Nutritional value and flavour of the cultivated potato

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The European form of cultivated potatoes, group Tuberosum of species *Solanum tuberosum*, as classified by Dodds[1], took approximately 200 years to evolve from its presumed ancestral form *Solanum tuberosum* group Andigena (Dodds), following the latter's introduction into Europe at the time of the Spanish Conquest of South America. In the next 200 years, it became a staple food and provided the classic example of the dangers of over-reliance on a single food commodity during the mid-19th century when late blight devastated the crop and caused the Irish famine. Nevertheless, the potato has spread from Europe to the rest of the world, and is now the fourth most important food crop after wheat, rice and maize. The potato is capable of producing a higher yield per unit area of highly nutritious food in a shorter growing season than all of the major cereals. The tubers provide an excellent balance of carbohydrates, vitamins and minerals and potato protein is superior in quality to that of cereals, despite being deficient in the sulphur bearing amino acids cysteine and methionine (Table 1). According to the US Department of Agriculture, "a diet of whole milk and potatoes would supply almost all the food elements necessary for maintenance of the human body." It is, therefore, hardly surprising that, in the last 30 years, the proportion of the world's potato crop grown in less developed countries has increased from 11 to 30 per cent and is still rising.

Demand in the more affluent societies of North America and Europe remains more or less constant, though the proportion of the crop processed into French fries and crisps is rising constantly. With an average consumption of approximately 100 kg *per capita* per annum, the potato remains an extremely important component of human diet in the UK.

Historically, practically all research into improvement of potatoes has been directed towards removing biotic and abiotic constraints on productivity; breeding for resistance to pests and disease for example[2]. In terms of selection for quality, such efforts have largely been directed to the reduction in antimetabolites, such as glycoalkaloids, eliminating after-cooking-blackening and improving fry colour[3], the assumption being that, nutritionally, there is very little variation if any between different cultivars. Similarly, in most conventional breeding programmes, it is impossible to taste all the clones in the early generation when most genetic variation is eliminated. Thus, flavour can only be assessed on the final few clones, very close to submission to statutory trials as potential new cultivars,

Constituents	Content
Calories	**100 K**
Protein	**3 g**
Carbohydrate	**23 g**
Fat	**Trace**
	Recommended daily allowance
Dietary Fibre	**12%**
Vitamin C	**45%**
Vitamin B	**15%**
Folic Acid	**8%**
Iodine	**15%**
Potassium	**20%**

Table 1 Average nutritional contents of a single medium size (*c.* 150 g) potato tuber.

[1]Hannah Research Institute

when the breeder is unlikely to discard a clone in which he/she has invested so much time and resource unless it has an obvious taint that no-one who eats it will fail to notice.

The burgeoning interest, in the UK at least, in 'flavoursome' old varieties may not be based on sound scientific evidence but it is a commercial reality and the success of special purpose salad or punnet types such as Anya[4] suggests more effort on quality and flavour may be necessary if modern high yielding, disease-resistant varieties are to satisfy end user needs and succeed in the marketplace. Moreover, special purpose varieties which fulfil the needs of a higher added value niche in the market may represent a more attractive option to growers than standard ware potatoes at current price levels.

From Table 1, the importance of potato as a source of vitamin C is self-evident. During some of our recent research, we have produced evidence of genetic variation for both quality and flavour that could be amenable to selection and improvement if desired. In a recent SERAD-funded FF project, designed to look at nutritional traits in genetically modified (GM) potatoes, we found statistically significant variation between the non-GM controls for most nutritional traits. For example, in the case of vitamin C, one unnamed clone had more than twice the level of vitamin than the cultivar Desiree and, though there were marked differences due to site and season, the cultivars Pentland Crown and Pentland Squire also had consistently higher levels than Desiree. Another study of over 40 different tetraploid *S. tuberosum* clones and cultivars indicated a five-fold range in their vitamin C contents, from 0.2 mg/g freeze-dried matter (FDM) to 1.3 mg/g FDM (see Fig. 1). These results were from material following 6 weeks storage at 4ºC. It is known that vitamin C content in potatoes, and also in

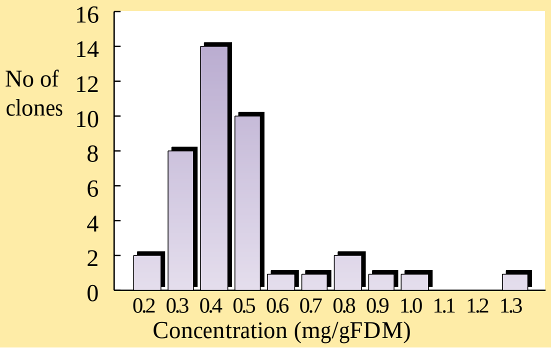

Figure 1 Distribution of vitamin C content in 40 different tetraploid *S. tuberosum* clones and cultivars.

