Institution: Abertay University

Unit of Assessment: 6 - Agriculture, Food and Veterinary Sciences

Title of case study: Improving efficiency for alcohol producers: from raw materials to final product

Period when the underpinning research was undertaken: 2014-2020

Details of staff conducting the underpinning research from the submitting unit:

Names:	Roles (e.g. job title):	Periods employed by submitting HEI:
Graeme Walker	Professor	1987-present
Peter Maskell	Senior Lecturer	2017- 2020

Period when the claimed impact occurred: 2014-2020

Is this case study continued from a case study submitted in 2014? No

1. Summary of the impact

Abertay University research in fermentation-derived alcohol has enabled the beverage and biofuel sectors of industry to a) operate more efficiently, b) develop new products and c) define final alcohol specifications more accurately. Research findings have resulted in enhancement of industrial processes that convert carbohydrate and cellulosic substrates to bioethanol and have also led to the commercial development of novel yeast nutrient products that boost industrial fermentation efficiency. For beverage alcohol producers, yeast physiology research conducted at Abertay has led to the introduction of a new range of commercial wines produced using pre-conditioned yeast cultures. For the brewing industry, our research has revealed alarming inaccuracies of beer alcohol declarations that have resulted in our recommendations for final product analyses being adopted by brewers, professional bodies, and government agencies in the UK and internationally.

2. Underpinning research

Contextual information

Yeast fermentation-derived ethanol represents the world's premier product of biotechnology, both volumetrically and economically speaking. Its production has a major benefit to the UK and global economies, both in the beverage and biofuel industrial sectors. For example, Scotch Whisky revenues of £5.5bn/year represent 25% of all British food and drink exports. For the Scottish economy, this sector contributes more than double that of life sciences (£1.5bn) and supports more than 42,000 jobs across the UK, including 10,500 people employed directly in Scotland, many in rural communities. Fuel alcohol (bioethanol) represents a major contributor to the renewable energy portfolios of many countries (including the UK) with global production of 100 billion litres per annum.

Nature of the research

Abertay research led by Professor Walker has provided new insight for industry to optimise alcohol production from raw materials to final product. We have revealed novel pre-treatment and saccharification approaches to bioconvert diverse industrial feedstocks to ethanol, including cereals (wheat, barley, maize, and sorghum), legumes (peas and beans) and lignocellulosic residues (spent grains and bagasse) **[3.1, 3.2]**. Maximum alcohol yields can now be obtained from wheat and maize starch, together with their cellulosic coproducts, using innovative bioprocessing technologies we developed in collaboration with The Scotch Whisky Research Institute **[3.1]**.

Key to the success for alcohol producers is a full understanding of yeast physiology. Abertay

research in collaboration with international partners has provided new information regarding nutritional and stress physiology of industrial strains of the yeast *Saccharomyces cerevisiae* that leads to improved fermentation performance. Regarding yeast stress caused by factors such as high temperature, collaboration with colleagues at the University of Latvia **[3.3]** has demonstrated for the first time that thermotolerance in *S. cerevisiae* is linked to anhydrobiosis resistance. Together with colleagues at the Technical Educational Institute of Athens we showed that "stuck" wine fermentations due to yeast stress can be alleviated using a novel salt-preconditioning protocol for yeast **[3.4]**. Yeast flocculation (cellular aggregation of yeasts into macroscopic clumps) is a phenomenon that can either be desirable, as in the case of brewing yeasts, or undesirable, as in the case of distilling yeasts. We have revealed key molecular and genetic cell-cell interaction mechanisms governing yeast flocculent behaviour in industrial strains of *S. cerevisiae* **[3.5]**. Collectively, these research findings on yeast physiology by Walker and colleagues at Abertay together with international collaborators have provided new practical insight and tangible benefits for yeast-based fermentation industries.

An additional aspect of Abertay research which is pertinent to alcohol producers concerns final product specifications, notably the declared ethanol contents of beverages. For example, are the quoted percentages of alcohol (expressed as alcohol by volume, or ABV%) on packaged products accurate? Dr Peter Maskell at Abertay University led a collaboration with colleagues at Dalhousie University in Canada and Heriot-Watt University in Edinburgh to conduct in-depth gas chromatography-mass spectrometry (GC-MS) analyses of beers from numerous large-scale and small-scale breweries **[3.6]**. This research revealed alarming inaccuracies of declared alcohol concentrations, highlighting serious issues of over- or under-payment of excise duty, particularly by craft brewers.

