Institution: Aberystwyth and Bangor Universities - Biosciences, Environment and Agriculture Alliance (BEAA)

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

Title of case study: Novel applications for fractionation of plant biomass in the food ingredients industry

1. Summary of the impact

Yield of valuable biomass fibre components and their utilization in the food industry has been maximised by novel, cost-effective and environment-friendly plant fibre extraction methods developed by BEAA. Specifically, application of these methods enabled patenting and commercialisation of oat fibre extraction by the Swedish company BioVelop, directly resulting in commercial impact through international sales of five nutritional products released since 2010. The most successful of these is produced at a quantity of 180,000 kg, or € 600,000 per year. In May 2013, world-leading food-additive giant Tate & Lyle took over BioVelop, securing the success and lasting commercial impact of the BEAA technology.

2. Underpinning research

Researchers in BEAA undertook the first systematic studies in the fractionation of lignocellulosic and starch-containing biomass such as cereal residues and abaca [3.1, 3.2, 3.3]. The initial focus of this work was the characterisation and fractional extraction of plant lignins and polysaccharides, in order to study the components in detail and isolate those relevant for industrial applications. Prior to this research, this biomass was insufficiently characterised to enable full exploitation of the potential benefits as an industrial feedstock and/or human and animal feed. In particular BEAA researchers mapped out and underpinned the need to combine specific dry and wet techniques in preparing biomass for wet-fractionation, leading to isolation of various cell wall, extractive and matrix components which was achieved in subsequent research for wheat [3.4] and demonstrated the generality of these methods amongst crops, including for abaca fibre [3.5].

The research was led by BEAA in the BioComposites Centre by Dr Mark Lawther (1986-1996) with research scientists Dr R.C. Sun (1996–2007) and Dr J.M. Fang (1999–2005) and Director Dr A.J. Bolton (1989–1999). Prof W.B. Banks (1977-1997) in the School of Agricultural and Forest Sciences co-initiated the research programme with Lawther in the period up to 1997. In the period 1993-2003, BEAA researchers generated over 80 papers in this field of work.

The separation, isolation and characterisation techniques developed, which span enzymatic, chemical and physical methods, were combined in novel ways that led to maximisation of yields of selected components of target biomass [3.6]. Through this work, the BEAA research demonstrated for the first time the potential of biomass such as wheat straw as a raw material for new markets, through replacement of non-UK or environmentally-damaging materials with chemical fractions derived from agricultural biomass. Because of this innovative approach, BEAA methodology has made valuable plant products, previously inaccessible due to their high cost or complex and environmentally unfriendly means of extraction, accessible for food, feed and other industry and an attractive and affordable alternative for synthetic or semi-synthetic alternatives. The research was supported by a number of grants from MAFF (subsequently DEFRA) [3.7, 3.8] and also led to patents which were central to the development of a number of products [3.9, 3.10].

The research was utilised 2001-2009 by Prof. Mark Lawther with the company BioVelop A/S (which became BioVelop International AB in 2005), as the underpinning basis to further develop (and up-scale) sequential enzymatic and physical processes for the wet-fractionation of cereal (wheat, oat, barley and rye) brans into fibre (lignocellulose), soluble fibre (hemicellulose), protein and oil, starch dextrin and oligosaccharide (low molecular weight hemicellulosic) fractions. These are effectively new ingredients which have substantial value in the food and personal care sectors and were commercially released from 2010.

In addition to commercial impact for Biovelop, the BEAA research was also instrumental in demonstrating the potential of plant biomass to replace fossil fuel derived products and played important contributions in the funding of new commercially focused projects such as the £10M investment by the Welsh European Funding Office in the BEACON Biorefining Centre of Excellence involving BEAA scientists [3.11].

3. References to the research

3.1. Lawther, J.M., Sun, R., & Banks, W. B. (1995). Extraction, fractionation, and characterization of structural polysaccharides from wheat straw. *Journal of Agricultural and Food Chemistry 43*, 667-675. DOI: 10.1021/jf00051a021. 156 citations.

