The T &T Foresight Project

NIHERST

Sector Foresight Project:

BIOTECHNOLOGY

Chapter 2: T&T Capability & 'Best Bets'

Steve Maximay, Allan Frazer, Nick Marsh

Final
October 17, 2006

CONTENTS

INTRODUCTION

These sector foresight projects are proceeding through a 5 Chapter Process. Chapter 1 focused on using global foresight to identify potential niche growth opportunities in each sector.

In Chapter 2, we examine the capabilities T&T has available to match selected global niche opportunities and any gaps that need to be addressed to be able to convert these opportunities into a commercial business investment proposition that will provide longer term economic benefits for T&T and help advance the country towards the Vision 2020 goal of achieving developed nation status.

As part of this Chapter 2 work, a number of 'Best Bet' areas were selected by specialist Trinidad and Tobago consultants who researched the capabilities and gaps associated with them. This document is a synthesis of the work done by the local consultants and the sector workshop outcomes compiled by NEXT.

In late July, these 'Best Bet' areas were discussed and refined into more specific first draft 'Best Bet' business cases by a number of key stakeholders from both the public and private sectors at sector foresighting workshops.

In Chapter 3 of the sector projects, the first draft 'Best Bet' business cases from all the five sectors being researched will be short-listed further into more defined propositions. In Chapter 4 these propositions will be developed into detailed business cases that can be put in front of investors. The final Chapter involves a process which endeavours to convert at least some of these detailed business cases into commercial ventures.

SECTION A

This section contains edited content from report material compiled by Dr Steve Maximay based in Trinidad & Tobago. Professor Julian Duncan at UWI was a key reference source for the project. For this reason one of his recent papers covering biotechnology in the Caribbean has been included in the Appendix at the end of this document.

1 Biotechnology Sector Overview

The Trinidad and Tobago Government's 20/20 Vision, as articulated by the Prime Minister, is rooted in two major objectives, the first of which is the sustainable development of the non-energy sector[1]. It fully recognizes the success of the energy sector and its role in the rapid growth of the economy. Trinidad and Tobago, a small country of just over one million persons and with relatively small hydrocarbon resources, has over the past twenty years taken a leadership position in the production of ammonia, methanol and LNG. The country now seeks parallel growth in the non-energy sector – manufacturing and services.

With this objective in mind, the Government has put into place certain institutional

[1] http://opm.gov.tt/news/index.php?pid=2001&nid=sp060130

structures: the National Entrepreneurship Development Company Ltd (NEDCO); the Business Development Company (BDC) and more recently, the Evolving TecKnologies and Enterprise Development Company Limited (eTecK). Specific mandates of eTecK have been to:

- Develop industries in which Trinidad and Tobago has some distinct advantages, and
- Develop the first Technopolis in Trinidad and Tobago at Waller Field.

Clearly, however, these initiatives while necessary can only lead to any level of success if there are people, educated and trained to venture into the world of business either as entrepreneurs or productive employees. It is anticipated that the University of Trinidad and Tobago (UTT) with its teaching programmes in entrepreneurship, and its emphasis on Research and Development, and commercialisation of research efforts will provide that body of professionals that will provide the growth in the manufacturing sector. Put another way eTeck will spawn the businesses, while UTT will provide the required training.

It is against this backdrop that NIHERST has been pioneering the structured development of a Biotechnology sector as projected through an intensive foresighting programme that appreciates inter-sectoral dynamism. To ensure coherence the OECD definition of biotechnology will be applied throughout:

"The application of Science and Technology to living organisms as well as parts, products and models thereof, to alter living and non-living materials for the production of knowledge, goods, and services".

2 Rationale

Why Biotechnology? Why Trinidad and Tobago? Why now?

The 19th century can be unarguably described as the "age of chemistry", while progress in the 20th century was fuelled largely by developments in the physical and engineering sciences, and in information and communications technology, the "age of physics." The 21st century promises to be the realm of new insights and developments in the life sciences and biotechnology leading to the "age of biology."[2]

Biotechnology is the fastest growing sector of global biobusiness (social, economic and commercial activity depending on the application of biology and life processes). Biobusiness includes traditional and modern agriculture and the manufacturing and service sectors using the biological or life sciences. Biobusiness in Trinidad and Tobago can be characterized as being low value-added and slow to adopt technological advances. The sector is associated with low wage, labour-intensive jobs. Any large-scale deviation from the energy sector must utilize alternative natural resources and the nation's inherent biodiversity.

Current estimates suggest that a significant percentage of the GDP of most countries will be impacted by innovations in biotechnology and the life sciences through a slew of developments. Those likely to feature directly or indirectly in Trinidad and Tobago's development include, *inter alia*, new and improved crops, new tools for

[2] G. Shahi 2004, Biobusiness in Asia, Pearson/Prentice Hall. Pg 1

biomedical diagnosis and treatment, more efficient industrial processes, and new approaches to environmental protection and bioremediation.

Trinidad and Tobago faces a number of challenges and opportunities

- A development strategy that was dependent on fossil fuel led (jobless) growth and a propensity for diversification along downstream energy sector lines
- A troubled healthcare system having to deal with emerging pandemics, lifestyle diseases associated with extended life expectancies
- Limited intrinsic attempts at food security and food sovereignty
- Rapidly declining arable land base, made more acute by irreversible zoning changes and competition from housing, infrastructure development and speculative pressures.
- Environmentally-linked losses of biodiversity, deforestation, salinisation of soils and aquifers
- Significant climate variability, if not climate change, exacerbating environmental degradation and loss of infrastructure
- Growth-related waste management and pollution control concerns
- An economy in boom cycle with significant foreign reserves and a State capacity to invest in long-term, high internal rate of return ventures requiring a shift in paradigm with regard to entrepreneurship, education, research, innovation and commercialisation.

In 2006, the political will, economic wherewithal and macro-institutional development are convergent and ideally aligned to self-propel the nation into the realms of an appropriate biotechnological industry.

3 Global Biotechnology Sector

The key trends that are shaping the sector include the following:

- The global biotechnology sector is maturing and total revenue is on a steady upward growth path.
- The US is the dominant player in the global sector, but the Asia-Pacific region is growing rapidly – especially in India, China, Singapore and South Korea. Europe's share is declining.
- Governments are investing vast amounts of R&D into biotechnology research and infrastructure development and this is stimulating the return of qualified expatriates, recruitment of offshore scientists and an inflow of private capital, both domestic and onshore, into the sector in those countries.
- The primary focus of global efforts is the health biotechnology sector.
- Industrial biotechnology is viewed as being the next big thing and investment is currently being driven by concerns around energy security and climate change impact mitigation.
- Research funding trends show a shift towards funding interdisciplinary research teams and research at the convergence of disciplines to drive discovery and innovation.
- Societal reactions and concerns remain an important barometer of the acceptability of emerging biotechnologies.

The sector offers opportunities right throughout the value spectrum.

4 Biotechnology Capabilities in the Caribbean and Trinidad and Tobago

There are disparities in the levels of technological advance in biotechnology among the islands of the Caribbean: the larger countries of Cuba and to a lesser extent the Dominican Republic are at the upper end of the scale, with the islands of the OECS, with the possible exception of Grenada, at the lower end. Trinidad and Barbados occupy a position somewhat to the higher end of the mid- region, with Jamaica slightly higher.

The level of competence achieved in the field appears to be less related to the GDP of the country than to the size of population and ease of facility to a tertiary education (hence size of critical mass of scientific personnel) and to the political will of the government to establish a firm foundation for science and technology and provide funding to drive the sector.

