Biotechnology in New Zealand

An agricultural and environmental perspective

Max J. Kennedy and Selwyn C. Yorke

New Zealand has strong agricultural and horticultural resources. Biotechnology is vigorous and flourishing and the future is promising. Applications of genetic engineering and biotechnology are progressing well in agriculture and food production, animal husbandry, forest conservation and environmental security. This article discusses the status of the biotechnology applications with special reference to agriculture and environment.

Dr. Max J Kennedy
Biopharmaceuticals Manager
Industrial Research Ltd
PO Box 31-310, Lower Hutt
New Zealand
Tel: (+64-4) 569 0000
Fax: (+64-4) 5690132
E-mail: m.kennedy@irl.cri.nz
http://www.irl.cri.nz/biopharm
Dr. Selwyn Yorke
President
New Zealand Biotechnology Association, Research Manager, New Zealand Pharmaceuticals Ltd, PO Box 1869 Palmerston North, New Zealand
Tel: (+64-6) 325 8676
Fax: (+64-6) 325 8698
E-mail: selwyny@nzp.co.nz
http://www.nzp.co.nz

Introduction

During the first half of the 20th century, New Zealand's economy developed around meat, wool, dairy and forestry exports. This was a logical outcome of New Zealand's location in temperate latitudes, its good quality soils for land-based production and its limited mineral resources.

New Zealand's investment in research and development has helped improve the quality of commodity produce, added value to meat and wool processing, diversified milk products and improved on-farm productivity. The evolution of biological technology in New Zealand has led to a strong interest in biotechnology. A number of industries have emerged as a result of the strong emphasis on plant and animal science.

New Zealand has several unique attributes that make it a high quality food exporter. It is an island nation, so the ocean provides a valuable natural barrier to pests and diseases. It has a large proportion of fertile land, with no serious or List A animal diseases, and a relatively small human population. The native plants and animals are unique and it has some of the most ancient tree and plant species in the world.

Defining biotechnology

One outcome of the agricultural and horticultural strength of New Zealand was the adoption by the New Zealand Biotechnology Association (NZBA) of a slightly broader definition of biotechnology than that of the OECD. New Zealand's definition of biotechnology is: "*The application of scientific and engineering principles to the processing of material by biological agents and the processing of biological materials to improve the quality of life*".

This definition of biotechnology includes natural products, which the NZBA defines as "*goods of natural origin (ex*

isting in or by nature, not artificial) which are unprocessed or minimally processed".

An outcome of the definitions is that the NZBA has a wide membership, including interested members of the public, and scientists and marketers from private companies, Government research institutions and universities.

The constitutional objectives of the NZBA are to:

- Nurture the improvement and diffusion of biotechnology in New Zealand;
- Represent the interests of those concerned with biotechnology in New Zealand;
- Provide a forum for interaction among the disciplines involved in biotechnology; and
- Foster an environment conducive to the growth of biotechnology-based industries in New Zealand.

Foresight Project

In 1999, the New Zealand Ministry of Research, Science and Technology created the Foresight Project to gain insight into New Zealand's vision of itself in 10 years time. This was a key part of some recent major changes behind the philosophy of public funding of research. These changes will impact heavily on New Zealand's science research directions and will have a beneficial outcome for biotechnology in the country.

In association with Biotenz, the biotechnology products export industry-based organization, the NZBA submitted a document to the Foresight Project called "The Industrial Biotechnology and Natural Product Sectors 1998 - 2010". This document, available on the NZBA's website (www.biotech.org.nz), gives an overview of where these organizations see biotechnology in New Zealand in the year 2010. This approach has been used to assist the Ministry for Research, Science and Technology in refocusing its funding of government funded research.

An outcome of this strategy has been an increased interest in the funding of biotechnology known as the Strategic Portfolio Outline (SPO) for Advanced Biological Enterprises. Although the SPO is vital for biotechnology, funding of biotechnology in the medical and health industries remains. Additionally, horticulture and agriculture as well as the more specific food and animal based industries have biotechnology components. The changes in philosophy by successive New Zealand Governments will provide a considerable boost to research, science and technology in biotechnology and, in general, to the natural products industry.

