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Profiling Phytochemical and Nutritional Components of Potato

Key external stakeholders:
Plant Breeders, Growers, Agronomists, Scientific Community, Non-Governmental Organisations

Practical implications for stakeholders:
Potato is generally recognised as a good source of carbohydrates, vitamin C and plant secondary metabolites; however the variation of the content of secondary plant metabolites across different varieties is poorly understood. The main outputs from this project indicate a significant variation in the content of plant secondary metabolites across 60 commercial potato varieties.

Main results:
All of the phytochemical compounds studied showed higher levels in the skin than in the flesh of tubers. The skin of the tubers accumulated on average between 2.5 and 3 times more carotenoids, 6 times more phenolics, between 15 and 16 times more flavonoids, 21 times more glycoalkaloids and showed 9 to 10 times higher antioxidant activity in the flesh. Genotype was found to have a significant effect for all the parameters studied, but different varieties showed different maxima values for the different compounds. Nevertheless, yellow skin of fleshed varieties had higher contents of total carotenoids than those with paler or white tissues, and blue fleshed varieties showed higher values of total phenolics, total flavonoids and antioxidant activity than other flesh colours. Levels of expression of phenylalanine-lyase (PAL) and chalcone synthase (CHS) genes were higher in varieties accumulating high contents of phenolic compounds. However, levels of expression of phytoene synthase and L-galactono-1,4-lactone dehydrogenase were not different between varieties showing contrasting levels of carotenoids and ascorbate respectively.

Opportunity / Benefit:
Differences in the levels of nutrients or secondary metabolites in potatoes could make an important impact in the nutrition and health of countries where potato is a staple food. Therefore, information about the quantities of these compounds in existing varieties and their relationship to the corresponding underlying biological mechanisms of synthesis and accumulation is fundamental. This information could be used by potato breeders and scientists genetically modifying plants to obtain more nutritious varieties or with enhanced phytochemical content. This could allow consumers and growers to select varieties with higher levels of phytochemicals or vitamins, increasing the potential marketing appeal of these varieties.

Collaborating Institutions:
Teagasc
UCC

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1. Project background:

Potato is the fifth most consumed vegetable consumed globally. Therefore, differences in the levels of nutrients or secondary metabolites in potatoes could make an important impact in the nutrition and health of countries where potato is a staple food. With this aim, potatoes have been genetically modified producing increases of carotenoids, phenolic compounds and vitamin C, but commercialization of genetically modified products is not permissible within the European Union. Another approach that has been undertaken is conventional breeding. Traditionally breeders have been focused on maximizing yield, organoleptic properties and resistance to pests, rather than enhancing the nutritional value of vegetable products. Increasing demands for more nutritious foods have expanded the focus for potato breeding and efforts are made to increase carotenoid and anthocyanin contents in potatoes by incorporating in many cases wild potato germplasm into commercial cultivars. In these studies information on these compounds is fundamental. Most studies looking at levels of phytochemical compounds in potato have used a reduced number of varieties and were not grown in controlled field trials. Only 25% of the varieties considered in this study were found included ion previous studies, focusing on the metabolites which were the focus of this study. Therefore there is limited information with respect to these compounds and this project attempted to expand available information on vitamin C, carotenoids, phenolic compounds and glycoalkaloids in a wide range of potato varieties.

2. Questions addressed by the project:

The aim of this study was to evaluate (1) the phytochemical and nutritional profile of a range of potato varieties grown in field trials over two years and plantations sites (2) the levels of expression of key genes involved in synthesis of phytochemical and nutritional components of interest in cultivars showing contrasting levels of accumulation of nutritional or phytochemical metabolites.

3. The experimental studies:

Sixty varieties of potato were cultivated in 2010 at two different locations in Ireland and in 2011 in one location. Mature tubers were harvested after approx. 5 months of growth, and composite samples were prepared with tubers from the same plant. Potato tubers were peeled and flesh and kin tissues were freeze dried. Fresh samples were preserved for RNA extraction.