A comparison of the research conducted in the countries deemed to be midway along the scale shows a great deal of overlap in both techniques used and objectives; in instances even in respect of species under investigation. This might be due in part to the fact that campus presences in these countries are all units of a regional University. Much of this can thus be explained on the basis of collaborative effort on the part of the scientists.

There are areas in which Trinidad and Tobago seem to lack a competitive edge, but four areas show promise on account of possible clusters of competences, natural resources and the potential for generation of IP through the existing expertise in plant breeding and aquaculture. Among the natural resources that hold promise are cocoa and the Buffalypso. Expertise in which the country holds some advantage is in plant breeding and in the development of aquaculture production systems.

5 Indicators of Critical Mass for Biotechnology in Trinidad and Tobago

There are positive indicators of burgeoning critical mass for biotechnology in Trinidad and Tobago including the scope of research, the commercial implications of the findings derived from many of these research projects, the collective value of injected capital in the form of grants to fund these projects, and the associated administrative and academic staff who are responsible for assuring attainment of deliverables. The invested equipment and instrumentation at the laboratories of the University of the West Indies, at Mount Hope, CAREC, CARDI and collaborating industries and centres are all indicative of the sector capability

The University of the West Indies has recognized the potential of biotechnology adoption in view of this critical mass of resources and has identified biotechnology as one of five key research areas for further development and funding. A university-based committee, comprising researchers and campus administration, has been established to assist in competing for large grants for biotechnology-led research and to aid in building human resource capacity and coordinated collaboration for research and advocacy.

The country's innovation experience has been one highly influenced by State-funded or State-inspired start-ups. (Point Lisa's history) The full-scaled commercialisation of innovative aspects of the sector is unlikely in the absence of significant State support. Fortunately, there are several activities, initiatives and philosophies to which the State is unswervingly committed. The following have been identified for the purposes of providing the initial 'fuel' to power the biotechnology sector and subsequently the likely refuelling stations on linked roads.

The State is a signatory to the Millennium Development Goals. In particular, goals 1, 6 and 7 (poverty eradication, disease management and environmental sustainability), and a commitment to sustainable development place some of the biotechnology applications on the State's doorstep. 'Mainstreaming adaptation to climate change in the Caribbean' is a CARICOM supported initiative with a mandate to incorporate any and all mechanisms to bolster the region's effort to minimize the impact of climate change. Pursuant to discussions coming out of the 1994 SIDS meeting in Barbados there is an increasing acceptance of the need to monitor the climate variability to which the region and Trinidad and Tobago are being subjected. The efforts coming out of the biotechnology

6 Draft Roadmap For Biotechnology in T&T

The TT roadmap will necessitate layout based on a double lane as opposed to a superhighway. Efforts will have to be focused on a few areas of current or perceived significance as distilled from the foresighting exercise. Distilled, because the full range of potential areas must be subjected to the scrutinizing 'heat' of analysis and the more volatile ideas rejected or reconfigured. The biotech vehicle must be a utility vehicle capable of off-road manoeuvring. The roadmap has a common destination of a progressively viable biotechnology sector contributing to the global competitive positioning of selected goods and services earning sustained returns on investment in economic, financial and environmental terms.

The key to the layout/vision for the roadmap is a network of interconnected (linked) parallel roads utilizing supports (fuelling stations) that can assure progress of the biotech vehicle. The sector will be a compact that delivers high value products/services in niche areas that have been carved out by dint of near exclusive rights. Said rights will be based on Intellectual property that has been appropriately managed in conformity to WIPO and industry-specific standards.

The sector is being developed in keeping with the three horizons concept. The business and strategic plans associated with horizon one and two respectively have been superseded by foresight research, PESTE analysis and scenario development. This Horizon three perspective will then drive the business strategic planning of the desired Biotechnology industry

Trinidad and Tobago has to avoid the 'valley' opportunities; these are the commoditised opportunities where there are many competitors, low barriers to entry and low margins as characterized by raw material production. Valley products will only be important if the country can develop knowledge-intensive innovations that will transform them to 'summit' opportunities. Summit opportunities are technology and knowledge intensive opportunities where there are few competitors, high barriers to entry and high margins. Whilst these are of interest, the country has to keep a clear commitment and investment in on-going innovation and new knowledge creation research to maintain the competitive edge. The cloud opportunities are even more

technology and knowledge intensive and differ from the summit in that the business case is not as well developed but the earning potential could be great.

TT will have to continuously develop the capacity to translate insights and understanding arising from Research (R) through the Development pipeline (D) into practical Applications (A) in the marketplace, the R-D-A translation process. The country will require a cadre of enlightened Policy-Makers who understand the opportunity and value associated with appropriate infrastructure, trained human resource and a supportive policy environment. Towards this end the foresighting activities must involve a plain English reporting format to keep policy-makers in the loop.

Technology innovators and entrepreneurs need to be identified by dint of initial self-propulsion or focused institutional screening policies and programmes. Once identified, they would need to be matched with appropriate mentors and supported in cluster arrangements. The country must develop mechanisms that promote stakeholders and long-term investors as linchpins of the overall biotechnology effort. These nurturing conditions can only be sustainable in countries where a significant segment of the general public is involved in genuine communication about the sector. Communication that reinforces the improved quality of life and health from innovative products and services as well as the attendant creation of jobs and the generation of income.

The overarching consideration should be that Biotechnology has applicability in all dimensions of life and can substantially impact on food production, disease management, industrial processes and environmental protection.

"There is substantial value to be generated for those who have the knowledge and skills to find solutions to the myriad of problems and concerns our societies face – and the cost of validating new technology insights, creating exciting new products and bringing such innovations to market can be surprisingly low for those who actually know what they are doing".[3]

7 Initial Areas For Finding Best Bet Niches

The matrix considered by the consultants from NEXT Corporation indicated possible niche areas with the following typology: regenerative medicine, reproductive technologies, genomic medicine, nutrition, agri-technology, industrial biotechnology, environmental biotechnology and security/defence. Of those areas, Trinidad and Tobago has greatest potential for, or overt interest in, agricultural, environmental, veterinary reproductive and industrial technologies.

The development of an industry for the production of 'fine' chocolate and drinking chocolate is at the "valley" stage but can be moved to a summit opportunity. There are also interconnected opportunities in nutritional modification of selected foods, as well as xerophytic and halophytic adaptations of key cultivars. Other horticultural opportunities reside in the production of novel colours, flavenoids and aromas in traditional and exotic ornamentals. The summit opportunities are inextricably linked to the Intellectual Property Rights associated with those modifications. Trinidad and Tobago, apart from being TRIPS compliant has a WIPO-recognized IP Office that has been used as the flagship office for the southern Caribbean. Given its long

[3] G. Shahi 2004, Biobusiness in Asia, Pearson/Prentice Hall. Pg 269

positive history of direct foreign investment in the energy sector, modern tax infrastructure and accession to UPOV and other conventions, IP inspired niches are plausible for Trinidad and Tobago.

The country is already a world leader in the Artificial Insemination (AI) of sheep. Tobago has established an international record in terms of the success rate and this can be moved to summit opportunities by integrating other improvements into the reproductive technologies. The research to develop similar capabilities with goats is in progress and would benefit from a "Horizon 3" perspective as determined from the country's foresighting exercise. There are also fledgling capabilities in bovine and ovine endocrinology and diagnostics that can be bolstered by the envisioned sector-wide developments.

The integration of environmental stabilizing adaptations to native plants presents a timely and plausible opportunity as the nation and region grapples with the extremely variable climate. The summit opportunities lie in bioremediation that can be coupled with other aspects of environmental protection and stabilization.

