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Keynote address: Economic well-being of the potato processing industry now and in 2010

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The aims of the conference were to consider developments over the next 10 years, foster links between research and industry, and review technical excellence to meet consumer expectations. My presentation was an overview at the end of the Conference. Ten themes were covered. ① Basic information on the potato, ② pressures for change, ③ the challenges facing agriculture, ④ global perspectives, ⑤ the central rôle of plant breeding, ⑥ GM crops – opportunities and constraints, ⑦ mergers and acquisitions in agriculturally related industries, ⑧ predictions on the future of agriculture over the next 50 years, ⑨ a SWOT analysis of the industry, and ⑩ an overall analysis of components of the potato processing industry.

1. The Potato

A native of the Peruvian-Bolivian Andes, the commercial species of the potato, *Solanum tuberosum,* is one of around 150 species: seven are commonly grown in Central and Southern America, but until now only *S. tuberosum* is grown elsewhere. There are expectations that cultivars of *S. phureja* will be adopted in several markets. Pivotal to the potato becoming the fourth most important crop worldwide is its ability to produce tubers, which are the swollen sub-apical zones of stolons – diagravitropic shoots which are normally formed below soil level. Tubers are variable in size, number per plant, colour, shape, chemical composition including toxic compounds and flavour, and dormancy of the spirally arranged buds ("eyes"), and dry-matter content. The potato plant has a complex anatomy, can reproduce sexually by forming true seed, and tends to exhibit susceptibility through to tolerance or even resistance to a wide range of pests and diseases, dependent on the cultivar. Indeed, yield is dependent on the cultivar, its efficiency in the use of water and nutrients, temperature, light (radiant flux density, spectral composition and photoperiod), pathogens, and agronomic practices. Tubers contain large, readily extractable starch grains which have special characteristics influencing their cookability and chemical and physical properties. Globally, potatoes are being grown on an ever-increasing scale, at a rate of expansion that is much greater than for most other crops. There has been reference to a "root and tuber revolution" as both the area of land and productivity of root and tuber crops have increased in recent years. Despite the fact that *S. tuberosum* has highly complex genetics (it is an autotetraploid with small, difficult-to-visualise chromosomes;*S. phureja* is a diploid), it is regarded as a facile species in biotechnological terms – it can be manipulated or modified with relative ease. Potato processing extends back centuries with chuño (or chuñu) which is the edible product produced by successively freezing, thawing, and dehydrating potatoes as practiced by the native peoples of the Andes.

2. Pressures for Change

In most of the more-developed countries (MDCs), especially members of the European Union, consumers represent an ageing population, with a tendency towards snacking ("grazing"), enjoying the benefits of improving food quality in concert with decline in the proportion of household spend on foodstuffs (less than 10% in the UK), and conscious of the linkage between diet and health. Convenience foods, sophisticated retailing, entertainment, the trend towards developing the kitchen as a fashion accessory, and eating out represent major trends favouring the uptake of processed potato products.

3. Challenges facing Agriculture

The major challenges include (a) globalisation of research and development (R&D) which will modify current arrangements for accessing intellectual property (IP) and technology transfer. (b) Mitigating the effects of many current agricultural methods which can generate pollution, erosion, unnecessary energy expenditure, infestations and reservoirs of pests and diseases, diminish biodiversity, and increase vulnerability to biotic and abiotic factors by narrowing the genetic base. (c) Sustaining and improving the Green Revolution – never have so many been fed so well. (d) Addressing some of the predicted effects of global climate change will be especially difficult, not least for a crop which has a long conventional breeding cycle to release improved cultivars. (e) Reversing the trend of a declining skill base of advanced growers and relevant scientists, engineers and technologists. (f) Developing more efficient methods are required for the transport, storage, supply regularity and packaging of relatively low-value materials and products. (g) Upgrading the associated industrial infrastructures. (h) Facing up to the "Carruthers" effect. Perhaps one of the potentially biggest changes would be if there were a reversal in the terms of trade such that the countries with the greatest populations in future dropped their emphasis on agriculture and concentrated on manufacturing, software, electronics *etc.* such that the MDCs were to become the chief suppliers of foodstuffs (the "Carruthers" effect). Certainly, by 2020 the supply of foodstuffs and the ownership of the associated intellectual property will be major political issues. (i) Adapting to political pressures. Depopulation of rural areas and greater urbanisation is exacerbating the urban-rural social and political divide, leading to political interference on the business of farming as a heavy price of subsidies. (j) Adapting to societal impedance. Often as a result of pressure groups and media activity, there is a rapid expansion in statutory and public impedance to innovation with heavyweight safety and precautionaryregulations which frequently apply to environmental issues and the production and release of foodstuffs. Even R&D can be severely restricted. (k) Meeting the needs of "organic" growers and niche markets representchallenges which will be difficult without this introduction of new technologies.