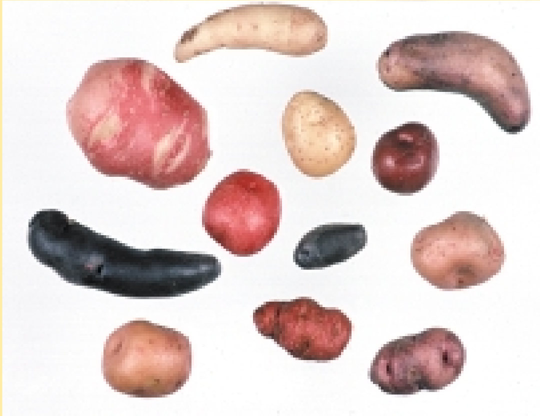

Figure 2 Diversity of Group Andigena tubers.

many perishable foodstuffs, declines during storage. The decline may be up to 50% and so such results as in Fig. 1 will be a product of both the inherent levels of vitamin C and also the effect of the genotype on the stability of vitamin C during storage. Studies are continuing to examine genotypic differences, environmental responses and also the analyses of both parents/lines and derived progeny for molecular markers associated with this important nutritional trait.

Starch is the major component of potato dry matter. It is generally accepted that the amylose component of potato starch ranges from 18-23% but, in a very limited sample of SCRI breeding material, we have identified clones with amylose levels down to 16% and as high as 30%. Amylose/amylopectin ratios will affect the properties of the starch which could include organoleptic characteristics too but these have not been exploited.

In South America, at least seven forms of cultivated potato are still grown and some attract a premium because of their eating qualities.

Broadening the genetic base of the European potato by the use of landrace and wild material has permitted great improvements in pest and disease resistance over many decades. Until now, few attempts have been made to include flavour in the list of traits under routine selection by breeders, and hence widening of the genepool has had a negligible effect on this trait. The potential to expand the range of flavours, textures and cooking qualities in material adapted to UK conditions is now evident. As European tastes become more adventurous, exploiting a wider range of variation for these traits is increasing in priority. Collections containing landrace material of cultivated

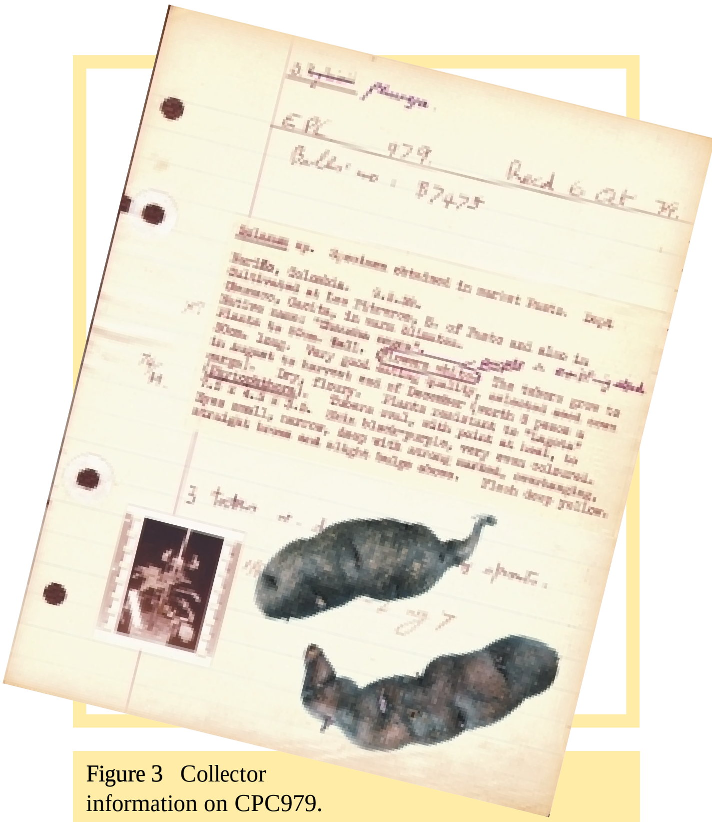

Figure 3 Collector information on CPC979.

accessions, such as the Commonwealth Potato Collection (CPC), can provide a tremendous wealth of variation for flavour and cooking quality traits as well as wide variation in tuber form and colour (Fig. 2). Such variation is generally greater in landraces from the central Andes, such as those from Group Stenotomum and Group Andigena, than those from Group Tuberosum.