The industrial applications are varied and inter-sectoral and will be fuelled by the outcome of the foresighting processes in the other sectors in Trinidad and Tobago as championed by NIHERST.

8 *Matching Global Niche Opportunities With Local Capabilities*

Having reviewed the global outlook for biotechnology, identified the existing expertise and current levels of scientific interest, the stage has been set to explore the foresighting mechanism with regard to the best sub-sector niches. The long-term views developed through foresight will develop a picture of how a business Horizon 3 may look 10 – 20 years from now – which is often quite different to how it looks today. This horizon shapes understanding of the future destination aimed for – the desired scenario. By backcasting from Horizon 3, a 3 – 5 year strategic plan (Horizon 2) can be developed. Subsequently, a short- term business or implementation plan (Horizon 1) can be determined.

In this approach, commercialisation of opportunities discovered during the research and evaluation process is made within a long-term context. There are a number of tools and processes that can be used to help shape Horizon 3. These include foresight research, the PESTE analysis and scenario development.

The object of the exercise is to root the vision for the sector in the existing capacity, infrastructure and legislative environment without being limited or circumscribed by them. Alan Kay put it best 'Don't worry about what anybody else is going to do… the best way to predict the future is to invent it. Really smart people with reasonable funding can do just about anything that doesn't violate too many of Newton's laws'.

The country's best way to predict its future in biotechnology is to invent it through the development of its best niche areas. The Best Bets for Trinidad and Tobago are a function of the country's geography, biodiversity, current interests, culture, economic history, potential capacity, Intellectual Property Rights sophistication and development philosophy.

Trinidad and Tobago, due to its continental origin, has the greatest biological diversity of the islands in the Caribbean archipelago. Of the 2,160 species of flowering plants in Trinidad and Tobago, 110 are endemic, including many palms. There are approximately 420 species of birds, 100 mammals, 55 snakes, 25 amphibians and 85 reptiles. There are probably about 2,500 species of plants and about 10 times as many animals, the majority being insects and other invertebrates.

Each of the following sub-sector niches is grounded in an existing area of competence, interest, strategic significance or natural resource abundance.

9 Capability analysis for selected Biotechnology sub-sector niches

The key sub-sector niches identified in no particular order of merit are as follows:

1. **Bioremediation:**
2. **Plant Varietal Improvements and Licensing**
3. **Biopesticides**
4. **Gran Couva/Trinitario Fine Chocolate industry**
5. **Bioplastics/ Waste Management Technologies**
6. **Integrated Aquaculture Systems**
7. **Exotic Livestock Development**
8. **Therapeutic and Nutraceutical plants**

9.1 Individual Sub-sector Niche Descriptions

1. **Bioremediation:** the use of micro-organisms in the abatement of pollution, particularly that caused by petroleum and petroleum products. The country's energy sector is fossil fuel based and involves the input of several major multinational corporations all with a vested interest in environmental protection. Marine and terrestrial spills have been recorded throughout the country's exploration and transmission history. Preliminary and pre-commercialisation levels of research are ongoing and an expandable core of expertise exists. The country also has a rapidly expanding yacht-based tourism sector thriving on the safe anchorage and accessibility of repairing/refurbishing skills. Occasionally there may be small fuel sheen on the water surface near boats. Although it may be only a tiny amount from some boats, the cumulative impacts can be damaging. Once in the aquatic environment, oils and fuels have a tendency to accumulate in bottom sediments and concentrate in aquatic organisms. These harmful substances commonly enter the aquatic environment through improper engine maintenance techniques and waste fluids disposal practices. Bilge water purification and treatment systems are a feasible niche as part of an overall bioremediation facility utilizing the linkages inherent in the TT economy. The country has also taken a lead Caribbean role in the Global Water Project through which the remediation efforts can be channelled.

2. **Plant Varietal Improvements and Licensing –** there is sufficient interest and expertise to develop improvement programmes for, *inter alia*, orchids, hot peppers and anthuriums. Whilst the orchid industry

in Thailand is centred on the genus *Phalaenopsis* the centre of origin of the genus *Epidendrum* is the Americas. No one has to date developed an industry based on that genus. Work in Trinidad is centred on collection of species of the genus, broadening the genetic base through a breeding programme and producing elite types upon which an industry can be based. The region is also the centre of diversity of hot pepper *Capsicum chinense.* This species is truly adapted to the tropics, is resistant to *Phytophthora* a major fungal pest and is very pungent. The aim of the breeding programme will be to produce new varieties with improved yield potential that can be competitive with the varieties of *Capsicum annuum,* a temperate crop. Improvements on the agronomy, flavenoids and organoleptic characteristics will be the basis of the licensed seed/product industry. Apart from being grown at the commercial level as a crop for production of seed for sale to farmers, the species can be used in the production of medicines, sprays and in the food industry. Genetically engineered improvements of *Anthurium andraeanum* for novel colours, resistance to bacterial blight (*Xanthomonas)* and leaf spot (*Acidovorax*) will use molecular markers and the known pathways to colour change by gene manipulation. Novel varieties of the species in question will be developed, licensed and sold to seed producers in the case of pepper and to other countries for production of the volume of blooms required for sustaining a viable industry.

3. **Biopesticides**: development of biological control agents as part of a pest management programme; use of Bt as a pesticide; use of other micro-organisms in the control of pests on vegetables, ticks in animal husbandry and weevils in legumes. The country has a vast gene pool, given its documented biodiversity, from which to source transgenic solutions for the control of a range of crop and livestock pests. Potentially there are several endemic plant species, extracts from which, can induce pest stasis of human ectoparasites and related pests.

4. **Gran Couva/Trinitario Fine Chocolate industry** – Demand for the Trinitario cocoa type exceeds supply. Trinitario cocoas are regarded in the trade as being a ‘fine’ cocoa, and is used as a component of all brands of fine chocolate produced worldwide. The flavour of the beans determines whether a cocoa is classified as ’fine’ or not. Although these clones have been exported to the major cocoa growing countries, Trinidad and Tobago has an edge on these regions, for flavour, which is genetically determined, is enhanced by soil type and fermentation regimes. There are opportunities for expanded production, improvements in fermentation techniques, plant genetic modification, and unique typology that facilitates use of a Geographical indication. A geographical indication is a sign used on goods that have a specific geographical origin and possess qualities or a reputation that are due to that place of origin. Most commonly, a geographical indication consists of the name of the place of origin of the goods. Agricultural products typically have qualities that derive from their place of production and are influenced by specific local factors, such as climate and soil. Whether a sign functions as a geographical indication is a matter of national law and consumer perception.

5. **Bioplastics/ Waste Management Technologies:** Bioplastics are a form of plastics derived from plant sources such as hemp oil, soybean oil and cornstarch rather than traditional plastics, which are derived from petroleum. This is regarded as a much more sustainable activity, as it relies considerably less on fossil fuel imports and produces less greenhouse emissions, producing between 0.8 and 3.2 tonnes of carbon dioxide less per tonne of bioplastics vs. the same weight in petroleum based plastics. In addition, bioplastics are truly biodegradable, as opposed to what is traditionally referred to as "biodegradable plastic", which is derived from petroleum and is mixed with heavy metals, which will cause polyethylene to break down. The TT government signed an agreement, in April 2006, with U.S. firm Westlake Chemical Corporation to develop a US$ 1.5 billion ethylene complex at an industrial site in Trinidad. The project is important to the country's continued efforts to diversify the energy sector, create spin off industries and optimise hydrocarbon resources. A wide variety of bacteria synthesize a poly-B-hydroxyalkanoate (PHA) polymer the main advantage of PHA's over other types of biodegradable plastic is that since they are of biological origin, they degrade naturally and completely. Bacteria can completely break down the PHA into carbon dioxide and water. PHA's also do not require special environmental conditions to degrade so they can undergo rapid biodegradation under any conditions, thus solving the problem with the decreasing space of landfills Bioplastics downstream industries can also be created building upon current expertise in the commercial sector and emerging opportunities related to unique T&T based product concepts and derivatives.

