robust, systematic characterisation of materials to that used in her AFM studies.

The research programme integrated surface enhanced Raman scattering (SERS) techniques with a high-throughput microfluidic approach to chemically characterise cells with a high degree of spatial and temporal resolution [3.3]. The rapidly changing chemical dynamics of the cells were measured using a unique combination of Raman and microfluidic approaches designed by UofG. The high-resolution, high-throughput nature of the work demonstrated the potential of this combination to generate reliable databases of results that could be used in industry.

In 2010, Devro entered a Knowledge Transfer Partnership with UofG to apply Prof Yin's AFM and Raman-microspectroscopic techniques to develop a material database for Devro, characterising the different consistencies of collagen. These analysis techniques have been used by Devro to determine which specific manufacturing processes alter the chemical composition of collagen, making it harder or softer and thus of varying suitability for their sausage casings.

3. References to the research

3.1. McPhee, G., M. J. Dalby, M. Riehle and H. B. Yin (2010). "Can common adhesion molecules and microtopography affect cellular elasticity? A combined atomic force microscopy and optical study." Medical & Biological Engineering & Computing 48(10): 1043-1053. DOI: 10.1007/s11517-010-0657-3 *

3.2. Yin, H. B., B. Z. Ji, P. S. Dobson, K. Mosbahi, A. Glidle, N. Gadegaard, A. Freer, J. M. Cooper and M. Cusack (2009). "Screening of Biomineralization Using Microfluidics." Analytical Chemistry 81(1): 473-478. DOI: 10.1021/ac801980b *

3.3. Zhang, X. L., H. B. Yin, J. M. Cooper and S. J. Haswell (2008). "Characterization of cellular chemical dynamics using combined microfluidic and Raman techniques." Analytical and Bioanalytical Chemistry 390(3): 833-840. DOI: 10.1007/s00216-007-1564-9

*=best indicators of quality

4. Details of the impact

[5.1] Devro is a leading international supplier of sausage casings, [text removed for publication].

Fundamental research from UofG has had a transformational effect on Devro, including impact on company practice and culture, environmental impacts and economic impacts.

Reduced wastage and environmental impacts at Devro

As a result of the KTP with UofG, Devro deployed a material database in 2013 to define the most suitable collagen for each product, thus avoiding the processing of inferior collagen, with associated reductions in cost [5.2, page 9]. In-house research led by Dr Cheng (the former KTP

associate) has enabled new data on different collagen sources to be acquired and monitored [5.3, page 7, section 8]. This allows Devro to tailor their products to their customers' needs. [text removed for publication] [5.1].]

Impacts on practice and culture

Prior to the sharing of techniques developed at UofG, Devro did not have a Research and Development (R&D) department. Acknowledging the value of the KTP research, Devro opened its first R&D department, appointing Cheng as Research Technologist. With this Department, the techniques and research developed at UofG are continually in use and have been important in the company's progression in new markets in China [5.4].

"As a direct result of the KTP, Devro created a Research and Development department for the first time in 2012. I was the first employee of this new department after the completion of the KTP, in the newly established role of Research Technologist. Using the AFM and Raman techniques developed at the University of Glasgow, along with other techniques, a new understanding of how the chemical, physical and mechanical collagen properties varied during different stages of the manufacturing process was achieved. This helped Devro to improve and develop our global manufacturing processes (this work is ongoing in our global research)." – Shuying Cheng, now Group Research Scientist, Devro [5.4].

The KTP was Devro's first R&D-based academic partnership. Subsequently, Devro have changed their practice and are more confident in initiating and pursuing academic partnerships that will continue to support the Research Department, bringing further changes in practice and economic impacts to Devro [5.3 page 4, bullet 1, 5.4].

"Further to impacting the company structure, manufacturing processes and manufacturing sites, this KTP with the University of Glasgow has also enhanced a collaborative culture at Devro and inspired more academic partnerships. We have successfully sought further partnerships with the University of Glasgow, collaborating with mathematics, chemistry and engineering colleagues on projects that will continue to support the R&D department and bring considerable benefits to Devro in the future" [5.4].

Devro have also reported a transformation in their collaborative working practices since the KTP — *"Participation in the KTP has transformed the way Devro collaborates around the group and acted as a catalyst to effective partnerships with industrial and academic partners;* [text removed for publication] [5.1].

Economic impacts in Devro

Although it is difficult to quantify the portion of Devro's profits since the KTP based on UofG research, the company have explained that developments underpinned by the research are linked to an increased product yield [text removed for publication] [5.1].

5. Sources to corroborate the impact

5.1. Testimonial: Group Head of Research, Devro Plc.
5.2. "The Case for Collagen". Case study compiled by Devro on impacts of their increased understanding as a result of the KTP on their business.
5.3. UofG/Devro plc Knowledge Transfer Partnership final report.
5.4. Testimonial: former KTP associate and current Group Research Scientist, Devro Plc.