Global Perspectives

The scale of the challenges facing agriculture can be appreciated and put into context when considering the following points. (a) Continued population growth, predominantly in the less-developed countries (LDCs), will alter the balance of markets, decrease the*per capita* area of cultivated land, and put pressure on fresh-water supplies, without decreasing the demand for improvement in social standards. (b) The loss of cultivated land will continue as a result of erosion, desertification and salination (0.3% *per annum*), pollution, buildings, roads, airport expansion, potential loss of low-lying land by rising sea levels, recreational use *etc.* In the shorter term, it is not expected that land reclamation or remediation will restore substantial tracts of cultivated soil. There is the loss of one hectare of cultivated land for between 3 to 40 extra people on the surface of the earth. (c) Population growth from the level of 6bn in 1999 will probably reach between 9–12bn by 2050. Given the fact that cereal crop yields tripled between 1960-1992 on the same area of cultivated land (1.5bn hectares), the challenge is how to double production on that area by 2050 without destroying natural habitats. (d) Over 90% of traded food is dependent on just 15 plant species (rice, wheat, maize, potato, sorghum, millet, sweet potato, barley, rye, common bean, soybean, peanut, cassava, coconut, and banana/plantain) and 7 animal species cattle, buffalo, sheep, goat, pig, duck, and chicken). This represents a small genetic reservoir potentially vulnerable to weather perturbations and the depredations of pests and diseases. (e) Biodiversity is threatened by the threat of extinction of 33,000 of the known 270,000 species of plant, and the loss of at least three animal species *per* hour in tropical forests. Only 6% of forests have any form of statutory protection. (f) Potential or actual global warming induced by authropogenetically introduced accumulation of "greenhouse" gases in the atmosphere, particularly those that attenuate energy in the 8-12μm "window", point to a whole series of consequences including rising sea levels affecting prime agricultural land and settlements, weather extremes and perturbations, plant pests and diseases that can overwinter (green bridge), spreading of tropical and semitropical pests and diseases to temperate zones, increased exposure to ultra-violet irradiation, modified soils *etc.* There is great debate about potential ecosystem changes, and their rôles as buffers and reservoirs of carbon dioxide. Similarly, the speed of change may be faster than current breeding strategies, especially for woody species. Unfortunately, the complexity of obtaining adequate spatial resolution with regard to temperature changes, rainfall, and windspeed merely reflect the difficulty of predicting the nature of changes, notably their timing, magnitude, impacts, and location; and factoring in the capacity for natural adaptations to change. Volcanically induced cooling, and feedback effects (*e.g.* increased cloud cover) also add uncertainty. It is not simply a matter of using analogues, *i.e.* growing current unmodified tropical and semitropical plants in cool temperature climates, because they have specific photoperiodic, thermoperiodic and other environmental requirements.

5. The Central Rôle of Plant Breeding

Civilisation has developed on the back of breeding and selection of improved crop plants. The process of conventional plant breeding tends to be long term, involves a complex infrastructure, is costly, requires access to parental material, is based on trialling - including statutory trialling systems, and seed multiplication arrangements, followed by marketing. Further complexity comes with the setting of an array of objectives encompassing multi-gene traits, seasonal growth and dormancy, juvenility/ripeness-to-flower especially in woody species, changing pest and disease backgrounds, changing market demands, incompatibility of parental types, and sometimes managerial/sponsor interference during the breeding cycles. Rigorous selection techniques and improved data analyses leading to enhanced predictive capacity of breeding still do not compensate for the exceptionally tight financial margins in conventional commercial breeding. For the potato, the prolonged utilisation of old-fashioned cultivars, often demanding of high inputs, and as a consequence the absence of plant variety rights or patent protection merely exacerbate the situation. Without improved cultivars, however, the sheer adaptability of pests and diseases to break down natural resistance mechanisms would, with time, make most of agriculture largely uneconomic and environmentally unacceptable. Biotechnology provides accelerated, targeted breeding strategies that are not reliant on selecting vast numbers of plants.

