

Impact case study (REF3)

Institution: Cranfield University		
Unit of Assessment: UoA6		
Title of case study: Reducing Food Waste by Controlling Ethylene		
Period when the underpinning research was undertaken: 2007 - 2020		
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 Leon A Terry	Research Officer to Professor	2001 - present
Period when the claimed impact occurred: August 2013-2020		
Is this case study continued from a case study submitted in 2014? Y/N Yes		
1. Summary of the impact (indicative maximum 100 words)		
<p>The United Nations has made action on food waste one of its key Sustainable Development Goals. In 2016, the Food and Agricultural Organisation (FAO) suggested 46% of all fruit and vegetables across the world are wasted annually throughout the supply chain.</p> <p>Cranfield co-developed and helped commercialise a superior and novel technology in which an active compound removes ethylene in the packaging of fresh produce, suppressing ripening and reducing food loss.</p> <p>Annual sales and exports of the technology licensed to It's Fresh! Ltd., total over GBP23,000,000 in global supply chains, with a typical Return on Investment of 300%.</p>		
2. Underpinning research (indicative maximum 500 words)		
<p>In collaboration with Johnson Matthey Plc., Cranfield developed and validated an ethylene removal technology to reduce fruit losses and waste across the fresh produce supply chain.</p> <p>The E+™ Ethylene Remover technology is based on initial research into a specifically selected zeolite clay impregnated with palladium (Pd) [R1 – cited 127 times]. The Pd-promoted powdered material was found to have significant ethylene adsorption capacity (4,162 $\mu\text{L g}^{-1}$ material at 20°C). Work on the material demonstrated how it was far superior to standard potassium permanganate (KMnO₄)-based scavengers when used in low amounts and in conditions of high relative humidity (RH). This performance was increased to 45,600 $\mu\text{L ethylene g}^{-1}$ under dry conditions (low %RH), thus, representing a 60-fold higher activity than KMnO₄.</p> <p>The binding behaviour of the adsorber was further investigated using transmission electron microscopy, which showed that the (Pd) particles (1-5 nm) are dispersed over the support material [R2]. The analysis showed that 84% of ethylene is bound to the Pd-promoted material (e.g. as π or di-σ bonded ethylene or other ethylene-derived adsorbed species) with the rest being converted to ethane which is physiologically inert, or carbon dioxide (CO₂) [R1, R2].</p> <p>Efficacy testing using different formats (raw powder, coated sheets and printed labels containing the actives) was carried out on numerous climacteric fresh produce types viz. banana [R1] and avocado [R1, R3] (a Johnson Matthey-funded studentship; R3, R4); an EPSRC studentship [R5, R6] showed that E+™ reduced respiration, maintained firmness, suppressed ripening-related biochemical changes (e.g., sugar hydrolysis) and retained colour. Unlike the ethylene binding inhibitor 1-methylcyclopropene (1-MCP), E+™ was shown to not disrupt subsequent ripening when fruit were transferred to ambient air [R4].</p>		

In addition to extending the preclimacteric life of banana (green stage) and of avocado fruit, E+™ was shown to be capable of extending shelf life even when the climacteric respiratory rise had been initiated: a first for such a technology [R1].

Work also showed that removal of ethylene could extend the postharvest life of strawberry fruits by up to 2 days by suppressing grey mould disease incidence caused by *Botrytis cinerea*, delaying sucrose hydrolysis and ABA and ABA catabolite homeostasis, and anthocyanin degradation; all of which are associated with senescent decline (R5). This work supports recent research at Cranfield, which demonstrated that ethylene is important in mediating senescent behaviour in some non-climacteric systems [R6].