Parameters of interest included vitamin C, total carotenoids, total phenolics, total flavonoids and antioxidant activity, which were determined using spectrometric methods and also glycoalkaloids by HPLC. Varieties with extreme values found for carotenoids, phenolic compounds and vitamin C, plus the variety 'Rooster', which is the most widely grown variety in Ireland were also selected to assess the gene expression of key enzymes involved in the production of the compounds of interest. Appropriate primers were designed and qPCR was used to determine expression levels of genes of interest.

4. Main results:

The main results from this study can be summarised as:

- Genotype was found to be a significant effect for all of the metabolites studied
- The values reported for carotenoids, phenolics, antioxidant activity and glycoalkaloids were in the range reported by previous studies
- Higher levels of phenolic compounds, carotenoids and glycoalkaloids and higher antioxidant activity

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were found in the skin than in the flesh of tubers
- Higher levels of phenolics were found associated with blue-fleshed tubers
- Phenolic compounds and flavonoids were found to contribute to the antioxidant activity of potatoes
- Higher levels of carotenoids were found associated with yellow tubers
- The glycoalkaloids α-chaconine and α-solanine appeared to be accumulated in a coordinated manner
- Glycoalkaloid levels were found below safe limits in all but 5 varieties (out of 60) in particular sites and years of cultivation
- The influence of the environment was found in almost all cases different depending on variety
- The accumulation of carotenoids appeared to be increased by higher temperatures
- The accumulation of ascorbic acid appeared to be increased by lower temperatures, increased rainfall and solar radiation and a more sandy and basic soil
- The accumulation of phenolic compounds appeared to be increased by lower temperatures, increased rainfall and solar radiation
- The accumulation of glycoalkaloids appeared to be increased by higher temperatures
- The accumulation of phenolic compounds in the flesh was found related to the expression of PAL and CHS genes, which suggest regulation, at least partially, at the transcript level
- The expression of PAL and CHS genes was not correlated to phenolic levels in the skin, which may indicate that gene expression, more closely follows accumulation of phenolics in the flesh
- No relationship was found between expression of FLS genes and phenolic content, PSY and carotenoids or GLDH and L-ascorbic acid
- A strong correlation was found among PAL, CHS and AN1 transcript levels, which suggest that these enzymes are regulated in a coordinated manner

5. Opportunity/Benefit:

Differences in the levels of nutrients or secondary metabolites in potatoes could make an important impact in the nutrition and health of countries where potato is a staple food. Therefore, information about the quantities of these compounds in existing varieties and their relationship to the corresponding underlying biological mechanisms of synthesis and accumulation is fundamental. This information could be used by potato breeders and scientists genetically modifying plants to obtain more nutritious varieties or with enhanced phytochemical content. This could allow consumers and growers to select varieties with higher levels of phytochemicals or vitamins, increasing the potential marketing appeal of these varieties.

6. Dissemination:

Main publications:

Valcarel, J., Reilly, K., Gaffney, M., O'Brien, N. (2014) Effect of genotype and environment on the glycoalkaloid content of rare, heritage and commercial potato varieties. *Journal of Food Science*, 79(5), T1039-T1048

Valcarel, J., Reilly, K., Gaffney, M., O'Brien, N. (2014) Total carotenoids and ascorbic acid content in sixty varities of potato (Solanum tuberosum L.) grown in Ireland. *Potato Research,* 58, 29-41

Valcarel, J., Reilly, K., Gaffney, M., O'Brien, N. (2016) Levels of potential bioactive compounds, including carotenoids, vitamin C and phenolic compounds, and expression of their cognate biosynthetic genes vary significantly in different varieties of potato (Solanum tubersum L.) grown under uniform cultural conditions. *Journal of the Science of Food and Agriculture* Vol. 96, Issue 3, 1018-1026.

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