Understanding potato quality traits important to consumers

Wayne Morris, Heather Ross, Laurence Ducreux, Tom Shepherd, Susan Verrall, Gordon McDougall, Alison Roberts, Glenn Bryan and Mark Taylor
SCRI, Invergowrie, Dundee, DD2 5DA, Scotland, UK
E-mail Wayne.Morris@scri.ac.uk Tel: +44 (0)1382 562731 Fax: +44 (0)1382 562426

SCRI living technology

Background

Potato flavour and texture are important factors in consumer preference trials. In order to improve germplasm we need to increase our understanding of the molecular basis of these traits. Our studies were based on the comparison of Phureja with Tuberosum tubers. Phureja tubers not only score higher in professional sensory evaluation panels but they also cook more quickly than Tuberosum tubers. This led us to make comparisons of flavour metabolites from boiled tubers from a range of Phureja and Tuberosum cultivars and investigate differences in tuber texture.

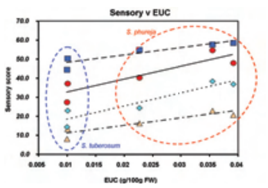
Aims of the project

- Understand the factors that contribute to tuber flavour and texture by comparing different potato germplasm and manipulating the expression of candidate genes.
- Exploit this knowledge to understand the metabolic pathways responsible for these traits in order to pinpoint target genes for use as breeding targets.

Results

Matrix associated umami compounds

The non-volatile matrix associated umami compounds enhance flavour and mouth feel. The major umami compounds present in potato tubers are the amino acids, glutamate and aspartate and the 5′ ribonucleotides, GMP and AMP. The synergistic effect between certain free amino acids and 5′-ribonucleotides can be measured using an equivalent umami calculation (EUC). Previous studies at SCRI have shown that Phureja tubers contain significantly higher levels of umami compounds compared to Tuberosum correlating strongly with acceptability scores from sensory evaluation data[1].

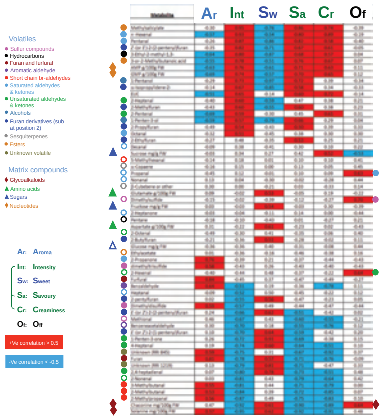


EUC v Sensory scores. *S. tuberosum* cultivars Maris Piper and Record were compared with *S. phureja* clones DB333-16 and DB257-28, and cultivar Mayan Gold. Square, flavour intensity; circle, acceptability; diamond, flavour sweet; triangle, flavour creamy.

Flavour and metabolite correlations

Quantitative descriptive analysis of potato samples by a trained taste panel was performed, comparing tubers from *Solanum tuberosum* group Phureja with those from *Solanum tuberosum* group Tuberosum, both at harvest and following storage. The cooked tuber volatile profile was analysed by solid phase micro-extraction followed by gas chromatography-mass spectrometry analysis in sub-samples of the tubers that were assessed by taste panels. A range of non-volatile metabolites including the major umami compounds, glycoalkaloids and sugars was also measured in tuber sub-samples. Correlation and principal component analyses revealed differences between the potato cultivars and storage conditions and demonstrated associations of metabolites with the different sensory attributes[2].

Principal component analysis revealed that component 1, explaining 49% of the variation, separates the two Phureja lines from the two Tuberosum lines. Score 3 explains 14% of the variation and shows all four cultivars responding in a similar manner to storage.

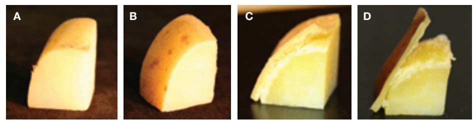


Heat map showing the correlation analysis between quantitative descriptive analysis scores of potato flavour attributes and levels of metabolites in cooked tubers. Regions in red and blue indicate positive or negative correlations between traits, respectively

Potato tuber texture

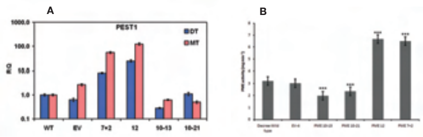
Tuberosum and Phureja tubers exhibit distinct textural properties[3]. Tuberosum tubers (A and B) show no evidence of tissue sloughing after cooking while Phureja tubers (C and D) show marked loosening of the tissue in the region of the vascular ring and cortex and the cortical/epidermal region sloughs off as the tissue cooks.