6. GM Crops – Opportunities and Constraints

According to Clive James of the International Service for the Acquisition of Agri-Biotech Applications (ISAAA), the estimated global area of transgenic (or genetically modified) crops for 2001 is 52.6m hectares, an increase of 19% over the area grown in 2000. The four principal GM-cultivating countries were the USA (68% of global total), Argentina (22%), Canada (6%), and China (3%). The principal crops were GM soybean (63% of global area), GM maize (19%), GM cotton (13%), and GM oilseed rape (5%), and the dominant improved traits were herbicide tolerance and insect resistance. This increase in global area was achieved in the face of unprecedented levels of hostility from pressure groups, most notably in Europe, that constrained market developments without justification on either health or environmental grounds when compared with conventional or organic crops.

GM potato occupied a relatively small area, despite its tendency to demand high agronomic inputs and leave a relatively heavy environmental footprint. Perceptions, no matter how ludicrous, undeserved or unbalanced, translate into market reality. The widely publicised Pusztai debacle, involving experimental material that was not designed at all for human consumption, was a huge setback.

Nevertheless, the sheer potential and actuality of GM crops will fundamentally reshape agriculture and the agricultural supply and processing industries, regardless of the approach currently adopted in Europe. They have the ability specifically to meet end-user needs.

There are three generations of transgenic crops. The first generation is aimed at crop protection, addressing weed control by introducing herbicide tolerance, as well as resistance to pests and diseases. Strategies are in place to overcome the possible build-up of counteracting resistance mechanisms in pests and diseases by stacking and mixing of key genes. Second-generation transgenic crops are designed to improve yield efficiency and quality. They focus on modified carbohydrate quality for industrial feedstocks and food processing, oil content and quality, amino acids and proteins, fibres, bioplastic substrates, tolerance to abiotic and biotic stresses, water-use and nutrient-use efficiency, photosynthetic efficiency, reductions in anti-nutritional and allergenic factors, modified colours and shapes, easier harvesting and storage, and hybrid-crop production. Third-generation transgenic crops encompass the production of pharmaceuticals, including vaccines, production of nutraceuticals, crops to restore contaminated land, water and the atmosphere (phytoremediation). More sophisticated technologies are being deployed and/or investigated, including switch technology to trigger or switch off changes in growth and differentiation, gene-use restriction technology, organelle transformation, virus-vector technology to avoid changes n the host genome, and the development of methods to target specific integration sites in the genome.

Technical hurdles remain, but are being eliminated as virtually all crops can be transformed. There remains the challenges of choosing the right parental material, climatic suitability, possible backcrossing, and most importantly, end-user and consumer acceptability.

Adverse publicity, most notably from the active pressure groups has centred on the use of antibiotic-resistance markers in the first releases of GM crops, the possible inadvertant induction of allergens and toxic metabolites, potential undesirable gene flow in the environment, loss of biodiversity, and the undesirable social consequences of vertical integration of farming with food processing and the agrochemical industry, most notably by multinationals based in the USA. Many of the protestors are anti-capitalist, anti-profit, and anti-science, too. Even so, at the time of preparing this article, over 70% of the global seed trade is controlled through the public sector. Virtually all of agriculture and horticulture – especially domestic horticulture, involves plants alien to the countries and continents in which they are grown, as well as their pests and diseases. Over 60% of crops grown in the LDG are *de facto* alien to those countries.

7. Mergers and Acquisitions in the Agriculturally Related Industries

As the profitability of agricultural primary production has fallen, in tandem with declining political influence, massive increases in imposed regulations, audit and quality-control arrangements, and retailer and end-user demands, there has been the development globally of larger farmer units, co-operatives and groupings to ensure continuity of supplies and quality assurance. Likewise, in those companies concerned with "upstream" activities (*e.g.* breeding, agrochemicals) the costs of introducing innovation, defending intellectual property, and meeting shareholder expectations have led to mergers, acquisitions, joint ventures, confidentiality agreements, and linkages of various kinds. Technological advances would inevitably lead to integration of seed companies and life science companies as the technologies converge, but investor and analyst perceptions do not favour such convergence during a period of poor perceptions and low profitability of agriculture. As a consequence, company structures at present tend to be somewhat fluid.