3.2. Lawther, J.M., Sun, R.-C. & Banks, W.B. (1996). Fractional characterisation of wheat straw lignin components by alkaline nitrobenzene oxidation and FT-IR spectroscopy. *Journal of Agricultural and Food Chemistry* 44, 1241-1247. DOI: http://dx.doi.org/10.1021/jf9502764. 39 citations.

3.3. Sun, R.-C., Lawther, J.M. & Banks, W.B. (1996). Fractional and structural characterisation of wheat straw hemicelluloses. *Carbohydrate Polymers* 29, 325-331. DOI: 10.1016/S0144-8617(96)00018-5. 152 citations.

3.4. Sun, R.-C., Lawther, J.M. & Banks, W.B. (1998a). Isolation and characterization of hemicellulose B and cellulose from pressure refined wheat straw. *Industrial Crops and Products* 7, 121-128. DOI: 10.1016/S0926-6690(97)00040-X. 34 citations.

3.5. Sun, R.-C., Fang, J.M., Goodwin, A., Lawther, J.M. & Bolton, A.J. (1998b). Fractionation and characterisation of polysaccharides from abaca fibre. *Carbohydrate Polymers* 37, 351-359. DOI: 10.1016/S0144-8617(98)00046-0. 40 citations.

3.6. Sun, R.-C., Fang, J.M., Goodwin, A., Lawther, J.M. & Bolton, A.J. (1999). Fractionation and characterisation of ball-milled and enzyme lignins from abaca fibre. Journal of the Science of Food and Agriculture 79, 1091-1098. DOI: 10.1002/(SICI)1097-0010(199906)79:8<1091::AID-JSFA331>3.0.CO;2-A. 28 citations.

3.7. *Crops for Industrial Use: Thermo-mechanical pulping of plant fibre (STRAW FRACTIONATION*). MAFF LINK grant LK0302. 1993-1997, £556,802 with commercial match funding.

3.8. *Sequential extraction of value-added products from wheat straw.* MAFF LINK grant LK0806 2000-2003, £894,500 with commercial match funding.

3.9. Inventors: Kvist, Sten; Carlsson, Tommie and Lawther, John Mark. “Process for the Fractionation of Cereal Brans”, 2002. Int. Publ. No. WO 02 / 067698, Eur. pat. No. 1363504.

3.10 Inventors: Kvist, Sten and Lawther, John Mark. “Soluble Dietary Fibres from Oat and Barley Grains”, 2003. SE 528 537 C2 and WOA1 0 024 270.

3.11 BEACON Biorefining Centre of Excellence. Welsh European Funding Office. 2010-2015. £10M with commercial funding.

4. Details of the impact

BEAA research by Lawther formed the basis for a series of patents on the fractionation of oats, which were central to the development of a number of BioVelop products and responsible for its large commercial success. BioVelop specializes in the development and scaling-up of cornerstone technologies relating to the chemical-free extraction of functional ingredients from cereal grains

and brans. Specifically, BioVelop produces five oat fibre derived products (PromOat™, released 2010; AvenaCare™, released 2011; PrOAtein™, released 2012; Oat insoluble fibre and Oat Maltodextrin, released 2013) as a direct impact of BEAA research [5.1].

PromOat is a betaglucan (hemicellulose) soluble fibre-rich ingredient sold as a nutraceutical for its beneficial effects on maintaining healthy cholesterol levels. It has a number of allowed health claims, including those which have been approved by the European Food Safety Authority, the Food and Drug Administration and Health Canada, for lowering cholesterol and reducing post-prandial glycaemic response. Because of these health benefits and its binding and emulsifying properties, PromOat is a very attractive additive for many food products, ranging from low fat sauces and dressings, to yoghurts, baked goods, meat products and ready meals. Thereby, BEAA research not only provides commercial benefits to BioVelop, but additional health benefits to consumers of a range of food products [5.1].