6. **Integrated Aquaculture Systems**: Use of a wide range of genetically modified organisms to be part of an integrated whole with regard to nutrient recycling in plant, mammalian and fish based systems. Current expertise has mapped areas for transgenic improvement. There are known protocols for intensifying production in Tilapia and other fresh water species of animals; sex reversal and production of super males in Tilapia. These modified systems have potential in food production and environmental remediation solutions. The development of aquaponic systems in which the water from the fishponds is circulated through a hydroponic system, whereby the plants receive nutrients from the water while 'cleaning' it for return to the ponds. In this way crops of fish and of vegetables can be obtained from one system. Production systems for fresh water conch and other exotic species will be improved based on gene manipulation, organoleptic demands and safety standards.

7. **Exotic Livestock Development**: Trinidad and Tobago because of its unique geography and consequent biodiversity has developed culinary delights based on non-domesticated animals and selected strains of more widely known animals. The agouti (*Dasyprocia variegata*) and quenk (*Pecari tujaca*) have long been associated with medicinal, restorative and healthy attributes. Research is ongoing with respect to the reproductive physiology of these animals that are uniquely adapted to the country's ecological regimes. There is significant potential for the development of improved parent material to stock viable production units. Extensive research has gone in to the agouti

stock and protocols can be developed for their improvement in terms of nutraceutical designation and organoleptic traits. In Trinidad and Tobago, research towards the development of good beef producers was carried out on the Indian water buffalo (*Bubalus bubalis)*. Various breeds of the animal were crossed and crossbred allowing for genetic recombination and expression of variability in the population. Selection was made for the progeny of the crosses. The resulting population, called buffalypso, possesses most of the characteristics of a new breed specifically suited for beef production in the tropics; the type has been exported to Venezuela and to the USA. Improving the buffalypso stock for greater milk production; identifying the time of heat; artificial insemination and embryo transplant in buffalypso, enzymatic processes for specialist cheeses and high value specialized milk products.

8. **Therapeutic and Nutraceutical plants**: The global trend of ageing populations is mirrored in Trinidad and Tobago. Increasingly "natural" or plant-based therapies are being sought to overcome the more common geriatric complaints. A nutraceutical or functional food is similar in appearance to conventional foods, is consumed as part of a usual diet, and has demonstrated physiological benefits and/or reduces the risk of chronic disease beyond basic nutritional functions. Leveraging the value of indigenous and specialist plants e.g. Carailli is one possible example which is attributed with providing health and wellness attributes. Angostura Bitters includes health and wellness plant extracts. 'Natural Viagra' sold by local herbalists and derived from the *Bois Bande* bark extract is another area that offers considerable potential with ageing populations and a shift to natural from pharmaceutical solutions. Genetic manipulation of indigenous material in isolation or as part of "new" plant varieties presents feasible opportunities for a biotechnological niche industry.

9.2 Strengths, weaknesses, threats, opportunities

Each sub-sector niche has been subjected to a SWOT analysis. The strengths and weaknesses relate to today's context and the opportunities and threats relate to the situation in the future – up to 5 – 10 years hence.

1. Bioremediation:

STRENGTHS	WEAKNESSES
• Works effectively in real life situations. • Can be used to clean up virtually every pollution challenge. • Exploratory research has been successful. • IP protection being sought. • Value added across sectors such as tourism and health.	• R & D funding constraints. • Equipment availability. • Efforts not coordinated amongst available expertise. • Lack of a global niche marketing strategy.

OPPORTUNITIES	THREATS
• Large emerging markets such as China and India which need to address problems quickly. • Oil and gas industry pollution. • Toxic waste management. • Rehabilitation of eroded and damaged environments. • Participation in mutually beneficial alliances.	• Social problems in T&T and keeping/attracting highly skilled individuals. • Poor facilities and support infrastructure. • Poor international connectedness.

2. Plant variety improvements and licensing

STRENGTHS	WEAKNESSES
• Expertise with several crops already exists both commercially and in the R&D field. • There are growth markets with high value available for specialist elite plant products where TT has access to potential valuable material e.g. orchids.	• Lack of development of products. • A lack of development as a business to date. • A need to improve breeding stocks and management techniques. • R & D funding. • Critical mass of expertise missing. • Lack of a global niche marketing strategy. • A lack of strategic global alliances.
OPPORTUNITIES	**THREATS**
• High value orchids – where collectors will pay high prices for unique and rare specimens. • Development of specialised mother stocks of seeds and propagation material for nurseries in major growth markets. • Anthurium and other unique cut flower cultivars – again as a mother stock source with IP attached for export. • Strategic alliances with key horticultural nurseries and distribution networks.	• Cross border quarantine agreements and issues. • Social problems in T&T and keeping/attracting highly skilled individuals. • Poor facilities and support infrastructure. • Poor international connectedness. • The cost of developing unique global market niches against competing products.

3. Biopesticides

STRENGTHS	WEAKNESSES
• Availability of natural bio-control agents in local flora and fauna diversity. • Crop and animal problems have been addressed by biological control solutions. • Fewer issues with resistance and tolerance.	• Lack of expertise. • Long lead times. • R & D resources. • Lack of alliances. • Lack of a global niche marketing strategy.

OPPORTUNITIES	THREATS
• Growing markets for organic products. • A shift from 'chemical' towards 'natural' solutions. • Large potential markets for crops such as sugar cane – increasingly being used for ethanol as a liquid fuel source. • Joining alliances with offshore specialist groups to jointly develop.	• Commodity price cycles and value erosion. • Social problems in T&T and keeping/attracting highly skilled individuals. • Poor facilities and support infrastructure. • Poor international connectedness.

4. Gran Couva/Trinitario fine chocolate industry

STRENGTHS	WEAKNESSES
• T&T has a unique hybrid which is in demand internationally. • A recognition by international buyers that the product is high-end. • There is expertise in growing and developing the crop. • T&T has climatic and soil advantages that enhance the quality outcomes. • There is potential to improve both the cultivars and the derived products.	• Cannot produce enough to supply demand. • Susceptibility to diseases. • A lack of development as a business to date. • A need to improve breeding stocks and management techniques. • R & D funding. • Expertise availability (?). • Production area not reserved for agriculture. • Lack of a global niche marketing strategy. • A lack of strategic global alliances.
OPPORTUNITIES	**THREATS**
• Potential geographical indication for Trinitario cocoas. • High-end quality products for niche global markets. • Development of improved cultivars for local and international use. • Refinement of fermentation and product development processes. • Strategic marketing alliances and partnerships.	• Other countries grow the TT clones as well or better than T&T and take over the niche. • Under-utilised IP protection. • Social problems in T&T and keeping/attracting highly skilled individuals. • Complying with international agreements. • Poor facilities and support infrastructure. • Poor international connectedness. • The cost of developing unique global market niches against competing products.

