Institution: University of Leeds

Unit of Assessment: D32

Title of case study: Keracol Limited: utilising food-waste in the production of sustainable, safe and commercially successful cosmetics

Period when the underpinning research was undertaken: 2007 to date.

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:**
Richard Blackburn	Associate Professor	1999 to date.

Period when the claimed impact occurred: 2007 to date.

Is this case study continued from a case study submitted in 2014? N

1. Summary of the impact (indicative maximum 100 words)

Keracol is a University of Leeds spin-out company launched in 2011 to commercialise the research of **Dr Richard Blackburn** and Professor Chris Rayner. The research created a range of patented techniques allowing the extraction of high-value ingredients from food-waste, scalable for the mass-production of skin and haircare products (2016-2020). Keracol have reduced food-waste through their own brand (Dr Craft) and products developed with partners (M&S Pure Super Grape), saving 24.3 tonnes (as of 2019). The technology removes reliance in hair-dye production on chemicals associated with health problems (aromatic amines). [text removed for publication]

2. Underpinning research (indicative maximum 500 words)

Richard Blackburn (Associate Professor in Sustainable Materials in the School of Design) & Professor Chris Rayner (Professor of Organic Chemistry in the School of Chemistry) have been collaborating on the development of sustainable cosmetic ingredients at The University of Leeds since 2002. **Blackburn's** background in sustainable dyes and historical dyeing techniques brought new insights into the range of applications possible by using natural materials. Rayner's expertise in extraction techniques allowed the collaboration to yield the ingredients found in these materials in larger quantities than previously possible.

Blackburn and Rayner secured DEFRA funding to explore new hair coloration methods using plant extracts and green extraction processes (DEFRA 2007-2009). Novel clean extraction methods were developed to isolate natural colorants (anthocyanins) from waste berries (from juice pressing). They received subsequent funding from InnovateUK that enabled them to work with industrial partners to hone the extraction processes to yield specifically high-value ingredients sustainably (InnovateUK 2010). **Blackburn** & Rayner also examined valorisation of other sustainable raw materials for cosmetic applications and secured InnovateUK funding to look more explicitly at extraction, isolation and application of these ingredients from British seaweed for high-value use (InnovateUK 2009-2011). The project successfully developed extraction processes and applications for two abundant species; Shetland seaweed farmers provided the raw materials and developed sustainable aquaculture methods – this study provided **Blackburn** and Rayner with experience in collaborating with producers. Research on waste berries led to publication of two key papers [1, 2] and several granted patents [4] on the methods and their applications in hair coloration; research on seaweed led to granted patents [5] on the methods and their applications in hair-care.

In researching safer hair dyes, **Blackburn** and Rayner concurrently also invented a novel catalysed hair dyeing system that enables the removal of the most hazardous synthetic hair dye

ingredients, which still allows a full shade range with permanent wash performance; patents have been granted extensively for this technology [6].

Background research over this five-year period led to the formation of Keracol in 2011 and secured key commercial collaborations. University of Leeds research continued thereafter involving academic teams and Keracol as an industrial partner, culminating in three BBSRC-funded projects. Through a collaborative project between University of Leeds, Keracol, and Neal's Yard Remedies (BBSRC, 2016-2017), novel extraction methods were developed to isolate compounds from liquorice for application in skincare, particularly natural UV absorbers. Further BBSRC funding developed previous research on anthocyanins from blackcurrant waste and developed novel enzyme-based methods to make these natural pigments more lipophilic for application in oil-based cosmetics and food [3] (BBSRC, 2017-2018). Subsequently, BBSRC Follow-on funding for **Blackburn**, Rayner & Prof. John Blacker (Chemistry) developed these processes to commercial scale, collaboratively with Keracol (for exploitation as cosmetic colorants) and Nestlé (for exploitation in food coloration) (BBSRC 2019-2020).

Blackburn's focus on sustainability led to him leading further collaborations concerning food waste streams on a global scale. **Blackburn** & Dr. Carolina Orfila (School of Food Science and Nutrition) secured funding for a BBSRC-Newton Fund project, involving Keracol and other industrial partners, examining how citrus waste from mandarin canning in China can be used as a key ingredient in new applications (BBSRC-Newton Fund, 2019-2021). Keracol is now exploiting these mandarin extracts developed through this project in Dr. Craft skincare products.