The state of biotechnology in New Zealand is vigorous and flourishing. The Crown Research Institutes are focussed on high quality research and on commercializing opportunities. The private sector is small but growing rapidly in both numbers of businesses and export sales. Natural products will continue to play an important role in exports from New Zealand. However, over the next decade, we shall see changes in the type of exports because of the application of new intellectual properties and new high-tech manufactured products.

Inquiry into GM

The New Zealand government established a Royal Commission of Inquiry into Genetic Modification. This commission has a broad brief to inquire into and report on the strategic options available to enable New Zealand to address genetic modification now and in the future. It can recommend changes to government policy and legislation. The Commission will review the current status of genetic modification in New Zealand, weigh the risks and benefits, the current evidence and the uncertainty about the application of genetic modification. The Commission will also consider the responsibilities associated with cultural and ethical issues, the environment and the possible outcome of either proceeding with or stopping development of genetically modified organisms, among other criteria.

The review could have far-reaching ramifications for the future of biotechnology in New Zealand. One of the possibilities in genetic modification in New Zealand is the potential to produce new pharmaceuticals through novel plant or animal production technologies. Another important effect of genetic modification could be the development of new methods of reducing the damage inflicted on pastures and the hill-side soil erosion (by rabbits, goats and pigs) or on native bird and forest populations (by possums and rodents). New technologies are under development to ensure a safer and more targeted poison delivery to these pests as well as research into the fertility of these pests that could lead to biotechnological methods of reducing animal pest fertility.

An outcome of this Royal Commission will be the resolution of uncertainty regarding the degree of high level biotechnology that will be permitted in New Zealand. Some New Zealanders believe that if the major food products produced in this country are GMO-free, the country may gain a competitive advantage in exports. Others, however, believe that the country should embrace genetic modification, with appropriate risk assessment, to produce "improved" herds and crops. These improvements could increase pest resistance, thereby reducing chemical use and chemical residues in the food supply, as well as producing crops with increased yields and/or improved post-harvest stability.

Fresh and minimally processed foods (fruit or vegetables) are growing exports from New Zealand and may gain even greater market acceptance if improved post harvest freshness can be introduced. New Zealand's research institutes are using advanced conventional technologies to achieve this outcome. New styles of high quality fruit, fresh vegetables and high quality chilled meat and fish are being developed without the need to introduce genetic modification.

New organisms

The Government authority that controls the importation and creation of new organisms is the Environmental Risk Management Authority (ERMA). ERMA's function is, in part, to consider applications to introduce hazardous substances and new organisms into New Zealand. ERMA is also responsible for monitoring compliance with conditions attached to approved applications.

ERMA has recently allowed the creation of a research flock of genetically modified sheep and a herd of genetically modified cows under strict controls. The sheep flock has been developed by the Scottish company PPL with the aim of producing a pharmaceutical protein in sheep's milk[1]. The dairy herd is being developed along similar lines by AgResearch[2], the intention being to produce another pharmaceutical in bovine milk that might successfully treat multiple sclerosis. Both herds are very securely con

tained and all wastes are to be treated to avoid release of foreign DNA into the environment.

Forestry has become a major export earner for New Zealand, and millions of tonnes of *Pinus radiata* logs are exported each year. Very sophisticated non-recombinant cloning technologies have been developed in New Zealand to mass-produce the highest quality trees for lumber production.

Forestry trees, however, are susceptible to various diseases that can be very destructive. Consequently, considerable research has gone into developing an appropriate genetic modification to introduce disease resistance to the trees. ERMA is currently seeking public submissions before it makes a decision on whether to allow the modification to undergo a field release[3].

Advisory council

Another contributor to the genetic engineering debate in New Zealand is the Independent Biotechnology Advisory Council (IBAC). IBAC's role has been to stimulate informed debate and enhance public understanding of biotechnology. It also surveyed public opinion on the place of biotechnology in society.