One pointer to particularly useful accessions can be found in some of the original notes made by collectors as they gathered material for the collection. Group Phureja line CPC979 for example, known as 'Chaucha Negra' to the Colombians who gave the material to the collectors, is noted for its dry, floury tubers and its very good eating quality (Fig. 3). A challenge for the future is the development of efficient means to transfer any of these interesting traits into genetic backgrounds adapted for European conditions.

Varieties of Group Phureja are widely grown in Colombia, Ecuador, Bolivia and Peru, where they are prized for their delicate yellow flesh, flavour and speed of cooking. They are generally grown for domestic use rather than as a cash crop, as they have lower yields, small tubers and sprout early in store, although 'papas amarillas' attract a premium in Lima supermarkets. Work, which began at the John Innes Institute in the late 1950s and was transferred first to the Scottish Plant Breeding Station and then to SCRI, has produced a population of Phureja which is adapted to long-day (UK) growing conditions. This was achieved by a process of cyclical mass selection and produced genotypes with higher yields, improved tuber size and longer dormancy than unadapted material[5]. The excellent cooking qualities of Phureja, however, have been retained. Some companies in the potato industry have now recognised the superior flavour inherent in this unique material, and three clones have been submitted to National List trials with a view to marketing them as novel cultivars[6].

Moreover, in collaboration with the Hannah Research Institute, it has been possible to quantify these flavour differences. A team of ten trained tasters was used to develop a suitable vocabulary of descriptors for each characteristic for use on both Phureja and Tuberosum potatoes. Useful flavour descriptors were found to be: creamy, sour, salty, bitter, metallic, and earthy; mouth-feel descriptors were: floury, sticky, dry, smooth, and grainy; and appearance descriptors were: yellow, white, cream, grainy and shiny. Intensity of each character was also recorded. Principal Component Analysis of the scores given to all sensory attributes, using the covariance matrix, found that the first two Principal Components accounted for 40% and 30% of the variance and a sensory space map of the scores for the individual samples on the first two dimensions was produced (Fig. 4). This distinguishes between the two parental groups, Tuberosum (CON cluster) and Phureja (PHU cluster). The data also showed that it was possible to distinguish between individual Phureja clones for some characters. Phureja material had a higher intensity of flavour and colour than Tuberosum with testers preferring Phureja. Clones from a hybrid progeny of a cross

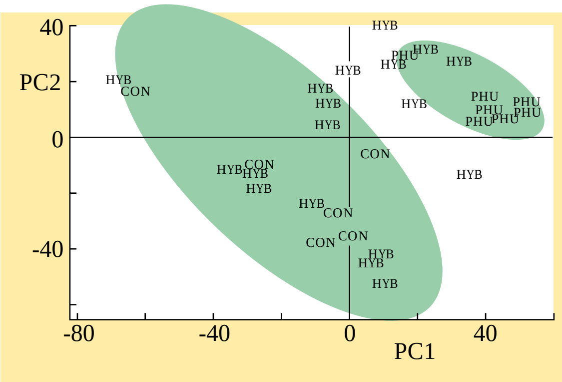

Figure 4 Sensory space map - all quality attributes.

between a dihaploid of Tuberosum (2x) and a Phureja clone were found to have characters which spanned the range between the two parental groups, indicated by the HYB plots in Figure 4.

That it was possible to repeatedly distinguish between the two parental groups of potatoes on flavour and other sensory characters, and that Tuberosum-Phureja hybrids have intermediate scores, indicates a genetic basis for the differences. Although tasting of large segregating populations is impractical, it should be possible to find molecular markers associated with these characters. Conventional breeding methods can be used to produce diploid (by the use of dihaploid Tuberosum) and tetraploid (by the use of unreduced gametes from Phureja) hybrids and, using marker aided selection, identify superior clones with Phureja flavours. Thus, there is the potential for accelerated transfer of flavour and other genes from Phureja into Tuberosum using molecular markers. Other positive quality characteristics which have been found in Phureja are generally lower levels of glycoalkaloids than in Tuberosum, less after-cooking-blackening, and enzymic (tyrosinase) browning. Enhancing Tuberosum with Phureja genes for cooking quality would introduce these desirable characteristics into varieties that are higher yielding, have larger tubers, improved tuber shape, long dormancy and, hopefully, resistance to diseases and pests, the strategic objective of most research to date[7].

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