3. References to the research (indicative maximum of six references)

Journal Articles

1. Farooque, S., Rose, P. M., Benohoud, M., **Blackburn**, R. S., & Rayner, C. M. (2018). Enhancing the potential exploitation of food waste: Extraction, purification, and characterization of renewable specialty chemicals from blackcurrants (*Ribes nigrum* L.). *Journal of Agricultural and Food Chemistry*, *66*(46), 12265-12273. doi:10.1021/acs.jafc.8b04373
2. Rose, P. M., Cantrill, V., Benohoud, M., Tidder, A., Rayner, C. M., & **Blackburn**, R. S. (2018). Application of anthocyanins from blackcurrant (*Ribes nigrum* L.) fruit waste as renewable hair dyes. *Journal of Agricultural and Food Chemistry*, *66*(26), 6790-6798. doi:10.1021/acs.jafc.8b01044
3. Cruz, L., Benohoud, M., Rayner, C. M., Mateus, N., de Freitas, V., & **Blackburn**, R. S. (2018). Selective enzymatic lipophilization of anthocyanin glucosides from blackcurrant (*Ribes nigrum* L.) skin extract and characterization of esterified anthocyanins. *Food Chemistry*, *266*, 415-419. doi:10.1016/j.foodchem.2018.06.024.

Granted Patents

4. **Blackburn**, R. S.; Rose, P. M.; Rayner, C. M. *Natural Hair Dyes*. Australian Patent 2010247136 (20-10-2016), Canadian Patent 2835316 (31-07-2018), European Patent 2477597 (03-10-2018), United States Patent 8361167 (29-01-2013).
5. **Blackburn**, R. S.; Rayner, C. M. *Personal care composition comprising a natural film-forming biopolymer and methods of making the same.* Australian Patent 2013369087 (12-07-2018), European Patent 2934682 (17-10-2018).
6. **Blackburn**, R. S.; Rayner, C. M.; Pask, C. M.; McGowan, P. C. *Catalysed Dye Systems*. Australian Patent 2010268006 (08-09-2016), Canadian Patent 2803942 (05-02-2019), Chinese patent 102470080 (29-08-2017), European Patent 2448545 (07-09-2016), European Patent 3111915 (04-10-2017), South Africa Patent 201200796 (31-10-2012), United States Patent 8535391 (17-09-2013).

Funding

"Novel hair coloration methods using natural plant extracts and associated green extraction processes" in (DEFRA, 2007-2009)

"Clean extraction and separation processes to obtain high-value biomolecules from sustainable resources" (InnovateUK, 2010)
"Extraction, isolation and application of natural polyphenols, polysaccharides and pigments from British seaweeds for high-value applications" (InnovateUK, 2009-2011)
"British liquorice a valuable source of active ingredients for skincare applications (LiquorEx)" (BBSRC, 2016-2017)
"FoodWasteNet – AnthoLip" (BBSRC, 2017-2018)
"Enzymatic esterification of anthocyanins extracted from food waste of high-value industrial application in cosmetics and food (ANTHOLIP2)" (BBSRC, 2019-2020)
"Citrus waste valorisation for improved food safety and human health" (BBSRC-Newton Fund, 2019-2021).

4. Details of the impact (indicative maximum 750 words)

The extraction and formulation techniques and associated products invented by **Blackburn** and Rayner and their development through Keracol are a driving-force for fundamental change in cosmetics production. Keracol have advanced their partners' sustainability and safety goals and equipped them to mass-produce in-demand and effective cosmetics. Keracol have created successful products (M&S Pure Super Grape, Dr Craft) and are instrumental in major production changes [text removed for publication].

Sustainable cosmetics: increasing circularity in production and reducing food-waste
Circularity (the reuse of waste in production) is an urgent focus for brands, manufacturers, and global organisations. The United Nations Environment Plan declared 2018 as the 'year of producing and consuming sustainably', and in 2019 the UK government launched a series of consultations on increasing circularity. Food waste specifically is a key concern of bodies such as global leaders the Waste and Resources Action Programme (WRAP); 2020 saw the release of their report 'Halving Food Loss and Waste in the EU by 2030' which identifies 'food waste valorisation' (the re-use of food-waste) as a key tool in achieving this aim.