8. Predictions on the Future of Agriculture over the Next 50 Years

Agriculture will remain diverse, commensurate with the diversity of climates, locations, and social systems. Some parts of agriculture will have a historical edge, reflecting the preferences of some and the needs of tourism, other aspects of agriculture will address recreation and acting as the lungs and kidneys of the urban population, and political preferences to sustain rural populations. The bulk of agriculture, however, will have access to (a) a vast range of high-health-status propagules of known genetic status, (b) automation, with a marked reduction in the numbers employed directly in agriculture, (c) microsite engineering, (d) management and decision-support systems for agronomic and market uses, (e) efficient transport, storage, quality-assessment, and value-added process, (f) fresh water in designated areas (g) reliable weather forecasts, (h) greater use of physical protection systems, (i) dignified maintenance of livestock, (j) reconfigured genomes and greater use of regenics to restore lost genotypes, (k) new germplasm sources, but the debate on the ownership of genetic resources will rumble on, (l) the capability to restore damaged landscapes, (m) new technologies arising from advances in metabolomics and diagnostics that will severely challenge 'organic' and 'natural' food claims, (n) enhanced bureaucracy, (o) contract production methods that will supplant traditional markets, (p) greatly improved profitability, (q) further mergers and acquisitions, (r) greater diversity of food types, and all-year-round supplies, (s) as will have been evident by 2020, agriculture will have returned to become an economically, scientifically, technologically, socially, and politically dominant activity in line with the social and economic power offered by the control of food supplies and the associated intellectual property.

9. A Strengths, Weaknesses, Opportunities and Threats (SWOT) Analysis of the Potato Processing Industry

STRENGTHS

- An expanding industry
- Increasing sophistication and the scale of investment needed makes it harder for new competitors to enter the market place
- Convenience-friendly
- Value-added founded on low-cost primary produce supplies
- Strong marketing strategies; strong brand images
- Willingness to communicate with other parts of the industry
- Lots of OPPORTUNITIES – dynamic

WEAKNESSES

- Stream of new products needed offering fundamental variants on current products
- Competition with cereal-based products
- Components of the supply chain do not have common objectives. There is an "inverted thermodynamic funnel" arrangement of thousands of growers operating with great expenditure of energy (*i.e.* "entropic") and with low profitability and market influence, feeding

up into relatively few processors, and then up to even fewer major supermarket chains that ultimately reap the benefit of value-added profitability (*i.e.* "negentropic" as they grow more powerful and complex), and influence the purchasing behaviour of consumers. The funnel profile is bound to change as the supply base condenses with horizontal integration, and more frequent vertical integration.

- Reliance on the retailer system
- Several THREATS

<u>OPPORTUNITIES</u>

- New types of science, engineering and technology (especially genomics, proteomics, metabolomics, bioinformatics, artificial intelligence and expert systems, advances in the social and economic sciences *etc.*) are revolutionising breeding, agronomy, processing, packaging, presentation and marketing, food and non-food uses, waste control, deployment of biosensors and enzymes *etc*. The crop has not yet reached its yield and quality potential.
- New products and processes, all offering protectable intellectual property
- New markets and marketing strategies in tune with the globalisation of convenience diets, the evolution of the World Trade Organisation, the expansion of the European Union, and accelerated urbanisation.

<u>THREATS</u>

- Linear thinking, failing to take on board new concepts and approaches, innovation and changing consumer expectations
- Imposition of environmentally sensitive contracts to reduce the environmental footprint of potato crops. This may drive the industry

to operate with improved cultivars which will also offer the added benefit of exclusivity

- Retailer controls and impositions, driving down profitability (to transfer it to the supermarkets?). A change in purchasing habits may in turn eventually weaken supermarket influence)
- Anti-technology and 'foody' pressure groups and media personalities/journalists that want to impose controls on what they regard as the nutritionally unacceptable *i.e.* use of the potato to convey oils, fats, grease or lard to the gut
- Taxation impositions by governments if the industry is seen to be "too" profitable. Often carried out in close association with regulatory impositions, governments have a long history of weakening their economic strengths
- New attacks or outbreaks of pests and diseases, or weather perturbations
- Restrictions on the use of fresh water, and burgeoning discharge costs
- Projected population declines in many existing markets
- Bad publicity or litigation relating to safety, health or environmental failures

10. An Overall Analysis of Components of the Potato Processing Industry

- During the Conference, we considered seven components of the industry.