IBAC concluded[4]: "*The public's views of the various roles that biotechnology could have in New Zealand varied from embracing the technology to a complete ban on it in this country. However, there was some confusion over the definition and scope of the term "biotechnology". Some respondents used it in its broadest sense, that is, a set of scientific techniques. Others used it with reference only to specific techniques such as genetic engineering.*"

The confusion over the definition of the word "biotechnology" is of concern to the NZBA who wish to emphasise that biotechnology is not a synonym for genetic engineering, but encompasses a wide range of technology, from traditional and appropriate technology right through to the most sophisticated medical or modern technology.

IBAC's survey also summarized the major risks that are of concern to the public[4]: "*Notwithstanding this confusion, the majority of respondents could see applications for certain aspects of biotechnology, primarily for medical applications. However, they urged extreme caution and highlighted the following provisos:*

- *The development of moral and ethical leadership and debate in the arena of biotechnology is required.*
- *A legal and regulatory framework for biotechnology to develop and operate in is required.*

The major risks identified by participants of this consultation focussed largely on agricultural applications of biotechnology. These are summarized below:

- *The centralization of power with large corporations, and their perceived lack of integrity.*
- *The unknown risks and inability to contain genetically modified organisms.*
- *The loss of biodiversity and the threat to the natural order.*
- *Concern about specific processes using genetic engineering.*"

Concern about biodiversity

One area of significant concern to New Zealand is biodiversity. New Zealand has been relatively isolated since its geological break from Gondwanaland, and human habitation began only in the last 1,000 years. Protecting the unique biodiversity of New Zealand is a focus of the recently introduced Biodiversity Strategy[5,6], which quotes New Zealand's stock of native species as follows:

"A*bout 20,000 indigenous terrestrial species have been described in New Zealand so far. These include: 700 protozoans; 3,080 plants, 5,800 fungi; 10,000 insects; 2,600 arachnids (spiders and mites); 200 myriapods (millipedes and centipedes); 500 snails and slugs; 1,000 worms (nematodes, earthworms and flatworms); four frogs; 61 reptiles; 88 birds (land and freshwater); and two bats. It is estimated that the true number may be closer to 70,000 species.*

"Small, spineless or subterranean, our most diverse groups of indigenous species on land (fungi, insects and worms) are the least known and appreciated. Fungi, for example (estimated at around 20,000 species) play a vital role in ecosystems in breaking down and recycling nutrients.

"New Zealand has lost a significant proportion of its large native land animals. As far as we know, in fewer than 1,000 years human-induced extinctions include:

- *32 per cent of endemic land and freshwater birds;*
- *Three of seven frogs;*
- *One of three bats;*
- *Three of 64 reptiles;*
- *11 of the 2,300 known vascular plants; and*
- *At least 12 invertebrates, such as snails and insects.*"

Biotechnology and environment

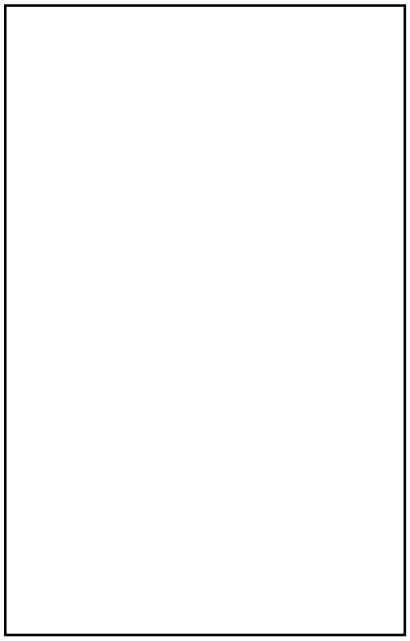
Biotechnology has an important role in environmental issues in New Zealand. As mentioned above, the export of high quality food products is a critically important industry for New Zealand. Many scientists are using advanced biotechnology methods (but not exploiting genetic modification) to ensure that food exports will grow and remain competitive with the rest of the world. More information can be gained on this topic by an examination of the Research Institutes and universities websites, especially Crop and Food Research, HortResearch, AgResearch and Massey University.