3. References to the research

3.1 Green, DIG, Agu, RC, Bringhurst, TA, Brosnan, JM and Walker, GM (2015) Maximising alcohol yields from wheat and maize and their co-products for distilling or bioethanol production. *Journal of the Institute of Brewing* 121(3): 332-337. doi: 10.1002/jib.236

3.2 Nasidi, M, Agu, R, Deeni, Y and Walker, GM (2015) Improved production of ethanol using bagasse from different sorghum cultivars. *Biomass and Bioenergy* 72: 288-299. doi: 10.1016/j.biombioe.2014.10.016

3.3 Rapoport, A, Rusakova, A, Khroustalyova, G and Walker, GM (2014) Thermotolerance in *Saccharomyces cerevisiae* is linked to anhydrobiosis resistance. *Process Biochemistry* 49(11): 1889-1892. doi: 10.1016/j.procbio.2014.07.006

3.4 Logothetis, S, Nerantzis, ET, and Walker, GM (2014) Alleviation of stuck wine fermentations using salt-preconditioned yeast. *Journal of the Institute of Brewing* 120(3): 174-182. doi: 10.1002/jib.143

3.5 Nayyar, A, & Walker, GM, Canetta, E, Wardrop, F and Adya, AK (2017) Influence of cell surface and nanomechanical properties on the flocculation ability of industrial *Saccharomyces cerevisiae* strains. *Journal of Food Research* 6: (5). doi: 10.5539/jfr.v6n5p1

3.6 Maskell, PD, Holmes, C, Huismann, M, Reid, S, Carr, M, Jones, BJ and Maskell, DL (2018) The influence of alcohol content variation in UK packaged beers on the uncertainty of calculations using the Widmark equation. *Science & Justice* 58(4): 271-275.doi: 10.1016/j.scijus.2018.03.003

The quality of our research is evidenced by the above papers published in international peer-reviewed journals. *The Journal of the Institute of Brewing*, is the gold-standard periodical for publications in brewing and distilling scientific research. The references cited above represent research that was initiated and led by Abertay University and which involved collaborations with external industrial and academic colleagues. Yeast and fermentation alcohol research at Abertay is funded by industry (Petroleum Technology Development Fund, Lallemand Biofuels & Distilled Spirits, Tatlock & Thompson Ltd., Speyside Cooperage Ltd.), research institutes (Scotch Whisky Research Institute), educational charities (Institute of Brewing & Distilling), research councils (BBSRC) and Scottish Government agencies (Industrial Biotechnology Innovation Centre).

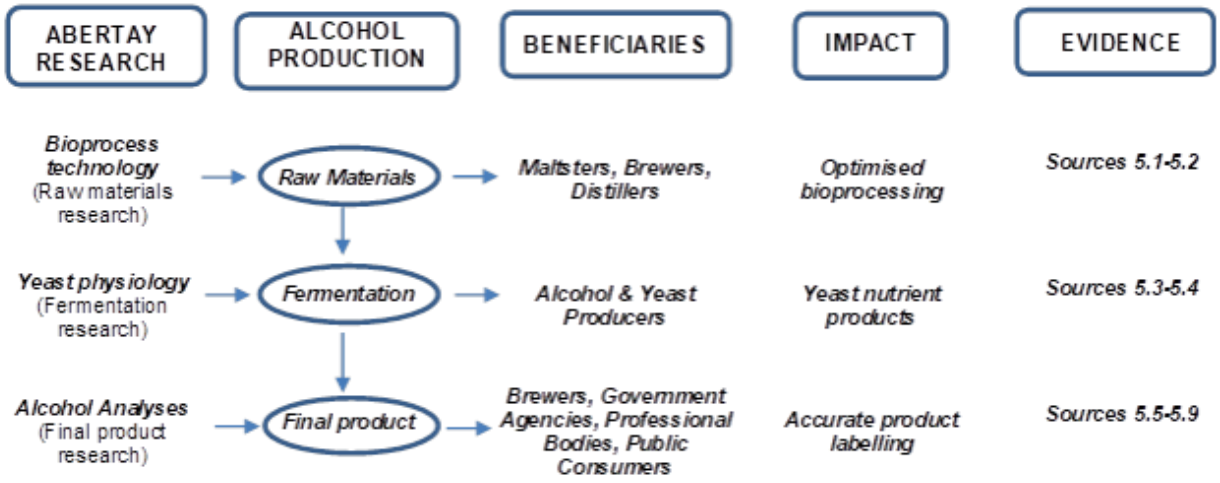
4. Details of the impact

The nature and extent of the impact

Research led by Abertay, in collaboration with academic and industrial partners, on several facets of alcohol production has resulted in improved bioprocess productivity, new product development and greater control of final product specifications. The extent of the benefits of Abertay's research is evident from the range of organisations positively impacted, including producers of yeast and fermentation nutrients, winemakers and brewers. Several companies, professional bodies and governmental agencies have verified the tangible impact of our research for the industrial alcohol sector.