Effect of cooking on sloughing in Tuberosum and Phureja tubers. Tuberosum tubers Pentland Dell (A) and Montrose (B), Phureja tubers Mayan Gold (C) and Inca Sun (D). Each sample is 2cm across the base.

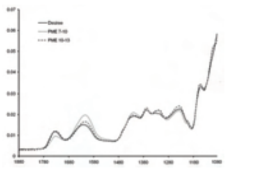


Previous work[4,5] has identified tuber pectin methyl esterase activity (PME) as a potential factor impacting on textural properties with the isoform encoded by *PEST1* being particularly important. Tuberosum cultivars exhibit higher levels of *PEST1* gene expression and associated enzyme activity compared with Phureja. Potato transgenic lines were generated expressing either the *PEST1* sense or antisense transgene. Tuber PME activity and gene expression profiles were determined in the trans

A) Total pectin methylesterase activity for wild type and empty vector (ev4) controls compared with sense (12, 7+2) and antisense (10-13, 10-21) lines. Values, expressed as ΔOD_{620nm} min^{-1} mg $protein^{-1}$, are presented as mean ± SE (n = 3).
B) Expression profiles of PME genes in potato tubers as determined by quantitative RT-PCR. WT, wild type; EV, empty vector; sense (12, 7+2) and antisense (10-13, 10-21) lines. RQ, relative quantitation. DT, developing tuber; MT, mature tuber. Values are presented as mean ± SE (n = 3).

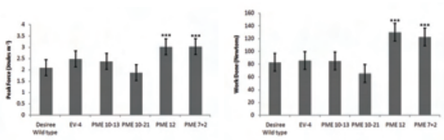


FT-IR analysis was used to investigate the level of pectin methylation in cell walls from the transgenic tubers. There were pronounced differences between the FT-IR spectra of the wild type and the transgenic *PEST1* sense lines suggesting reduced pectin methylation.



FT-IR spectra of isolated cell walls control and transgenic tubers. Each spectrum is the average of three replicate scans of three replicate cell wall samples. The wild type had higher signals in the region around 1730 cm^{-1}, whereas the transgenic *PEST1* sense lines had higher signals at approximately 1620 cm^{-1}

Transgenic plants overexpressing the *PEST1* gene exhibit a firmer texture compared to wild type and empty vector controls.



Texture comparisons of wild type, empty vector (EV-4) and PME transgenic plants. Sense (12, 7+2) and antisense (10-13, 10-21) lines.

Summary

Correlation and principal component analyses revealed differences between the potato cultivars and storage conditions and demonstrated associations of metabolites with the different sensory attributes.

Manipulation of *PEST1* expression level altered total PME activity and resulted in changes in the pectin methylation status of cell walls and cooked potato textural properties.

A genetic approach is currently being used to identify quantitative trait loci (QTL) associated with tuber flavour and texture.

References

1) Morris W.L. et al. **2007**. Umami compounds are a determinant of the flavor of potato (Solanum tuberosum L.). *Journal of Agricultural and Food Chemistry* 55, 9627-9633.
2) Morris W.L. et al. **2010**. Relationships between volatile and non-volatile metabolites and attributes of processed potato flavour. *Phytochemistry* doi: 10.1016/j.phytochem.2010.07.003.
3) Ross H.A. et al. **2010**. Discerning intra-tuber differences in textural properties in cooked *Solanum tuberosum* group Tuberosum and group Phureja tubers. *Journalof the Science of Food and Agriculture* 90, 1527-1532.
4) Ducreux L.J.M. et al. **2008**. Expression profiling of potato germplasm differentiated in quality traits leads to the identification of candidate flavour and texture genes. *Journal of Experimental Botany* 59, 4219-4231.
5) Ross H.A. et al. **2010**. Potato tuber pectin structure is influenced by pectin methyl esterase activity and impacts on cooked potato texture. *Journal of Experimental Botany* –in press.

Acknowledgements

This work was funded by the The Scottish Government Rural and Environment Research and Analysis Directorate (RERAD). We are grateful to Ian Pitkethly (SCRI, UK) for poster design.