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

- R1. Terry LA, Ilkenhans T, Poulston S, Rowsell L, & Smith AWJ (2007). Development of new palladium-promoted ethylene scavenger. *Postharvest Biology and Technology* 45, 214-220. <https://doi.org/10.1016/j.postharvbio.2006.11.020>
- R2. Smith AWJ, Poulston S, Rowsell L, Terry LA & Anderson JA (2009). A new palladium-based ethylene scavenger to control ethylene-induced ripening of climacteric fruit. *Platinum Metals Review* 53, 112-122. <https://doi.org/10.1595/147106709X462742>
- R3. Meyer MD, Chope GA & Terry LA (2017) Investigation into the role of endogenous abscisic acid during ripening of imported avocado cv. Hass. *The Journal of the Science of Food and Agriculture* 97, 3656-3664. <https://onlinelibrary.wiley.com/doi/10.1002/jsfa.8225>
- R4. Meyer MD & Terry LA (2010). Fatty acid and sugar composition of avocado, cv. Hass, in response to treatment with an ethylene scavenger and 1-methylcyclopropene to extend storage life. *Food Chemistry* 121, 1203-1210. <https://doi.org/10.1016/j.foodchem.2010.02.005>
- R5. Elmi F, Pradas I, Tosetti R, Cools K & Terry LA (2017) Effect of ethylene on postharvest strawberry fruit tissue biochemistry. *Acta Horticulturae* 1156, 667-672. <https://doi.org/10.17660/actaHortic.2017.1156.97>
- R6. Tosetti R, Elmi F, Pradas I, Cools K & Terry LA (2020). Continuous exposure to ethylene differentially affects senescence in receptacle and achene tissues in strawberry fruit. *Frontiers in Plant Science*, 11, 174. <https://doi.org/10.3389/fpls.2020.00174>

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

UN Sustainable Development Goal 12.3 aims to reduce food losses and waste by 50% by 2030. Consequently, innovation has been needed to disrupt traditional food supply chains and extend postharvest life. The development of E+™ Ethylene Remover technology, rooted in the findings from Cranfield's original research, has had significant technological, economic and environmental impact, benefitting practitioners across the supply chain. The work has also been used as an exemplar case study in the BBSRC/UKRI National Plant Science Strategy.

Technological Impact

Cranfield co-developed and validated E+™ Ethylene Remover technology with Johnson Matthey Plc. The research began through commercial work for Johnson Matthey and continued via PhD and MSc by Research studentships funded by Johnson Matthey, EPSRC and It's Fresh! Ltd. Research was also supported by a Defra-funded project (AFM277).

The industry and post-harvest knowledge [S1] that Professor Terry brought to the project along with specialist equipment and ability to conduct relevant and informative fresh produce trials:

“... meant our understanding of the behaviour of E+™ in ‘real-life’ conditions could be expedited and externally validated.... Professor Terry and his team’s expertise was of great importance to Johnson Matthey in developing this commercial product.” [S2] (Senior Scientist, Johnson Matthey Technology Centre)

The outcome of the work resulted in a collaboration with It’s Fresh! Ltd. and the commissioning of a new industry plant at Johnson Matthey to produce the raw material. Johnson Matthey patented the technology and, because of the collaboration, the timeline from research to exploitation of the E+™ Ethylene Remover was less than five years.

The technology was licensed to It’s Fresh! Ltd., to formulate the raw material into a wafer-thin membrane. This is currently the only existing technology that can be used with fruit and vegetables across the entire supply chain from grower to retailers that can extend shelf life (by 2 days), quality, reduce waste (typically by 40-50%) and add sales (typically 10%) [S3].

“By having these clear insights into the fundamental science we were not only able to bring a truly disruptive technology to market but also to broaden the use of technology This goes to prove that bold research collaborations can result in commercial benefits. In fact, we took things one stage further and as a business we relocated to Cranfield’s Technology Park in order to extend our research opportunities.” [S4a & S4b] (CEO It’s Fresh!)

The development of ethylene removal products is ongoing and now includes It’s Fresh! Transit Sheets that remove the need for controlled atmosphere shipping; It’s Fresh! Pads and It’s Fresh! Labels with active material printed onto top seal and flow-wrap packing lines. [S5]

Economic Impact

Before 2014, It’s Fresh! invested more than GBP10,000,000 to bring to market a range of simple products to reduce waste and create overseas exports for the E+™ Ethylene Remover (Rabo Bank innovation / start up) [S6, S3]. Annual sales and exports now total over GDP23,000,000 (USD30,000,000 (10-2020)) with the core technology being the sole product in It’s Fresh! commercial operations, creating value across the supply chain, with a typical Return on Investment of 300% [S3].