Impact on beneficiaries

The impact of Abertay research on the alcohol industry is summarised in the following scheme:



- ***Bioprocess technology: Raw materials research impact***

The Scotch Whisky sector has benefitted from work published by Abertay which demonstrated how distilling companies can save energy in processing cereals such as wheat and maize for wort production and fermentation **[3.1]**. Our work additionally revealed novel approaches for whisky distillers to gain added value from cereal processing residues (spent grains). The Director of the Scotch Whisky Research Institute (Prof James Brosnan) has stated:

"Findings from this fruitful Abertay-SWRI collaboration are demonstrably beneficial to distillers with regard to maximizing alcohol yields. This research with Abertay highlighted economic benefits to bioethanol and beverage alcohol producers seeking to understand the factors influencing the processing properties of different cereals. Results of our joint research with Prof Walker and Abertay University have practical value for our member distilling companies who represent both multinational and smaller SME Scotch Whisky producers" **[5.1]**.

- ***Yeast physiology: Fermentation research impact***

Abertay research outputs in yeast science and fermentation technology has proved beneficial to the bioethanol (fuel alcohol) sector of industry. The President and Managing Director of Lallemand Biofuels & Distilled Spirits (LBDS), a major global company producing yeast and fermentation products for the ethanol industry, has stated that:

"*Key aspects of yeast and fermentation alcohol research conducted and published by Abertay University has had a very positive impact on the commercial, research and training activities of my organisation. Research has proved especially fruitful in the development of our fermentation nutrients for the alcohol industry. In particular, Prof Walker's research into the role of metal ions (Mg, Ca, Zn) in dictating yeast fermentation performance has positively impacted efficiency of alcohol production and one of our products, Servomyces (a novel zinc-based nutrient for beverage alcohol producers) emanated from seminal work by Prof Walker. We are now leaders in the sale of nutrient packages for the beverage and biofuel industry with estimated annual*

sales of $12 million due in no small measure to our association with Prof Walker's research" **[5.2]**.

Yeast research at Abertay has also benefitted the research and development activities of international biofuels and distilled spirits companies due to the acclaimed *Alcohol Schools*. Under the scientific stewardship of Prof Walker, these events are held biannually variously in Canada, Scotland, France, Austria, Thailand, and the Caribbean and are recognised as the foremost international events for training of researchers, technicians and producers of biofuels and distilled spirits. LBDS sponsor the Alcohol Schools and their President has confirmed that:

"During the period 2014-2020, over 1000 industrialists have benefitted from attending these industrial workshops by gaining valuable transferable knowledge of alcohol production including the cutting-edge yeast research from Abertay. Numerous global producers who have attended The Alcohol School have subsequently been able to effectively troubleshoot fermentation problems and optimise their plant performances. Based on material presented at The Alcohol Schools over the past 5 years, in 2017 Prof Walker edited the 6th edition of 'The Alcohol Textbook' *which represents the seminal reference work for the alcohol industry, and which includes key research information from Abertay University dealing with the physiology of yeasts for industrial fermentations."* **[5.2]**.

The importance of Abertay's yeast and fermentation research to the fuel alcohol industrial sector was recognised by the United States Fuel Ethanol Workshop's (FEW) *Award of Excellence* to Prof Walker at a ceremony attended by over two thousand industrialists in Omaha, USA in June 2018**.** This *Award* recognized the significant contributions Prof Walker has made to the fuel ethanol industry through research, technical advisory and development activities **[5.3]**.

Regarding potable alcohol production, Abertay research on yeast stress physiology **[3.4]** has proved beneficial to the wine industry and has led to the production of new wine styles in Greece and in the US. For example, one leading Greek winemaker has stated:

"Specifically, we have now adopted the use of salt-preconditioned yeast in grape must fermentations pioneered by research with Professor Walker at Abertay University, and this has resulted in improved production of a range of our wines. The introduction of such novel products to a traditional marketplace has proved very beneficial for our company, both from a reputational and economic viewpoint. We have gained value from a public relations and marketing perspective. The development and production of our premium quality wines would not have been possible without the proof-of-concept research conducted at Abertay University" **[5.4]**.