Modern biotechnology is being used to improve technologies associated with the introduction of new crops, crop management, post-harvest care and pest resistance. Several safe micro-organism biocontrol agents are now in the marketplace, and more are being developed using modern biotechnology without requiring genetic modification.

Another area in which New Zealand is very strong is the production of animal vaccines, both by conventional methods and by the production of genetically modified organisms to produce them. Schering Plough, CSL and AgVax are producing new vaccines for use in the New Zealand animal health sector and for export.

The natural product industry is also of great significance to New Zealand. Markets are both national and international. The US market for natural products (including health food) was estimated to be US$ 7.5 billion in 1995, up 23 per cent on 1994. The New Zealand market for natural health products is estimated to be NZ$ 60 million per annum, with New Zealand exports of natural health products being worth NZ$ 30-60 million per annum [7,8]. Echinacea and St John's Wort have been recent popular products (Figure 1).

Figure 1: Echinacea and St John's Wort processing at Industrial Research Ltd



Rights over native plants

A key challenge for the natural product industry is the question of indigenous peoples' rights over native plants. This issue will be decided in New Zealand when the Waitangi Tribunal hears Claim 262, which deals with Maori rights over New Zealand's native *flora* and *fauna*[9]. Also of significance is the Mataatau Declaration. This declaration was made at the First International Conference of the Intellectual Property Rights of Indigenous Peoples held at Whakatane in June 1993 and convened by the nine tribes in the Bay of Plenty.[10]

Also of future impact will be the implementation of the UN Convention on Biological Diversity, which resulted from the United Nations Conference on the Environment and Development of Rio de Janeiro from 3-14 June 1992 (the Rio Earth Summit). In 1992, New Zealand signed the Convention, which contains various principles - especially Principle 22 (Agenda 21) - relating to the rights of indigenous peoples[11,12].

Claim 262 is of great significance to those wanting to utilize native plants and has been catalytic in presenting the issue of Maori intellectual property rights over native plants before a wide audience. Maori sensitivity to this issue is high, and in general this is one reason the natural product industry is wary of becoming involved with native plants. However, New Zealand native plants do offer a unique competitive advantage for New Zealand in that other countries are unlikely to have access to New Zealand native plants, and those enterprises which can find solutions to this issue will be well placed to benefit.[8]

Agricultural "co-products"

Part of the natural product industry, but one where New Zealanders have excelled is the processing of agricultural by-products into profitable, fashionably termed co-products. Apple pomace and kiwifruit wastes provide two recurring popular examples.

Apple pomace is the press cake resulting from pressing apples for juice. The uses of apple pomace can be broadly classified as either a waste reduction strategy, e.g. animal feed, fuel use or composting; or obtaining a high value product, e.g. aroma or pectin production; or preferably both. In terms of getting the apple pomace off site and away from the processor, human food incorporation, animal feeding, composting, landfill, and fuel use have been most popular. Apple pomace has been fed to cattle, sheep, pigs, horses, deer, bighorn sheep, rats, rabbits, geese and insects[13]. Cost of disposal is the driving force for seeking new pomace uses. A problem arises with transport costs. It is uneconomic to transport the pomace far. Garrity[14] analyzes the trade-off between transport costs and utility of the product. Transport costs would be much reduced if the pomace was first dried, but this is uneconomical. Fermentation of apple pomace has been popular. Products such as single cell protein (SCP), ethanol, citric acid, butanol and enzyme production have been attempted. All of these, with the possible exception of enzymes, have been low-value commodity produce, making profitable processes difficult to achieve. The same applies to the extractive processes of pectin and oxalic acid production. The higher value products, apple seed oil, aromas and xyloglucan production, offer some hope, but the problem remains of what to do with the waste after these products have been made.[15]

Kiwifruit is known worldwide as an attractive green fleshed fruit. Large-scale commercial growing began in New Zealand, and as the fruit transitioned from a high value item to a more common commodity, more effort went into recovering value from the waste (or co-products). New Zealand, in particular, has been keenly involved in the hunt for added value uses for kiwifruit. The grower and processor have one urgent aim; to get the waste dealt with as soon as possible and preferably off site. Thus the aim of finding uses is to reduce waste volumes or to find a high value product, preferably both.