5. Bioplastics / waste management technologies

STRENGTHS	WEAKNESSES
• T&T has considerable commercial experience in these areas using adopted techniques. • There is also R&D capability in this area. • Solid waste management is a State priority area.	• R & D funding. • Expertise not available. • Lack of commercial innovation. • Lack of identification and focus on specific niche opportunities. • Lack of a global niche marketing strategy.
OPPORTUNITIES	**THREATS**
• Building upon expertise to offer unique solutions to global plastics manufacturers. • Development of specialized value adding bioprocesses to increase biodegradability of plastics. • Building alliances and partnerships for the reduction of non-segregated solid waste.	• Under-utilised IP protection. • Lack of long-term funds for research and development. • Social problems in T&T and keeping/attracting highly skilled individuals. • Poor facilities and support infrastructure. • Poor international connectedness.

6. Integrated aquaculture systems

STRENGTHS	WEAKNESSES
• Considerable expertise in T&T. • Requires limited capital investment for production units. • Tilapia complements other agricultural activities. • Health and wellness associations with fish. • Integrated systems currently favoured by state initiatives.	• Lack of development as a business to date. • A need to improve breeding stocks and management techniques. • R & D funding. • Uncoordinated research and development. • Lack of recognition of the value of the local genetic pool. • Lack of a global niche marketing strategy.
OPPORTUNITIES	**THREATS**
• Global over-fishing is driving up the demand for farmed fish. • Favoured by consumers moving towards more white meats as opposed to red meats. • Health and wellness attributes associated with fish. • Derivative products. • Developing expertise for sale to other developing countries. • Alliances and partnerships.	• Inappropriate or contra-marketing. • Social problems in T&T and keeping/attracting highly skilled individuals. • Poor facilities and support infrastructure. • Poor international connectedness. • Praedial larceny. • Other countries in Latin America and Caribbean also well established.

7. Exotic Livestock Development

STRENGTHS	WEAKNESSES
• Stock of unique animals available. • *Brucella*-free Buffalypso available • Products deemed to have unique characteristics desired by consumers. • Current expertise in animal husbandry and breeding. • Limited research on the nutrition and physiology of exotic species. • Intensive management systems developed. • Disease-free island stock.	• Lack of development as a business to date. • A need to increase and improve breeding stocks and management techniques. • Long lead times. • R & D funding. • Expertise availability (?) • Lack of market research as to potential market value. • Lack of a global niche marketing strategy.
OPPORTUNITIES	**THREATS**
• Unique market slots (such as buffalypso mozzarella in Italy). • Potential to add value and expertise to other economies, especially in Asia and Africa, where water buffalo are common. • Exotic haute cuisine. • Animal registration and studbook. • Animal releases into the wild.	• Social problems in T&T and keeping/attracting highly skilled individuals. • Poor facilities and support infrastructure. • Poor international connectedness. • The cost of developing unique global market niches against competing products.

8. Therapeutic and nutraceutical plants

STRENGTHS	WEAKNESSES
• Specialty plants providing a basis for several products in T&T e.g. Angostura Bitters, 'natural Viagra', Carrailli, Noni. • Expertise already available in T&T. • At least one major player, Angostura, already has a global presence in the health and wellness consumer product market.	• Apart from Angostura, a lack of development as a business to date. • A need to improve breeding stocks and management techniques. • Lack of knowledge of beneficial effects. • Lack of consistency and traceability of products. • Long lead times. • R & D funding. • Expertise availability (?) • Lack of a global niche marketing strategy.

OPPORTUNITIES	THREATS
• To build on Angostura's expertise and success. • To be the world's first provider of QA/QC controlled 'natural Viagra' as an alternative to the chemical versions. • To use the health and wellness characteristics of Carailli as a selling point for value added nutraceutical type food products.	• Under-utilised IP protection. • Social problems in T&T and keeping/attracting highly skilled individuals. • Complying with international standards from food and medicinal perspectives. • Poorly developed facilities and support infrastructure. • Poor international connectedness. • The cost of developing unique global market niches against competing products.

9.3 Reviewing the 'Best Bets'

Having reviewed eight 'Best Bet' sub-sector niches the process should be guided by a Foresighting for Development approach. Foresighting is as much a creative as an analytical process. Rather than asking *what is the one most likely future*, which is the domain of forecasting, Foresighting asks *which futures are possible, desirable, disastrous or feasible*? This translates the system in question from 'a mere respondent to changes that are predicted' to one that is 'an active agent in the shaping of possible futures, one of which will be realized by the many actors that have been recognized.'

In addition, foresighting is designed to work best with different stakeholders, and to be used repeatedly over time. In this, it is a participatory, inclusive process rather than a single expert method; in fact, exercises often draw on several different methodologies to support the process. Foresighting is, in essence, a continuous process where four distinct activities are maintained:

- Continuous development, refinement and adaptation of the scenarios.
- Use and interpretation of the scenarios in new plans / programmes.
- Implementation of existing plans and programmes.
- Maintenance and evolution of the knowledge networks.

Finally, and also as a result of the social emphasis of foresighting as a deliberative process, motivation for change and implementation of future action is often less difficult as those involved in developing the ideas are the same people who will be involved in implementation.

10 Key Sources of Capabilities & Enablers

The following Tables list Intellectual Property Mapping options, key skills sets and entrepreneurs, and government enabling structures;

Table 2.1 Intellectual property mapping analysis

Sub-sector niche	Intellectual Property Mapping Analysis
Bioremediation:	Trade Secret, UPOV, Patent
Plant Varietal Improvements and Licensing	UPOV
Biopesticides	Patent
Gran Couva/Trinitario Fine Chocolate industry	Geographical Indication
Bioplastics/ Waste Management Technologies	Patent
Integrated Aquaculture Systems	Patent
Exotic Livestock Development	Patent
Therapeutic and Nutraceutical plants	UPOV, patent

Table 2.2 Key skill sets and entrepreneurial prospects

Sub-sector niche	Key skill sets and entrepreneurial prospects
Bioremediation:	Michael Joseph, UWI, Petrotrin, BHP Billiton
Plant Varietal Improvements and Licensing	Sigoolam Bidessie, Jennifer Avey, Christopher Greenidge, Professor Julian Duncan
Biopesticides	UWI Life Sciences, CARDI, Gregory Stone
Gran Couva/Trinitario Fine Chocolate industry	Scharffen Berger, BCCI, CRU
Bioplastics/ Waste Management Technologies	SWMCOL,
Integrated Aquaculture Systems	SFC, Indar Ramnarine, UWI
Exotic Livestock Development	Malabar Farms, Gary Garcia. Cicero Lallo, EWMSC
Therapeutic and Nutraceutical plants	Compton Seaforth, Francis Morean, UTT

Table 2.3 Government enabling infrastructure

Sub-sector niche	Government Enabling infrastructure
Bioremediation:	Support for Solid Waste Management Company (SWMCOL), Community-based Environmental Protection (CEPEP), legislative support through the Environmental Management Authority (EMA)

Sub-sector niche	Government Enabling infrastructure
Plant Varietal Improvements and Licensing	UPOV, CITES, PCT signatory,
Biopesticides	EMA, Pesticide Control legislation
Gran Couva/Trinitario Fine Chocolate industry	IP Protection, Brand support through Cocoa Board, Cocoa Research Unit, ADB Cocoa Revitalizer Loans
Bioplastics/ Waste Management Technologies	Downstream energy park support, UTT, eTECK,
Integrated Aquaculture Systems	Sugar Cane Feeds Centre, Ministry of Agriculture, School Feeding Programme
Exotic Livestock Development	Min of Agriculture, Veterinary Public Health, Wildlife Legislation
Therapeutic and Nutraceutical plants	UPOV, Patent, Trade Secrets

Table 2.4: Material and Infrastructure Resource Capability

Niche	Material and infrastructure resource capability			
	Raw materials	Business skills	Human resources	Infrastructure
Bioremediation:	√	X	X	X
Plant Varietal Improvements and Licensing	√	√	√	√
Biopesticides	√	√	√	X
Gran Couva/Trinitario Fine Chocolate industry	√	√	√	√
Bioplastics/ Waste Management Technologies	√	X	X	√
Integrated Aquaculture Systems	√	√	X	X
Exotic Livestock Development	√	√	√	X
Therapeutic and Nutraceutical plants	√	√	X	X

SECTION B – Outcomes from NEXT Facilitated Sector Workshop

1 First Draft 'Best Bet' Investment Opportunities - Biotechnology Workshop

This workshop was held in Port of Spain, Trinidad, on Monday, July 24, 2006. Those listed in the following Table participated in this workshop co-facilitated by Dr Nick Marsh of NEXT and Dr Steve Maximay with the support of Professor Julian Duncan of the UWI and Ms Maureen Manchouck, the President of NIHERST.

