Institution: University of Nottingham

Unit of Assessment: 6; Agriculture, Veterinary and Food Science

Title of case study: Optimising the production and processing of animal feeds

1. Summary of the impact

The University of Nottingham (UoN) has transferred an understanding of how starchy foods are modified by processing, attained through working with human foods, to the animal feed industry. The knowledge developed at UoN and further advanced by co-operative programmes with industrial partners, has enabled animal feed manufacturers to reformulate and modify their production procedures to optimise manufacturing operations, increase profitability and the nutritional quality of the feeds.

2. Underpinning research

Key researchers

Professor Sandra Hill, 1999-Present
Professor Julian Wiseman 1975- Present
Professor John Mitchell 1974-2008

Much of the feed materials used in modern animal feed production undergo some type of thermo-mechanical processing. In addition to the sanitisation of product, this treatment may cause the feed to become more palatable and improve the dietary energy value following digestion. To understand the interactions between processing and feed quality, it is essential that changes to the native raw dietary materials are understood in terms of how the physical and chemical structures alter during processing. By weight, the most important components of feed raw materials are carbohydrates and, of these, the starches dominate in terms of energy value and the materials that provide most of the structuring of the feed.

There is a long history of materials science at UoN that underpins food processing. Investigations, which started in the 1980s, have continued to develop the concept of starch hydration and the changes within native starch to render it amorphous and create a stable glass or a more mobile rubbery material. Many projects elucidating structures were funded through LINK Schemes and collaborative projects between the food science group at UoN and industry **[a & b]**. Predictive models for starch recrystallization from the rubber (retrogradation), resistant starch formation and physical aging (densification of starch stored in the rubbery state) in starch materials, that were generated by Professor Hill and colleagues, reinforced much of the thinking for the manufacture of snack foods, breakfast cereals and many extruded products **[a-d]** for human consumption. Groups of companies were introduced to the concept of “starch conversion” through a range of grants and dissemination events. For the state of starch to be described, multiple factors such as shear, chemical degradation, water content and temperature needed to be considered **[c & d]**. A feature of the work to investigate the behaviour of the starches was the development of a new battery of tests by UoN. This allowed studies to be applicable to foods and film for packages **[1, 3 & 4]**. In addition understanding of the changes occurring to proteins during processing were developed and methods found to assess changes in their functionality **[2 & 5]**.

Alongside this work on the properties of starch, protocols that demonstrated the energy utilisation of feeds were established by Professor Wiseman at UoN using both chick and pig models **[6]**. A series of projects **[e & f]** looked at the biomaterials (the cereal sources and the processing of the materials) and related these to the animals’ performance. It was shown that some of the processes that manufacturers were undertaking to produce feeds did not have the desired changes upon macromolecular ordering they had assumed were occurring. The research also demonstrated that different raw materials could be used in feeds, but only if the manufacturing processes were altered to allow for the change in characteristics of the ingredients **[6]**.

3. References to the research

UoN work generated more than 80 papers in this area between 1992 and 2012, and over 50% of this work was encapsulated by the concepts of understanding structures of foods and feeds and how these may be altered during processing. Evidence of the international quality of the research

is indicated by the publication of the papers in international, peer-reviewed high impact journals.

1. MITCHELL, J. R. and HILL, S. E. (1995). The use and control of chemical reactions to enhance the functionality of macromolecules in heat-processed foods Trends in Food Science and Technology. VOL 6(NUMBER 7), 219-224. DOI: 10.1016/S0924-2244(00)89081-0
2. MOHAMMED, Z. H., HILL, S. E. and MITCHELL, J. R. (2000). Covalent Crosslinking in Heated Protein Systems- Journal of Food Science. VOL 65(PART 2), 221-226. DOI: 10.1111/j.1365-2621.2000.tb15983.x
3. BECKER, A., HILL, S. E. and MITCHELL, J. R. (2001). Relevance of Amylose-Lipid Complexes to the Behaviour of Thermally Processed Starches Starke (Starch). VOL 53(PART 3/4), 121-130. DOI: 10.1002/1521-379X(200104)53:3/4<121::AID-STAR121>3.0.CO;2-Q
4. SEVENOU, O., HILL, S.E., FARHAT, I.A. and MITCHELL, J.R. (2002). Organisation of the external region of the starch granule as determined by infrared spectroscopy International Journal of Biological Macromolecules. 31(1-3), 79-85. DOI: 10.1016/S0141-8130(02)00067-3
5. BENGOECHEA, C., ARRACHID, A., GUERRERO, A., HILL, S. E. and MITCHELL, J.R. (2007). Relationship between the glass transition temperature and the melt flow behaviour for gluten, casein and soya Journal of Cereal Science. 45(3), 275-284. DOI: 10.1016/j.jcs.2006.08.011
6. WHITE, G.A., DOUCET, F.J., HILL, S.E. and WISEMAN, J. (2008). Physicochemical properties and nutritional quality of raw cereals for newly weaned piglets Animal 2(6), 867-878. DOI: 10.1017/S1751731108001936