PromOat was released on the market in 2010 and by 2012 a biorefinery had been built for the commercialisation and upscaling of production for BioVelop's patented oat products. PromOat retails for at least €15 per kg and with a cost for the raw ingredients of only €0.20, provides a high commercial benefit to Biovelop. Currently, the entire production capacity of the refinery is used and produces 180 tonnes of PromOat™ per year with an annual value of €600,000 [5.2]. In recognition of the importance of this technology and its application in the food sector, PromOat was awarded Best Natural Ingredient for Functional Drinks at the Beverage Innovation awards in 2011 [5.3].

PrOAtein, a protein and oil rich ingredient, and Oat insoluble fibre, have been sold successfully and increasingly since 2012 and 2013 respectively. Oat Maltodextrin was made ready for market in July 2013 [5.2]. Avenacare™ is BioVelop's first personal care product. This hypoallergenic liquid form of oat betaglucan, was commercially released in 2011 and is incorporated into a wide variety of skin care, hair care, personal care and baby care products to deliver the well-recognized and scientifically-substantiated benefits of oats. Its soothing, revitalising and strengthening properties have made this a highly successful product selling at €20 per litre [5.4].

The commercial impact of BEAA research for the commercialisation of fractionated biomass is further reflected in the success of Biovelop on the international market. In May 2013, Tate & Lyle, one of the world's leading providers of specialty food ingredients and solutions, acquired Biovelop, to expand its production of oat betaglucan as PromOat and AvenaCare [5.5]. As a consequence of this takeover, the production capacity of PromOat is being expanded to be more than tripled during the last 12-18 months [5.2]. As the patents are worldwide and held until at least 2022, continued success of the sales of these products derived from the BEAA technology is near guaranteed.

This research also demonstrated the potential of plant biomass to replace fossil fuel derived products and provided important background for the funding of new commercially focused projects such as the £10M investment by the Welsh European Funding Office in the BEACON Biorefining Centre of Excellence involving BEAA scientists (Iain Donnison, Rob Elias, Joe Gallagher, Adam Charlton, Ana Winters) with commercial partners and investment. BEACON provides a mechanism by which academia and businesses can collaborate and so far it has assisted 45 enterprises, entered collaborative R&D projects with 14 companies and induced investment of £3.6M. The focus of BEACON is therefore on the translation of academic research to create new products and processes. For example within BEACON oat phenolics (avenanthramides) are being profiled from BEAA bred oat varieties for use as active ingredients in skin care products, and xylose is being recovered from oat hulls and converting to xylitol. The EU Climate-KIC project "ADMIT BioSuccinovate" is developing the process for conversion of xylose to xylitol. The €13M project led by David Bryant in BEAA involves the fractionation of cereal straw with the primary objective of determining sustainable and economic commercial grade bio-succinate production from next generation C6 sugars. The work has therefore gone beyond the impact with BioVelop to create a lasting legacy and a culture of industry relevant research.

5. Sources to corroborate the impact

5.1. BioVelop website with description of the products and their benefits: http://www.biovelop.com/

5.2. A formal statement by the CEO of BioVelop International AB to confirm the link between the research and BioVelop's products, and the commercial scale of the sales successes.

5.3. News item on PromOat™ winning the 2011 Beverage Innovation Awards: http://www.biovelop.com/news_press/default6fab.html?page=article&id=16

5.4. A list of magazine features on Avenacare and its benefits can be found at: http://www.avenacare.com/press-releases/

5.5. Press release on the takeover of BioVelop by Tate & Lyle: http://www.tateandlyle.presscentre.com/Press-releases/TATE-LYLE-ACQUIRES-SWEDISH-OAT-BETA-GLUCAN-BUSINESS-426.aspx

5.6. Press release on the takeover of BioVelop by Tate & Lyle: http://www.fnbnews.com/article/detnew.asp?articleid=33739&sectionid=1