Name	Organisation	Contact	
		Phone	Email
Professor Julian Duncan	UWI	662 2002	pandora@carib-link.net
Adesh Ramsobhag	U.W.I.	645-1535	aramsubhag@fsa.uwi.tt
Vish Mooleedhar	Research Division, MALMR	685-1496	vishmool@hotmail.com
Cynthra Persad	" "	646-7657	
Nirmala Beharrysingh	Food & Drug Division, Ministry of Health.	623-2834	cfdd@carib-link.net
Ulrike Krauss	C.A.B.I.	662-4173	u.krauss@cabi.org
Kent Villafaua	C.A.B.I.	628-6872	ville8146@hotmail.com
David Butler	C.R.U.	662-8788	dbutler@intrehidequipment.com
Ramon Marks	T.H.A.	789-9818	infomas@tstt.net.tt
P. Umaharan	U.W.I.	663-2373	pumaran@fsa.uwi.tt
Gary Garcia	U.W.I.	742-9430	garygwg1cgmail.com
Suresh Benny	S.F.C.	743-4973	sfc@carib-link.net
Aaron Parke	I.I.C.A.	622-7050	aaron.parke@iica.int
Lillawatti Rastogi	Animal Production & Health Division. MALMR	669-5296	aphdivision@tstt.net.tt
Michael Joseph	U.W.I.	761-8776	michaelkjoseph@hotmail.com
Michelle John	CARDI	645-1205/7	ttunit@cardi.org

Dr Maximay presented the 8 'Best Bet' areas identified as having business investment prospects for Trinidad and Tobago to the workshop. The participants were then asked to work together in groups using a template to develop first draft 'Best Bet' options based upon the areas presented by using the following criteria:

- The title for the 'Best Bet' proposition.
- A description of the offer.
- Consumer groups to which the offer is targeted.
- What capabilities does T&T have?
- What capabilities does T&T need?

These first draft 'Best Bet' cases are detailed in the following section.

2 First Draft Biotechnology 'Best Bet' Business Opportunities

It should be stressed once again that these are first draft 'Best Bets' concepts developed by workshop participants after consideration of the potential opportunities and T&T capabilities and enablers presented by the research team.

1	**SECTOR**	**Biotech (Aaron Parke)**
2	**'BEST BET' TITLE**	**1. 'Herbal Heaven'**
3	**'BEST BET' DESCRIPTION**	• Products like essential oils. • Sports drinks and herbal beverages. • Herbal teas / dried herbal spices. • Cosmetics.
4	**GLOBAL MARKET NICHE FOCUS**	• On customers in the nutraceuticals and functional foods areas • Markets for herbal spices, beverages, essential oils, cosmeceuticals. • Foods to reduce obesity / food and work and lifestyle diseases.
5	**WHAT T&T HAS**	• Food and beverage companies that can exploit existing opportunities. • Centres of excellence at UWI, CARIRI to develop products. • A strong local traditional herbal sector.
6	**WHAT T& T NEEDS**	• Scoping of the biodiversity. • Phytochemical analyses to identify potential products / active ingredients. • Examination of traditional herbal products and development of QA/QC systems and market opportunities. • Value chain and market development.

1	**SECTOR**	**Biotech (David Butler, Ramon Marks)**
2	**'BEST BET' TITLE**	**2. 'Brown Gold'**
3	**'BEST BET' DESCRIPTION**	• Cacao based products with reduced sugars and high anti-oxidants. • Production of 12,000 MT of cacao by 2017 (15,000 ha). • Own brand of chocolate e.g. Gran Riviera. • 10% of export revenue to help local communities. • 'A nugget of chocolate a day is good for your health'.
4	**GLOBAL MARKET NICHE FOCUS**	• Middle to upper income groups in Asia, Japan, NZ, Australia, Russia, USA, Canada, and Europe. • Gourmet outlets. • Health food stores – sell the anti-oxidant factor (heart conditions). • Organic market. • A JV marketing programme with Angostura.
5	**WHAT T&T HAS**	• Tradition. • Black bean. • Expertise. • Unique environments. • Marketing plan and branding. • Research – use of 'cocoa pods'.
6	**WHAT T& T NEEDS**	• To preserve good land for agricultural use. • Incentives for production of best quality cocoa. • An industry marketing plan. • An limited liability company to organise production through supply chain (fermentation etc). • Farmers as majority shareholders. • Improved production – inputs and harvesting. • Ago-tourism – linking with TT experiential tours. • Own storage facilities in Europe. • TT to lead and link with Jamaica, consumers, etc. • Labour saving devices. • Skills lack – pruning. • New export industry – 'hot' CCIB. • Manager (2 years) from BESO or FAO with local counter front on contract.

1	**SECTOR**	**Biotech (Lillawatti Rastogi)**
2	**'BEST BET' TITLE**	**3. Buffalypso and Sheepalypso**
3	**'BEST BET' DESCRIPTION**	• Production of buffalypso embryos for the export market and sheep embryos. • Farms to produce organic buffalypso beef - low cholesterol – organic milk and mozzarella cheese. • Export of sheep genetics.
4	**GLOBAL MARKET NICHE FOCUS**	• Consumers who are looking for exotic fashion and health foods, organic foods and milk products, and low cholesterol milk and meat. • Development of markets for disease free Buffalypso and sheep embryos and semen. • Farmers and governments in the Latin America and Central America who need breeding stock – American Buffalypso farmers. • Organic Buffalypso steaks and mozzarella.
5	**WHAT T&T HAS**	• Owners and developers of Buffalypso breed at WIB. • Disease free population of Hair sheep and Buffalypso. • Production techniques developed. • Known exporters of the breed. • Foot and mouth disease free status.
6	**WHAT T& T NEEDS**	• Buffalypso development plan, which includes a plan for increasing the numbers. • A marketing plan. • Legislation to establish traceability to satisfy food safety conscious consumers (and regulatory needs). • Animal identification and performance recording to establish the quality of the genetics.