In 2014 M&S launched the Pure Super Grape anti-ageing skincare range developed for M&S by Keracol, becoming the first company in the UK to extract resveratrol from its own English grape waste (Pinot Noir produced for M&S by Chapel Down Vineyard in Kent) [C]. Grape is one of the largest fruit crops in the world (4th largest in 2018 – source: statista.com), only 20% is used through mainstream food production: the pomace (skins) that remains is usually discarded unused. The Pure Super Grape range saved 17.3 tonnes of pomace from entering UK landfill from 2014-2019 [D].

Production of Keracol's own brand Dr Craft has to date saved 5 tonnes of blackcurrant waste and 2 tonnes of mandarin waste from landfill or incineration [E] and has attracted significant media attention raising public awareness about valorisation of food waste and sustainability of cosmetics [F]. Dr. Craft products have also won European sustainability awards [G].

Safe cosmetics: removing reliance on ingredients that are harmful to health
Blackburn and Rayner's research has directly led to patented techniques which remove reliance on hair-dye ingredients which are harmful to human health. [text removed for publication] all oxidative hair dyes predominantly rely on compounds such as *para*-phenylenediamine (PPD). For the general population these compounds are suspected carcinogens (cancer causing), tumourgens (tumour causing), and/or mutagens (genetic mutation causing) and may also affect human fertility and reproduction[123]
and are proven to cause allergic reactions[4]. Cancer risks to salon-based staff such as hairdressers and barbers are acknowledged by the NIH: National Cancer Institute (the leading cancer research agency in the USA) in their Hair Dye Factsheet [I].
The new catalysed hair dyeing technology developed by **Blackburn** and Rayner through Keracol has removed reliance on harmful aromatic amines such as PPD. [text removed for publication]

Profitable cosmetics: tapping into the market for safe green cosmetics

The global natural cosmetics market was estimated to be worth $34 billion in 2018 and is projected to register annual growth of 5% from 2019 to 2025 [J]: this growing demand has precipitated key commercial opportunities for Keracol both through partnerships with [text removed for publication] M&S [C,D] and through its own brand Dr Craft [E].

[text removed for publication]

The Pure Super Grape product range developed with Keracol and M&S, has sold [text removed for publication] Since 2011, Keracol has turned over £1.3m and launched its own cosmetic brand, Dr Craft [E] (sold through Amazon and drcraft.co.uk), which has achieved commercial success and sustainability recognition. The success of these products demonstrate the scalability of the techniques developed by **Blackburn** and Rayner through Keracol's commercial partnerships.

5. Sources to corroborate the impact (indicative maximum of 10 references)

[A] [text removed for publication]
[B] [text removed for publication]
[C] Article on Marks and Spencer's Pure Super Grape range and the use of grape waste (also available in PDF upon request): Marks & Spencer skin care range from grape waste product (cosmeticsdesign-europe.com)
[D] [text removed for publication]
[E] [text removed for publication]
[F] News articles downloaded and available in PDF upon request:
Ribena waste used by Leeds scientists to make hair dyes (BBC, May 2018);
Scientists develop 'Ribena' hair dye using skins from left-over blackcurrants (Telegraph, May 2018);
BERRY NICE We tried the revolutionary new hair dye made from RIBENA. Here's how it turned out (The Sun, June 2018);
The eco guide to clean beauty (Guardian, July 2016);
How seaweed could help change the face of the cosmetics industry (Guardian, April 2010).
[G] Awards for Dr Craft (also available in PDF upon request):: And the winners of the 2019 Sustainable Beauty Awards are… (cosmeticsdesign.com)
[H] [text removed for publication]
[I] NIH Hair Dye Fact Sheet (also available in PDF upon request): Hair Dyes and Cancer Risk - National Cancer Institute
[J] Grand View Research: data on the market for Natural Cosmetics (also available in PDF upon request): Natural Cosmetics Market Size, Share, Trends | Industry Report, 2025 (grandviewresearch.com)