Invited Speaker Plenary 3: Gene-Nutrient Interactions

Delivering nutrition and health benefits through genetically-modified plant-based foods

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Plants are the mainstay of human diets, either through their direct consumption, or as the primary source of nutrients for marine and terrestrial animal production. The plant kingdom is comprised of an enormous species diversity that exhibits a vast array of chemical compositions in both vegetative and fruiting tissues. This diversity results partly from different plant species implementing different adaptive responses to the various environmental challenges they faced during evolution, and also partly from purely random variations that have no consequences for plant fitness but are maintained in species because of their selective neutrality. Thus, plants did not evolve their specific chemical compositions in order to meet the particular nutritional requirements of humans, but in response to their own survival imperatives. Humans have simply chosen from within this abundant variety, a limited array of plant foods that are primarily safe to eat, provide sufficient essential nutrients for life and reproductive fitness, and that are desirable to our tastes. Most of these plants foods have been taken into cultivation since the advent of agriculture and have been selectively bred to further improve their yield, performance, consumer appeal and, in some cases, nutritive value.

Through advances in human nutritional research we have an increasing understanding of the relationship between the chemical composition of our food and the status of our health and well-being. We now recognise the role of a wide range of nutrients, vitamins and minerals in our general health and the impact that deficiencies in these can have in bringing about specific illnesses. In recent years, much has also been learnt about the role of particular "bioactive" compounds in alleviating or controlling a range of degenerative diseases that are increasing in prevalence in the now long-lived populations of the developed world. The roles of specific fatty acids, sterols, antioxidants, and other metabolites in reducing risk of cancers, cardiovascular disease, inflammatory conditions, and neurological disorders are being widely acknowledged and the mechanisms of these effects are being unraveled. Not surprisingly, it is being revealed that many traditional foods selected in much earlier times for safety, culinary appeal and basic nutrition by humans having a significantly shorter life span, are either lacking or deficient in many of these bioactive compounds that have favourable impacts on the degenerative diseases of older populations. For example, land plants lack any of the long-chain polyunsaturated fatty acids (LC-PUFA) that are present in marine microalgae and fish and which have been shown to have valuable health benefits in prevention and control of a range of diseases. Similarly, phytosterols having significant LDL-cholesterol lowering properties occur naturally in our food oils at concentrations that are too low to have significant health benefits at normal dietary intake levels. Although such shortcomings in our diets might be able to be alleviated at least in part through changing the spectrum of foods that we eat, this is not always feasible or practical, and has proved a frustratingly difficult strategy to implement in both developed and undeveloped cultures. In recent years, an alternative strategy has been adopted by the food industry through the fortification of foods during processing with nutritionally desirable bioactives extracted from enriched sources. These so-called "functional foods" attempt to provide nutritionally effective levels of bioactives in mainstream foods that are already well-accepted by consumers. Although this may be an effective strategy, it can also be a costly one, particularly where the source of the bioactive is relatively rare or the costs associated with its development as an ingredient are high. For instance, the high costs of phytosterol extracts contribute substantially to the large price premium for cholesterol-lowering spreads containing phytosterol esters compared to conventional spreads. Large premium prices can restrict the widespread adoption of these beneficial products, thereby limiting the extent of public health benefits achieved and also raising issues of nutritional equity.

An alternative strategy for delivering nutrition and health benefits associated with specific bioactives is to genetically enhance (bio-fortify) the levels of these compounds in food raw materials through the use of plant biotechnology. The presence of a bioactive compound in an organism is simply the result of it having specific genes that encode the enzymes responsible for the synthesis of that compound. The appropriate genes from a source rich in the bioactive can now be cloned and transferred to mainstream food plants to equip them with the ability to synthesise nutritionally effective levels of the bioactive. Using this approach, Golden Rice was recently developed to contain sufficient β-carotene to avoid vitamin A deficiency in populations consuming rice as their staple food. Similarly, plants are now being developed to contain the essential LC-PUFA such as EPA and DHA, to overcome our reliance on dwindling fish supplies for these important nutrients. The bio-fortification approach has potential to be applied to a range of other nutrients and bioactives that are now being revealed to have significant benefits to human health and well-being, and in many situations may be more attractive than the current approach of ingredient fortification.