1	**SECTOR**	**Biotech (Suresh Benny)**
2	**'BEST BET' TITLE**	**4. 'Fish & Trips'**
3	**'BEST BET' DESCRIPTION**	• Branding (of genetic pool) of local aquaculture resources (T&T fish and conch). • Aquatics – T&T farmed fish foods for restaurants. • Integrated agro-tourism. • Development of organic food producing eco-resorts. • Rehabilitation of spent quarry land – eco-attractions – rejuvenation, agro-forestry, aquaculture. • T&T branded Cascadura, conch, Tilapia.
4	**GLOBAL MARKET NICHE FOCUS**	• Organic consumers – health and wellness. • Eco-tourists – as part of a package – conch, wild meat, organic foods. • Investors and farmers into production systems – T&T integrated systems. • Farm produced quality certified fish, conch and other aquaculture products. • Eco-resorts. • Consultancy and training services.
5	**WHAT T&T HAS**	• Cascadura, conch, T&T Tilapia – 2 local delicacies. • Climatic conditions. • High interest – eco-resorts, quarry owners, farmers wit land and some without land. • Cultural (Cascadura) and culinary attractions (curry, broth) etc – tourism. • Emerging organic agriculture industry. • Disconnection between industry development and research.
6	**WHAT T& T NEEDS**	• An overarching company with a core function to develop aquaculture systems and stocks, to certify, process, contract farmers, market, form alliances with the eco-resorts, provide consultancy services, have an on-line shop. • Strengthened research – human and facility resources. • Connection between research and industry development – and tourism industry (industry agency?). • Marketing strategies – international and local. • Development and certification of targeted species. • Certification and branding of production systems. • Less reliance on government, more reliance on the private sector. • Quality assurance upstream (production) and downstream (processing) – certification /legislation (HACCP).

1	**SECTOR**	**Biotech (Michael Joseph)**
2	**'BEST BET' TITLE**	**5 'Pollution Solutions' – oil and gas bioremediation**
3	**'BEST BET' DESCRIPTION**	• Provides solutions to environmental problems associated with industrial development – terrestrial and marine.
4	**GLOBAL MARKET NICHE FOCUS**	• The green responsible corporation – oil and gas industry, marine services, ports.
5	**WHAT T&T HAS**	• Petroleum and natural gas • Petrochemical industries • Downstream industries • Smelter plants – SPLs • Solid wastes • 2 major ports – more to come • Marine services industry } All sources of pollution. • Indigenous microbes. • The Green Fund. • Trained bio-scientists and a research infrastructure – UWI, UTT.
6	**WHAT T& T NEEDS**	• A legislative framework – an ability to adapt to global standards. • Trained personnel and HR a real issue – we need incentives to produce human resources – foreign and local. • The appropriate equipment. • Industry recognition services. • Certified service sector. • Administrative structure dedicated to bio-remediation. • CERCLA – super fund.

1	**SECTOR**	**Biotech (Dr Gary Garcia)**
2	**'BEST BET' TITLE**	**6. 'Kentucky Fried Agouti'**
3	**'BEST BET' DESCRIPTION**	• The development of T&T disease free tropical animals. • The production of healthy neo-tropical animals for specialist markets. • T&T neotropical genetics.
4	**GLOBAL MARKET NICHE FOCUS**	• Neo-tropical animal cuisine – a new offer to high-end consumers (possibly strong in China and surrounding Asian markets?). • Neo-tropical animal breeding stock (registered animals and breeds). • Part of the T&T eco-tourism product – develop hunting lodges.
5	**WHAT T&T HAS**	• 33% of the important neo-tropical species. • Animal populations with a wide range of genetic / phenotypic variability. • 10 – 15 species of neotropical animals. • We have developed the expertise in developing production systems for neo-tropical species. • A large number of potential graduate students for doing the research and running a specialist centre. • An expert in neo-tropical species. • The world expert on the agouti. • An Agricultural Science and Veterinary facility to support R&D.
6	**WHAT T& T NEEDS**	• A Centre for Neo-Tropical Animal Wildlife Production & Breeding. • Legislation to establish the traceability requirements. • A good system for animal identification and performance records. • Market research, market development, and marketing. • Branding. • Commercial investment.

1	**SECTOR**	**Biotech (Ulrike Krauss)**
2	**'BEST BET' TITLE**	**7. 'Bio Bug Killers'**
3	**'BEST BET' DESCRIPTION**	• For turf grass, ornamentals, fresh fruit and vegetables. • T&T a one stop shop for commercial scale production of chemical and indicative biological control product development. • Cosmetic market development. • Garment industry – Sea Island cotton.
4	**GLOBAL MARKET NICHE FOCUS**	• Regional tourist sector, cruise ships, eco/edu tourism • Green consumers.
5	**WHAT T&T HAS**	• Biodiversity – a source of BCAs. • Exotic crops – opportunities for BC. • Early R&D expertise. • Reputation as a BC leader.
6	**WHAT T& T NEEDS**	• Roll out and commercialisation expertise. • Investment and infrastructure. • Regional marketing support – links to input importers. • Updating of legislation. • Legal archives – international.

1	**SECTOR**	**Biotech (Pathamanathan Umaharan, Julian Duncan, Vishnarayan Moolleedhar, Michelle John)**
2	**'BEST BET' TITLE**	**8. 'Soca Flowers'**
3	**'BEST BET' DESCRIPTION**	• Novel tropical flowers found in all hotels and most of the homes in the Caribbean and in supermarkets and flower shops in North America and Europe. • A twenty-fold increase in economic returns to local flower growers. • Commercial technical packages (including plant material, business plan, training and consultancy services for growing throughout LA and the Caribbean available.
4	**GLOBAL MARKET NICHE FOCUS**	• Flower purchasers on the North America East Coast, Europe, the Caribbean. • Flowers for the tourism sector in the Caribbean. • Seeds and planting material – for Latin America and the Caribbean.
5	**WHAT T&T HAS**	• Human, biological, and financial resources. • Indigenous knowledge. • Existing development programmes. • Good micro-propagation and seed production facilities. • Regional trade framework and ready access to markets. • Ideal low cost growing environment.
6	**WHAT T& T NEEDS**	• Increased capacity (human) and infrastructure for R&D. • Linkages between research and technology institutions and commercial interests. • A consortium to drive development and prioritise R&D initiatives. • R&D policy and funding mechanism. • Increased private sector involvement. • Efficient quarantine system and quality control. • Reliable marketing presence in Europe and North America. • Greater connectivity to markets through dedicated flights.

3 What Happens Next?

These Best Bets will be peer reviewed by both key Trinidad and Tobago stakeholders and other specialists both within T&T and offshore to determine which offer the greatest potential commercial prospects. In some instances there is a degree of overlap with 'Best Bet' propositions from other sectors. This overlap will be integrated into an overall 3-4 'Best Bets' selected for each of the five sectors being examined as part of this foresighting project.

Appendix: A Key Review of Biotechnology Capacity & Capability in the Caribbean and Trinidad & Tobago

Interim Report
on
Biotechnology capacity and capability in the Caribbean in general and in the Republic of Trinidad and Tobago in particular

E. Julian Duncan

Introduction

The Convention on Biological Diversity (1992) defines biotechnology as 'any technological application that uses biological systems, living organisms or derivatives thereof, to make or modify products or processes for specific use.' Such a definition embraces a continuum of technologies from the simple, such as fermentation and breeding –often referred to as traditional, through reproductive technologies of *in vitro* fertilization, embryo transplant and micro-propagation, to techniques based on recent advances in cell and molecular biology. These last are referred to as contemporary biotechnology and include recombinant DNA technology, genetic engineering and transformation, functional genomics and proteomics. Biotechnology thus embraces many disciplines, principal among which are the life sciences and engineering.

Biotechnology, as such, is nothing new and has been used for centuries to produce food, and to solve problems related to human health, the health of domestic animals and to the environment. It is generally accepted that biotechnology, particularly the newer techniques, holds promise for addressing key challenges in agriculture, health and environmental management. Indeed Article 19 (1) of the CBD encourages the use of biotechnology by calling on parties to initiate 'measures appropriate to provide for the participation in biotechnological research activities …….. especially developing countries which provide the genetic resources for such research….'

