Institution: 10007822

Unit of Assessment: 6

Title of case study: Reducing Waste in the Fresh Produce Supply Chain

1. Summary of the impact

Cranfield's work on ethylene supplemented storage is now exploited in the supply chains to major supermarkets in the UK, including Waitrose and Tesco, reducing waste and avoiding volatility in supply for fresh food products such as onions and potatoes. By prolonging storage life by up to six weeks it is also having a positive impact on the UK's self-sufficiency in these products, displacing imports from overseas.

Complementary work has also led to commercial ethylene scrubbing technologies for packaging, which typically save around 50% of in-store waste and add two days to the product life for a range of fruit and vegetables. Such packing is now in use in most mainstream UK supermarkets, and in the USA where it has created a new export market for the manufacturer.

2. Underpinning research

The postharvest physiological behaviour of fresh produce has historically been classified as either climacteric or non-climacteric. However, Terry's research at Cranfield has shown that many crops currently described as non-climacteric are both sensitive to ethylene and also the ethylene binding inhibitor 1-MCP (1-methylcyclopropene). Importantly, his team has described many of the associated underlying physiological, biochemical and transcriptomic mechanisms, primarily using onion as a model [1,2].

Following a Defra HortLINK (HL0164; 2003-2006 [PI = Terry]) on onion quality, and a Horticultural Development Council funded PhD studentship (CP_20; 2003-2006; PI = Terry), further research in collaboration with UK industry was commissioned by Defra (Sustaining UK fresh onion supply by improving consumer acceptability, quality, and availability; HortLINK HL0182; 2007-2010 [PI = Terry]). From this, the first onion oligonucleotide microarray was developed in collaboration with Warwick HRI. This was used to determine differential gene expression in onion during curing and storage, so that transcriptional changes could support targeted metabolomic and physiological analyses. Cranfield's analyses provided novel insights into key regulatory triggers for sprout dormancy release in onion bulbs and the potential for the development of biochemical and transcriptional markers for sprout initiation. The research identified that the ratio of monosaccharides (fructose and glucose) to disaccharide (sucrose) and the concentration of the cytokinin zeatin riboside could be used as pre-symptomatic markers for discriminating between sprouting and pre-sprouting bulbs [1]. Using this novel onion microarray in combination with targeted metabolomic and physiological data, the sprout inhibiting effects of ethylene and 1-MCP proved to be greater when the two treatments were applied in unison [2]. This led to the hypothesis that 1-MCP may only bind to certain ethylene receptors and that the combination of both ethylene and 1-MCP may further extend the storage potential of onions and potentially other produce. The practical outcome has been to extend storage life by up to six weeks by supplementing onions with ethylene and related treatments [2,3]. Similar results have been achieved for potatoes and sweetpotato through research directly sponsored by industry (Monsanto and PepsiCo), AHDB and the Commonwealth Commission.

In complementary work on the response of fresh produce to ethylene, Cranfield-led research, in conjunction with Johnson Matthey Plc (JM) and It'sFresh!, has led to the development of a new palladium (Pd)-promoted ethylene adsorbing material (E+™ Ethylene Remover) [4, 5]. Uniquely, the material reduces ethylene to sub-physiologically active levels at low temperature and under high relative humidity. Unlike ethylene binding inhibitors, the Pd-material does not disrupt subsequent ripening behaviour (e.g. avocado and banana [6]). This work began with a consultancy for Terry followed by a fully funded studentship from JM [Meyer; 2006-2009], a Defra FoodLINK (Developing prototype palladium-based ethylene scavenging technology; AFM277; 2010 [PI = Terry]) project, one EPSRC CASE studentship (Elmi; 2009-2013; 0900987) and two MSc by

Research students funded by It'sFresh! (Collings and Cas; 2012).