- ***Alcohol analyses: Final product research impact***

In collaboration with Dalhousie University in Canada and the International Centre for Brewing & Distilling in Edinburgh, research work led by Abertay on the alcohol content of packaged beer has revealed that inaccurate declarations of beer alcohol concentration (% v/v alcohol by volume or ABV) has serious economic and social implications for brewers, tax-raising authorities, and consumers. In essence, breweries either lose money from overpayment of declared alcohol duty or underpay the excisable duty due to agencies such as HMRC, resulting in fines. Abertay researchers (Walker and Maskell) have calculated the financial savings for breweries of varying size, and for larger operations these approximate to £200,000 saved per annum for each 0.1% difference between declared and actual ABV. We publicised the importance of this issue in a trade magazine (Brewer & Distiller International, March 2019 "*Duty calls: the financial importance of accurate ABV measurement*") which emphasised economic implications for the UK and international brewing industry. Several master brewers, brewing industry professional societies and government agencies have subsequently either changed their ABV measurement practices or have supported Abertay's recommendations for industry-wide change in analytical practice. For example:

- 71 Brewing Ltd. Founder and Owner (Duncan Alexander) has stated: "*As a result of their important findings, especially regarding the observed discrepancies between actual and declared alcohol concentration in packaged beer from UK craft breweries, we have tightened up our analysis of %ABV of our own products. We would certainly advise fellow*

craft brewers to, at the very least, conduct accurate measurements of wort gravity, as recommended by the Abertay researchers in their Brewer & Distiller International (2019) paper" **[5.5]**.

- American Society of Brewing Chemists (ASBC) President (Scott Britton) has stated: "*The conclusions made by the Abertay researchers are very pertinent to the activities of the ASBC membership and we fully support their recommendations for craft breweries to ensure greater accuracy for the analysis of the %ABV (percent alcohol by volume) specified on their finished products. Overall, the publications from the Abertay group and their collaborators has pointed the way for the brewing industry to maintain greater consistency when they declare the %ABV of their beverages and which is critical from both a consumer and regulatory standpoint"* **[5.6]**.
- The Institute of Brewing & Distilling Chief Executive Officer (Jerry Avis) has stated: "*The work reported by the Abertay group raised critically important issues for all brewers, but particularly smaller craft brewing enterprises, on accurate determinations and declarations of the alcohol content of their products"* **[5.7]**.
- A rulemaking by the Alcohol & Tobacco Tax & Trade Bureau (TTB) from the Department of the United States Treasury has stated it will amend its regulations governing the labelling and advertising of alcohol beverage products in order to improve understanding of the regulatory requirements and to make compliance easier and less burdensome for industry members. Following research published by Abertay University revealing that it is not possible for craft breweries to operate with a tolerance of 0.3% alcohol by volume, the TTB has subsequently stated: *"a proposed tolerance of 1.0 percent ABV in beers should be adopted based on their current research"* **[5.8]**.
- The Vice-President of The Siebel Institute, the oldest Brewing School in USA (since 1872), has stated: *"I strongly support the proposed (and industry-wide more achievable) 1% tolerance adjustment to be adopted based on the Abertay research. This issue will be discussed with incoming students with training and guidance for the next generation of brewers"* **[5.9]**.

5. Sources to corroborate the impact

5.1 Testimonial from Scotch Whisky Research Institute. Director James Brosnan *corroborates the impact of Abertay research into raw materials processing on whisky production.*

5.2 Testimonial from Lallemand Biofuels & Distilled Spirits, Montreal. President Angus Ballard *corroborates commercial impact of Abertay research to his company.*

5.3 United States Fuel Ethanol Workshop (FEW). *2018 Award of Excellence to Prof Walker in recognition of Abertay research contributions to the fuel alcohol production sector.* http://ethanolproducer.com/articles/15377/few-recognizes-moore-walker-for-contributions-to-fuel-ethanol

5.4 Testimonial from Domaine Evharis Winery, Greece. Owner Haris Antoniou *corroborates the production of a new range of premium wines based on Abertay yeast research.*

5.5 Testimonial from 71 Brewing Ltd. Founder and owner Duncan Alexander *changes practices for analysing beer based on Abertay research.*

5.6 Testimonial from The American Society of Brewing Chemists. President Scott Britton *advocates Abertay recommendations for members to adopt more accurate beer analyses.*

5.7 Testimonial from The Institute of Brewing & Distilling. Chief Executive Officer Jerry Avis *corroborates the critical importance of Abertay research on beer ABV measurements for the brewing industry.*

5.8 General notice from The United States Alcohol and Tobacco Tax and Trade Bureau stating that *proposed tolerance limits on declared alcohol contents of packaged beers should be altered based on Abertay research*. https://www.regulations.gov/docket?D=TTB-2018-0007

5.9 Testimonial from The Siebel Institute/World Brewing Academy (Chicago). Vice President and Director of Education John Hannafan *supports changes to alcohol tolerance limits in beer based on Abertay research.*