In 2018, It’s Fresh! secured a further GBP7,630,000 investment from Agrofresh to enable the business to accelerate global expansion [S7]. As a result, the E+™ Ethylene Remover is now sold across leading supermarket chains in the UK (M&S, Waitrose, Sainsbury’s, Co-op, Tesco, and Morrison’s), Europe (Carrefour) and USA (CostCo and Walmart). [S8] It is now used in North and South America, Europe, Africa, and Australasia for a range of fresh produce types.

It’s Fresh! and parent company Food Freshness Technology Holdings (FFTH) have secured over GBP26,500,000 (USD35,000,000 (02-2021)) investment from Anterra Capital, JRJ Group, AP Ventures and BXR Group to bring ethylene removal products to market. [S9]

Environmental Impact

In the UK alone, post farm food waste totals 10,200,000t per year (worth GBP20,000,000,000), and is associated with more than 22,000,000t of greenhouse gas emissions (WRAP, 2019 report). It’s Fresh! technology has helped to address in a significant and sustainable way, the key industry challenges of food security, profitability, and global food waste, by extending quality, prolonging freshness and enhancing flavour [S3].

In 2019, based on the findings from Cranfield’s original research [R1], It’s Fresh! signed an agreement with the Ecuadorian Banana Association (Agrobanec) to extend the green life of bananas for up to 70 days (effectively doubling the life span). The technology has been

introduced to 28 affiliate growers and exporters in the region, responsible for over half of the world's banana exports resulting in an estimated reduction in waste of 40 to 50% [S3]. The preservation of green life is of huge importance to the banana trade but also for addressing the global food waste crisis, which is an ongoing commitment of It's Fresh! [S10].

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

- S1. Article for Johnson Matthey explaining advances in postharvest technologies to reduce food waste and maintain fresh produce quality:
<https://www.technology.matthey.com/article/62/1/107-117/>
- S2. Letter of Support from Senior Scientist, Johnson Matthey Technology Centre, 20/05/2020
- S3. Letter of Support from Technical Sales Director, It's Fresh! 01/10/2020
- S4. a) It's Fresh! presentation at Cleanequity Monaco in 2016 linking It's Fresh! with Cranfield University research: <https://www.youtube.com/watch?v=T4Zfa1Kkhrk> (@4.39 & @9.20-10.25).
b) It's Fresh! Lease at Cranfield University 2014-2019, proving It's Fresh! move onto Cranfield site (as per video)
- S5. Ongoing development of ethylene removal product range based on Cranfield's research
<https://itsfresh.com/ethylene-removal-products/>
- S6. RaboBank investment start up article linking It's Fresh! to Cranfield University:
<https://www.rabobank.com/en/about-rabobank/innovation/start-ups/articles/putting-an-end-to-wasted-fruit.html>
- S7. It's Fresh! Secures USD10,000,000 (01-2018), (GBP7,630,000) investment for expansion:
<https://www.andnowuknow.com/quick-dish/agrofresh-solutions-invests-10-million-its-fresh/kayla-webb/56605>
- S8. Demonstrates the link between Professor Terry's work and It's Fresh! product being used by leading supermarkets:
<https://www.producebusinessuk.com/services/stories/2016/07/12/it-s-fresh!-is-ready-to-scale-new-peaks>
- S9. Key industrial partners USD35,000,000 (02-2021) investment into It's Fresh!
<https://itsfresh.com/about-us/>
- S10. Ecuadorian Banana Association link with It's Fresh!:
<https://www.foodnavigator-latam.com/Article/2019/07/11/Ecuadorian-banana-association-partners-with-UK-s-It-s-Fresh!-for-supply-chain-tech>