From Patient to Potato: "Cardiovascular" Magnetic Resonance in Potato Blackheart

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Introduction: In humans, cardiovascular magnetic resonance (CMR) represents the gold standard imaging modality for numerous cardiac pathologies and is uniquely placed to probe both the function of the heart and infer its microstructure. For example, native T1 at 3T is increased by approximately 20% following myocardial infarction, accompanied by morphological changes, LGE and altered diffusivity. In the potato (*Solanum tuberosum* cv. 'King Edward'), the disorder Blackheart can be characterised by a region of cell death and darkly pigmented tissue in the central pith of affected tubers. Although the cause of Blackheart is poorly characterised, it has long been attributed to poor oxygen availability and an increased metabolic demand in central pith cells. This ischemic-like disorder develops during long-term cold storage and cannot be detected externally or by normal quality control methods, and is responsible for a large proportion of UK potato waste and consumer dissatisfaction. While the route from potatoes to myocardial ischemia is well documented (and often goes via a deep-fat-fryer), we demonstrate here the agricultural applicability of "C"MR techniques.

Methods: *Preclinical Potato Imaging:* Whole-potato ischemia was induced via vacuum packing and incubation at 37 ºC in a home-built MRI-compatible waterbath. Potatoes were placed supine in a 7T Varian MRI system inside a 72 mm $^{1}H/^{13}C$ birdcage coil. Temperature was monitored via IR pyrometry. Under these conditions, blackheart develops within ~12 hours, and a scanning protocol acquiring ADC (b_{max} 10^4 s/mm^2; 3 directions, 0.78 mm^2 x 2 mm resolution; 1 s TR) and T1 maps (IR Look Locker; 5º FA; 8 readouts; TR 50s; 8 TIs from 0.1 to 5 s; 0.58 mm^2 x 2 mm resolution) were undertaken approximately hourly for 24 hr. *Clinical Potato Imaging*: A double-blinded randomised trial in a clinic was conducted on two healthy and two Blackheart potatoes on a Siemens 3T Tim Trio MRI system. T1 maps were obtained via MOLLI from isothermal potatoes at rest (8 readouts, 60 bpm nominal heart rate, 0.86 mm^3 in-plane resolution).

Results: Preclinically, potato pith T1 was significantly increased with disease progression over time, with an increase in ADC from 2.6 to 3.3x10^{-3} mm^2/s. In the clinic, a blinded observer highly inexpert in potato anatomy was able to classify all tubers accurately on the basis of IR T1 maps.

Discussion and Conclusion: In common with the human heart, potato Blackheart is characterised by a loss of cell membrane integrity following hypoxia insufficient to meet metabolic demands. We hypothesise that this drives the T1 alteration seen, which is diagnostically accurate. Future work will aim to demonstrate these differences using Earth's field MRI.

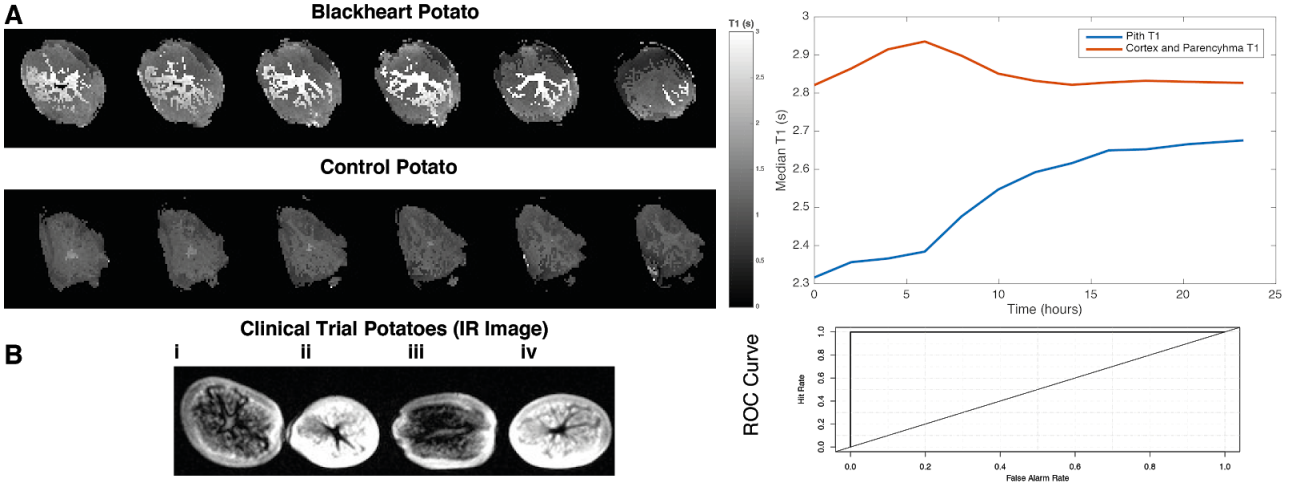

Fig. 1: **A**, left: Multi-Slice preclinical potato T1 maps demonstrating a clear difference in pith T1 between control and blackheart potatoes. Right: under model induction, median T1 increases as the disease is induced. **B**, left: Inversion recovery with TI≈1.2 s enables the immediate discrimination of Blackheart potatoes (i, iii) from controls (ii, iv) with 100% specificity and sensitivity (right).