Key staff	Post	Dates	Research
Prof Leon Terry	Professor of Plant Sciences	1997–present	metabolomics, ethylene, postharvest biology and technology

3. References to the research

1. Chope, G.A., Cools, K., Hammond, J.P., Thompson, A.J. and Terry, L.A. (2012) Physiological, biochemical and transcriptional analysis of onion bulbs during storage. *Annals of Botany* 109, 819-831. doi: 10.1093/aob/mcr318
2. Cools, K., Chope, G.A., Hammond, J.P., Thompson, A.J. and Terry, L.A. (2011) Ethylene and 1-MCP differentially regulate gene expression during onion (*Allium cepa* L.) sprout suppression. *Plant Physiology* 156, 1639-1652. doi: 10.1104/pp.111.174979
3. Downes, K., Chope, G. A. and Terry, L. A. (2010). Postharvest application of ethylene and 1-methylcyclopropene either before or after curing affects onion (*Allium cepa* L.) bulb quality during long term cold storage. *Postharvest Biology and Technology* 55, 36-44. doi: 10.1016/j.postharvbio.2009.08.003
4. Meyer, M.D and Terry, L.A. (2010) Fatty acid and sugar composition of avocado cv. Hass in response to treatment with an ethylene scavenger or 1-methylcyclopropene to extend storage life. *Food Chemistry* 121, 1203-1210. doi: 10.1016/j.foodchem.2010.02.005
5. 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 (3) 112-122. doi: 10.1595/147106709X462742
6. Terry LA, Ilkenhans T, Poulston S, Rowsell L & Smith A. (2007) Development of new Palladium-promoted ethylene scavenger, *Postharvest Biology and Technology*, 45 (2) 214-220. doi: 10.1016/j.postharvbio.2006.11.020

4. Details of the impact

Technologies flowing from Cranfield's research on ethylene-supplemented storage of non-climacteric produce (such as onions and potatoes), are already exploited by the Restrain Company. They are being used in the storage facilities of major suppliers, such as Moulton Bulb Company and Stourgarden who service Waitrose and Tesco respectively. The technologies are also having influences beyond the UK, as many of these companies are international businesses. Enhanced storage has prolonged storage lives for onions and potatoes by six weeks, reducing waste and reducing dependence on synthetic chemical sprout suppressants.

The annual value of onions going to retail and food manufacturing is estimated at £200 million, of which 54% are produced in the UK (Defra 2009). The UK potato industry also delivers sales value of £947 million at the farm gate and £3.8 billion at consumer level (Potato Council Statistics 2013). Ethylene supplementation is having a positive effect on the economics of onion and potato supply by improving the timing of produce release from storage. Prolonging storage is avoiding volatility in supply and contributing to the maintenance of produce prices. Unit waste levels during storage are between 3-10% for onions and potatoes in the UK [1]. A 25% reduction in waste due to enhanced storage is therefore valued at £5 million for onions alone. Such improvements in storage also have a positive impact on the UK's self-sufficiency agenda through greater displacement of imports of onions sourced from overseas.

E+™ Ethylene Remover

The E+™ Ethylene Remover, based on Cranfield research, was launched commercially in 2009 and is now in use in packaging for most mainstream supermarkets in the UK (Tesco, Waitrose, M&S) and USA, where it has been shown to reduce wastage of a range of fruits and vegetables. The relevant patent is held by Johnson-Matthey Plc. [2,3], and is licensed to It'sFresh! [4], who stated in 2013 that *'based on current commercial roll-out, It'sFresh! typically saves around 50% of in-store waste and adds a minimum of two days' product life'* [5]. It'sFresh! has invested more than £10 million to bring to market a range of simple products to reduce waste, protect food and increase quality [6], and created overseas exports for the E+™ Ethylene Remover. The timeline

from research to exploitation of the E+™ Ethylene Remover was less than five years.

5. Sources to corroborate the impact

1. Terry, L.A., Mena, C., Williams, A., Jenney, N., Whitehead, P., 2011. Fruit and vegetable resource maps. Mapping fruit and vegetable waste through the retail and wholesale supply chain. (No. RSC008). WRAP, Banbury.
2. Johnson Matthey e+™ Ethylene Remover http://www.chemicals.matthey.com/page-view.php?pagename=e-plus-ethylene-remover
3. Ripe for the Picking – New Technology to Stop Fruit and Veg from Spoiling http://www.matthey.com/Sustainability2009/case-studies/products_cs_27.html
4. Food Freshness Technology (It'sFresh!) http://www.foodfreshnesstechnology.com/
5. FreshPlaza: New research at Cranfield conference confirms importance of ethylene removal in extending strawberry product life http://www.freshplaza.com/article/112657/New-research-at-Cranfield-conference-confirms-importance-of-ethylene-removal-in-extending-strawberry-product-life
6. Plasteurope.com: Marks & Spencer Introducing an ethylene copolymer removal strip / New technology for fresh fruit industry / Longer life, less waste http://www.plasteurope.com/news/detail.asp?id=221261