Underpinning research programmes carried out in co-operation with sponsoring companies:

a. 1988-1996: Amorphous crystalline transitions in foods (Actif 1 and 2). BBSRC funding. £0.5 + 1.3 million. UON
b. 1991-1994: Hydration of hydrophilic materials in foods and drug delivery applications (Hydra). BBSRC and DEFRA funding. £1.1 million. UON
c. 2001-2004: Stability of foods and food ingredients in the glassy state (Drystore). BBSRC and DEFRA funding. £400,000. UON
d. 2012-2014: Development of physically modified hydrocolloids and starches for enhanced salt perception (Mixlink). BBSRC and DEFRA funding. £360,000. UON
e. 2003-2004: Towards the sustainable management of the weaner pig through nutrition (Nutwean). DEFRA and HGCA funding £169,872
f. 2006-2009: Reduction in diffuse pollution of poultry operations through selection of wheat cultivars of high and constant quality (Chicklink). DEFRA, DANISCO and HGCA funding £642,215

4. Details of the impact

A significant proportion of cereal production and other carbohydrate sources are used as animal and pet feed materials. The petfood market in the UK for cats and dogs alone is £2.4BN, and the European market is worth €13.5BN per annum. The animal feed industry utilises 50% of UK cereal production and is a major consumer of imported maize each year. A scientific framework that allows materials and process conditions to be matched for optimal manufacture is a useful contribution to minimising wastage and improving product quality.

UoN research has had a major influence on animal feed producers, many of which have initiated further research projects with Professor Hill to elicit a better understanding of their processes and how these can be modified to achieve optimum levels. The work was disseminated to the industries, where it is most relevant, through a series of conferences and invited talks to companies about this subject (**Source 5**). The degree of penetration of the topic has been such that the concept of starch conversion, coined by UoN researchers **[1]**, is now used within the industry to illustrate the complex series of changes that occur to starch as it is broken down. Modelling the changes to the starches as they were hydrated, heated and sheared has provided companies with new options for their processing lines. This allows for optimisation of the current processes or the use of different technologies so that the required product quality, in terms of energy yield and palatability, can be achieved. The impact of our research is significant in three

major areas. These are:

A) Implementation of revised processing strategies for feeds

B) Upgrading of analytical techniques to establish nutrient benefits of animal feeds

C) Extension of possible resources for animal feeds through novel processing

An example of **A**) that shows that a company altering their processing regime to optimise nutritive performance comes from a quote from the Head of Monogastric Development at BOCMPauls, a major UK animal feed manufacturer. "*Data generated showed that with correct thermo mechanical processing, the rate of starch degradation in-vitro, as measured by glucose release, is significantly improved. This information has been incorporated in to our piglet starter diet formulations as part of our new product development programme. The new diets have demonstrated enhanced performance whilst controlling nutritional scours which can develop as a consequence of undigested starch passing into the hind gut*." **(Source 1).** Further quotes from the company also indicate that they are utilising the battery of analytical methods developed by UoN (**B**). These are now robust enough and the understanding of the relationship between nutrition and processing sufficiently well-established and measurable, to enable environmental issues to be dealt with in the holistic mix. "*The extrusion process is an energy hungry process, however the input of adequate specific mechanical energy is critical in getting the benefits of the thermo mechanical processing*. *The data generated* (from research programme e and f) *has helped with developing methodologies for quantifying the relationship between energy in and benefits out for the extrusion process. By doing this we are now able to optimise production conditions and therefore minimise units of electrical energy consumed per tonne of product*." This company has put a monetary value for this understanding in terms of energy saving "*Under "normal use" the extruder would be consuming around £10 worth of electricity per tonne of throughput. We saw that with careful optimisation we could save in the order of 5% of this cost with no negative effect on physical quality or starch gelatinisation."* (**Source 1**).