One of the first efforts in using reject kiwifruit went into producing kiwifruit juice (Figure 2). This highlighted the problem that treating kiwifruit juice at high temperature and under the acid conditions of the juice itself meant that the kiwifruit chlorophyll degraded to pheophytin. Thus the kiwifruit juice and canned products were olive green/brown instead of bright green. Much effort then went into retaining the chlorophyll, and hence the bright green colour, and was successful.

Following this hurdle, the next breakthrough was the development of kiwifruit wine, popular at tourist outlets in New Zealand. This was followed by distilled kiwifruit liqueur and kiwifruit vinegar. Preston Group Ltd started the only kiwifruit vinegar production facility known to the authors in Tauranga. This product, vinegar with excellent flavour characteristics, is innovatively used by New Zealand food manufacturers. Kiwifruit vinegar must rank as one of the most underutilized uses of kiwifruit wastes.

One of the most intensely studied kiwifruit products is the proteolytic enzyme actinidin, which has been promoted as a meat tenderizer. For many years the economics of the production of actinidin were not considered favourable. Part of this pessimism was due to strong competition from widely available products such as papain, which one author estimated is available for one third to one half the cost of producing actinidin[16]. Despite the pessimism, as the mode of action of the proteolytic activity has become better understood, niche uses for actinidin has meant that the enzyme is now manufactured by New Zealand Pharmaceuticals Ltd, to a food grade quality. A host of other enzymes from kiwifruit have been studied, mainly in relation to post harvest treatment. None of the other enzymes in kiwifruit have re

ceived the same level of commercial attention as actinidin.

Pectin and vitamin C production from kiwifruit have also been considered, but the pectin was not sufficiently distinct from other fruit pectin to warrant development. Animal feed and landfill must surely be the methods of last resort for disposing of kiwifruit wastes. Minimally processed food provides a new paradigm for kiwifruit processing and this offers a new avenue for fruit producers.

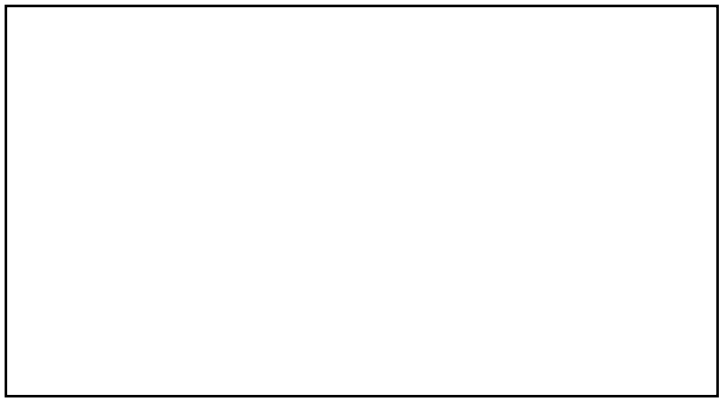
One use not considered to date but which may be worth investigating is the use of kiwifruit pomace as a mushroom compost ingredient. Trials on apple pomace have proved successful.[17] Minor products such as aroma products[18], enzyme inhibitors and cell wall components are of research interest currently but may expand in the future.

Two other kiwifruit vine products deserve attention although these are not related to the fruit. These are kiwifruit mucilage and kiwifruit pollen. Kiwifruit mucilage is the polysaccharide exudate produced from pruning wounds. Its use as a lubricant has been touted. Kiwifruit pollen also offers potential as a novel, natural health product related to its free radical scavenging and other activities. Commercial development is still awaited.[19]

Conclusion

In summary, biotechnology is playing a significant role in the New Zealand economy and contributing to the well being of New Zealanders. There are two biotechnology industry groups in New Zealand, which promote biotechnology; the NZBA (www.biotech.org.nz) and Biotenz (www.biotenz.org.nz).