(a) MARKETS

- Global *versus* local requirements – it is imperative not to assume that the two are the same, although there is a growing commonality in the demand for convenience foods
- Fresh *versus* processed – perceptions and stated preferences are not the same as reality
- The seed potato market is a specialist area, required to sustain high phytosanitary standards of clonally propagated material
- New markets could be envisaged for products covering convenience foods, health foods (functional foods, nutraceuticals), industrial feedstocks *etc*
- The industry has to adapt to consumer sophistication, government imperatives, international trading, and the actions of pressure groups and media-conscious activists

(b) <u>GENETICS & BREEDING</u>

- Access to germplasm collections to acquire parental material is becoming an issue, extending to accessing specific genes
- Conventional and biotechnological breeding strategies are changing. Access to the new technologies ("freedom to operate") is also an issue, as is exclusivity of use of improved cultivars.
- Consumer perceptions now focus on the process rather than the products of breeding
- Longer-term prospects for the new technologies are buoyant

(c) <u>CULTIVATION OF POTATOES</u>

- New agronomic methods, concepts and management tools now assist in planning, growing and harvesting of crops appropriate for the type of market segment

(d) <u>ENVIRONMENT</u>

- Modern techniques need to be adopted to lessen the environmental impact/memory of the crop (*e.g.* nitrogen, nematocides, insecticides *etc.*)
- Genotype by environment (GXE) interactions mean that the growing environment needs to be carefully monitored
- Statutory regulation may mean that the costs of cultivating potatoes in the current major growing areas will increase
- Post-factory remediation or utilisation of waste water and solids will become higher profile, leading to increased production costs

(e) <u>POST-HARVEST</u>

- Storage conditions of the potato crop influence tuber dormancy characteristics, sensitivity to bruising, composition, texture, cooking quality and derived waste
- Some tuber qualities may be enhanced in storage, and surface contamination can be readily removed
- More sophisticated energy-efficient storage systems need to be deployed to a much greater extent. Temperature, gaseous composition, and applied chemicals need to be monitored, and automated handling, sampling and quality-control systems incorporated

(f) <u>PROCESSING</u>

- Improved preparation of tuber material, processing and packaging systems are needed
- New methodologies (slicing, secondary processing, cooking, use of additives (fortification) and flavourings, preservation of the processed product, including the prevention of photo-oxidation, replacement of current generation of fats and oils, *etc*) need to be introduced

- The potential for non-food products, medicinally related products and multi-purpose potato crops needs to be explored

(g) MARKETING

- Continued dependence on a few major retailers for marketing narrows future options for change
- A stream of new presentation strategies is essential
- Due allowance needs to be made for the expansion of one-person households, ageing populations, "grazing" or snacking, expansion of the restaurant, café, hotel and entertainment sectors, and the growing awareness of the linkage between diet and health
- Safety and vulnerability to litigation will be an increasing burden, demanding management time and resources. Failures will receive stunning levels of publicity. People are highly aware of what they put in their mouths. Food irradiation will become acceptable.

(h) INTELLECTUAL PROPERTY

- IP is pivotal to the industry, different segments of the industry must safeguard themselves against new entrants or associated bodies that generate or acquire IP that will impinge on their activities
- Since 1980, there were more than 4,000 patents and 12,000 scientific articles on potato biochemistry and pathology alone. Areas to watch include patented genes that can modify crop performance or processing quality; diagnostics for pests, diseases and quality characteristics; sensors; software; transgenic plants and microbes; agrochemicals; and automated analytical and processing instrumentation.

(i) MANAGEMENT

- Supply-chain management, integration of activities, and financial-management systems are crucial

- Development of shared common objectives from the seed producer to the retailer is needed

Finally, I thank the organisers and sponsors of the Conference for all their efforts.

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