An example of utilisation of understanding of processing and how this can be manipulated to use materials not previously commercially viable as feeds (**C**) is being exploited by the livestock feed company Dodson and Horrell**.** They are using understanding of processing generated by UoN to study a material considered as a co-product from the brewing industry (brewers' grain) as an animal feed stock. In a statement on the UoN work on brewers grains, the Director and Consultant Nutritionist of Dodson and Horrell commented that the work was "*promising in terms of reducing final product cost, utilisation of a feed ingredient that previously had only been considered as a ruminant feed as a replacement for a proportion of cereal content and as a protein source."* **(Source 2).**

UoN facilities, expertise and willingness to work with industrial partners have also allowed a route for serendipitous exploitation of ideas. An example of one such case is the use of the pilot scale equipment within the School of Biosciences and Professor Hill's research expertise on extruded starches, to investigate the possibility of extruding silage to create a novel feed for horses, which is now being manufactured by Dodson and Horrell on a commercial scale. "*Studies in the Food science department, utilising their extruder and understanding of extrusion technologies has enabled Dodson & Horrell to develop a unique extruded whole-crop maize product for horses. This product satisfies a number of criteria, in that the yield per hectare is high relative to other feed materials, it is produced local to the D&H mill (environmental criteria), as a high energy feed for horses replaces a human food material (oats, human food criteria) and does not occupy farm ground that would be used for human food as the maize forms an ideal break-crop within the farm cereal production cycle*. *Dodson & Horrell has launched this feed ingredient in its performance and competition feeds and has maintained horses feed sales in an otherwise falling market place*" **(Source 2)**.

Those working within the animal feed industry need robust predictors of animal performance and the use of the battery of tests UoN developed through the LINK programmes have helped establish a range of *in vitro* tests that indicate *in vivo* performance. This has led to publications by ABVista (an international supplier of animal feed ingredients) and their sponsoring of the implementation of these ideas. The work has led to a new classification of maize samples so that the company can differentiate itself from other companies by targeting its animal feed enzymes to the maize variants.

The company uses an online corn quality assessment (**Source 3**) as part of their sales tools and part of the validation of this has been carried out with the University of Nottingham. A quote from a research manager at ABVista states (**Source 4**), "*Optimising the methodology has allowed us to improve our experimental efficiency and reduce costs. For example in this last budget year we have saved significant amounts of money by not commissioning digestibility studies which we now know are inappropriate. For example, an animal trial may carry a cost of £25,000".* "*Such information is essential for us to maintain our position in a highly competitive environment and to enable us to move forward and expand our sales in all markets. It is impossible to put an exact value on such research, but it would be impossible for us to stay competitive without it."*

The combined knowledge of material changes during processing and animal nutritional quality makes UoN an obvious first port of call for companies looking to establish improved and novel processing for animal feeds. For example Professor Hill took part in and organised a number of workshops (five between 2008 and 2011) that helped shape the strategy and basis for the Mars Petcare business **(Source 5).** A further example of the impact of the understanding of nutrition and processing understanding is demonstrated by GA Petfoods. This company are developing a novel process and between 2010 and 2013 they invested £18 million for the innovative manufacture of dry pet foods. To aid in the success of this venture a knowledge partnership was established with Professors Wiseman and Hill as, "*the group in Biosciences at Nottingham University are leaders in this field and have a proven record of industrial co-operation." "Their knowledge will help assure that the investment is beneficial and will allow greater penetration of the UK and European pet food market*" **(Source 6).**

5. Sources to corroborate the impact

1. Head of Monogastric Development, BOCM Pauls. *Provides corroboration that UoN research led to process changes that reduced costs for the company and changed formulation of piglet diets.* 2012.
2. Director and Consultant Nutritionist Dodson and Hurrell. *Provides confirmation that technology exchange with UoN led to development of a unique product for horses.*2013.
3. Corn assessment http://www.abvista.com/services/corn-quality-service. *An online tool developed in collaboration with UoN to provide a service to the industry.* 2012.
4. Research Manager ABVista. *Confirms that use of UoN research has optimised company methodologies resulting in cost savings.* 2013.
5. IP Specialist – Corporate Legal, Mars Petcare. *Corroborates the involvement of Prof Sandra Hill in workshops that shaped the Mars strategy for pet food processing.* 2013.
6. Managing Director, GA Petfoods. *Confirms that a partnership with UoN underpins strategies to improve the market share of the company in the petfood sector.* 2013.