The New Zealand government has been increasingly involved with biotechnology by reorganizing its science and technology funding, establishing an Independent Biotechnology Advisory Council, and setting up a Royal Commission of Enquiry into Genetic Modification. The New Zealand Government controls genetic modification through its Environment Risk Management Authority. Biotechnology and natural products are a significant and rapidly growing industry in New Zealand, and take advantage of New Zealand's traditional strength in agriculture and its rich biodiversity. New Zealand is well placed to benefit from the biotechnology revolution.



References

1. PPL GM sheep; http://www.rsnz. govt. nz/archives/news_pre_oct99/news/ y_1999/m_03/d_23/a_12. php
2. AgResearch GM cows; http://www. ermanz.govt.nz/NewsIssues/files/ PressReleases/2000/pr20000 725.htm
3. ERMA, 2000; http://www.ermanz. govt.nz/search/srch_text.asp
4. IBAC "Public Views on the Biotechnology Question", August 2000.
5. Department of Conservation and the Ministry for the Environment, "The New Zealand Biodiversity Strategy, Our Chance to Turn the Tide", February 2000.
6. Ministry for the Environment, "The State of New Zealand's Environment, 1997".
7. Shaw, R., "Commercialization of a Natural Ingredient". New Zealand Biotech: A Commercial Review: The Annual Conference of the New Zealand Biotechnology Association, Auckland, 9-11 April, 1997.
8. Kennedy, M.J. and Smith, B. "The Plant-Based Natural Health Product Industry in New Zealand", Primary Industry Management, 2 (1), 22-29, 1999.
9. Waitangi Tribunal, "Concerning the Treaty of Waitangi Act 1975", Claim Wai262, by Haana Murray (Ngati Kuri), Dell Wihongi (Te Rarawa) *et al*, 1994.
10. Ministry of Maori Development. "Mana Tangata: Draft Declaration on the Rights of Indigenous Peoples, 1993: Background and Discussion on Key Issues: An Explanatory Document", Wellington, 1994.
11. Ministry of External Relations and Trade, Wellington, New Zealand, "Report on the United Nations Conference on Environment and Development", Rio de Janeiro, 3-14 June, 1992.
12. Ministry of External Relations and Trade, and the Ministry for the Environment, "Outcomes of the Conference: United Nations Conference on Environment and Development", Rio de Janeiro, 3-14 June, 1992.
13. Kiviat, E., "Apple Pomace Characteristics and Uses", Hudsonia, Bard College, Annandle, NY, 1982.
14. Garrity, B., "Profitable Feeding for High Production", Dairy Farm Annu 46:55-58, 1994.
15. Kennedy, M.J., List, D., Lu, Y., Foo, LY., Newman, R.H., Sims, I.A., Bain, P.J.S., Hamilton, B.H. and Fenton, G. "Apple Pomace and Products Derived from Apple Pomace: Uses Composition and Analysis", Modern Methods in Plant Analysis, Vol 20, p75-119, 1999a.
16. Strachan, G., "Processing Kiwifruit", New Zealand Ministry of Agriculture and Fisheries Kiwifruit Seminar, Tauranga, 1974.
17. Kennedy, M.J., "Apple Pomace and Kiwifruit: Processing Options", Australasian Biotechnology 4(1): 43-49, 1994.
18. Maarse, H., Vissher, C.A., "Volatile compounds in food: Qualitative and Quantitative Data", Vol 2. TNO-CIVO Food Analysis Institute, Zeist, The Netherlands, p1030-1031, 1989.
19. Kennedy, M.J., List, D., Lu, Y., Foo, LY., Robertson, A., Newman, R. and Fenton, G. "Kiwifruit Waste and Novel Products made from Kiwifruit Waste: Uses, Composition and Analysis," Modern Methods in Plant Analysis, Vol 20, p121-152, 1999b. ❑