Major areas of concern are agriculture, human health and the environment and in keeping with these concerns biotechnology has been categorised as:
'Green biotechnology' encompassing a wide range of techniques including the culturing of plant tissues and organs for the mass production of genetically identical plants for distribution to farmers, horticulturists, foresters and nurseries on a year-round basis; transformation of plant species through genetic modification, towards the production of varieties resistant to, or tolerant of stresses both biotic and abiotic; and techniques used in livestock husbandry. Green biotechnology should thus not be thought of as genetic engineering only.

'Red biotechnology' - genetic engineering techniques that have been used since the mid-1970s to produce drugs and vaccines in micro-organisms, animal cells and more recently plants. A wide range of diagnostic techniques and veterinary vaccines are produced using red biotechnology.

'White biotechnology'- a range of processes resulting in fermented products and chemicals as well as technologies used in recycling wastewater, industrial effluents

and solid wastes. These processes, known as bioremediation are critical in addressing pollution problems.

All three of these categories have found application in the Caribbean, some more so than others.

The Caribbean archipelago comprises a chain of sovereign nations which in the main are small, island-states. The total land area is about 22.9Mh with a population of about 35.6M. Many 'lack the resources to make the investments needed in research and product and process development and innovation to harness biotechnology for sustainable social and economic development and wealth creation.'[1] This is particularly so in the smaller countries where populations are too small to support the critical mass of scientific personnel required to drive research and development, and in which there is no university presence. While many of the territories have undertaken endeavours in some aspect of biotechnology it is at the lower to middle end of the spectrum in most. The larger countries, with a university presence and thus a number of scientists closer to the critical mass required, are the ones in which cutting edge research is done.

The National Institute of Higher Education (Research, Science and Technology) [NIHERST] of Trinidad and Tobago has embarked on a sector foresighting exercise to create policy options for science and technology research by analyzing the long-term future prospects for selected economic sectors in the nation.

One of the four (4) sectors chosen is biotechnology. An initial step in the foresighting process is determining the capacity and capability of the nation in the field. In order to assess the strengths and weaknesses in local capacity/capability and to avoid unnecessary duplication of effort, it is desirable to view our position in the context of the capacity/capabilities in the Caribbean region as a whole. The exercise on which this document reports was designed to address this issue.

Methodology

1. Questionnaires (Appendix I a and b) were sent to key scientists in the Anglophone Caribbean countries in which there is a biotechnology initiative and to Cuba and the Dominican Republic. In addition desk top research was conducted, and documents were obtained from the Trinidad office of the Inter-American Institute for Cooperation on Agriculture (**IICA**) and the Technical Centre for Agricultural and Rural Cooperation (**CTA**), Holland.

2. Visits were made to research institutes in Trinidad and interviews conducted with key researchers on the work in progress, the results obtained and the prospects for development and commercialization.

Results

Response to the questionnaire was poor. A comprehensive reply was received from Barbados only. Response from Jamaica, though adequate, was not as comprehensive as that received from Barbados. As a result, the reports on these two countries are more detailed that those of the others to which questionnaires were sent.

Following are summaries of the status of biotechnology in Cuba, the Dominican Republic and the Organisation of Eastern Caribbean States (**OECS**), and fuller reports on the status in Barbados and Jamaica.

Cuba

Cuba is the largest island nation in the region and supports the largest number of research centres. The Republic embraced biotechnology in the 1980s and in 1986 a state-of-the art Centre for Genetic Engineering and Biotechnology (**CIGB**) – occupying over 60,000 square metres of floor space- was inaugurated. Over the past two decades the republic invested heavily in 'red biotechnology' and has become an important producer of biotechnology derived medicines, vaccines and diagnostic kits. The **CIGB** is an affiliated centre of the International Centre for Genetic Engineering and Biotechnology (**ICGEB**), Trieste, Italy.

In addition successes have been achieved in the areas of industrial biotechnology, process and quality control and in 'green biotechnology' through tissue culture and transgenesis (with modified genomes) of plants towards disease resistance, along with production of biopesticides and fertilizers and veterinary vaccines.
The principal areas of research at the **CIGB** are:

- Proteins and hormones: recombinant DNA techniques are used to produce proteins for both human and veterinary medical applications.
- Vaccines and diagnostics: development of vaccines against tropical and subtropical diseases, through cloning of surface proteins of viruses and bacteria.
- Energy and biomass: transformation of various kinds of biomass via chemical methods and enzymes.
- Plants and fertilizers: improvement of plant varieties using genetic engineering and biotechnology.
- Mammalian cell genetics: using cells of higher organisms to clone genes for protein production.
- Quality control: 'verifying purity, structural integrity, molecular composition, functioning, clinical and pharmacologic properties as well as immunologic response and undesirable side effects.' [2]

Dominican Republic

In 2000 the Centro de Biotechnologia y Biodiversidad (CIBIO) was established to 'serve as the national and scientific base for finding biotechnology solutions to the main problems affecting agriculture, forestry and fisheries sectors.'[1]
In addition to the **CIBIO** there are 12 tissue culture laboratories with a capacity for producing 8M plants per year; 3 molecular diagnostic laboratories; 3 industrial laboratories (publicly funded) and 10 private companies; 2 universities, **CIBIO**, and one Botanical Garden are involved in germplasm conservation.
Twenty (20) scientists – about 4% of the critical mass of scientists in the country- are involved in biotechnology research on which 0.05% of the national budget was invested over the past 4 years.

Areas of research include:

- **Tissue culture**: current approaches are a switch from organogenesis to embryogenesis; establishment of quality control systems in *in vitro* production; plant transformation.

- **Molecular biology:** use of molecular markers for assisted selection in avocado.
- **Industrial biochemistry**: fermentation – production of wines and vinegars; lactic acid and other acids; 100% ethanol as a bio-fuel.
- **Bioactivity**: identification of bioactivity in endemic medicinal plants; production of bio-inputs (bio-pesticides and bio-fertilizers) for organic farming; worm lixiviation and characterization.
- **Germplasm:** management and conservation.[3]

Jamaica

In Jamaica a Biotechnology Centre was established at the Mona campus of The University of the West Indies in 1989, with a specific mission 'to develop the research capabilities and training programmes in biotechnology' in Jamaica. The Centre 'collaborates with other units within the University and with other research organisations.'[4] In addition to the work carried out at the University Centre, biotechnology research is in progress at the Scientific Research Council (**SRC)** established in 1960 as the national centre for science and technology development in the nation, and at both the Coconut Industry Board and the Sugar Research Council.

Work at the Biotechnology Centre (UWI) includes:

- **Plant tissue culture:** improvement of micro-propagation methods; production of disease –free yam (*Dioscorea* sp.) plantlets; somatic embryogenesis of herbaceous and woody plants medicinal; development of regeneration protocols for hot peppers (*Capsicum chinese*).
- **Plant genetic transformation:** development of papaya (*Carica papaya*) plants resistant to papaya ring spot virus (PRSV) and production of fruit (both fresh and processed) fit for human consumption (in collaboration with Cornell University, USA); development of tomato plants resistant to tomato yellow leaf curl virus (TYLCV-ls) and production of fruit fit for human consumption (in collaboration with the University of Wisconsin –Madison and Hebrew University; production of insect attack resistant, transgenic Sea Island cotton (*Gossypium barbadense)* plants containing *Baccillus thuringiensis* (Cryl and 2A) toxin gene.
- **Molecular biology:** molecular characterization of yams, dasheen (*Colocasia* sp.) and cocoyam (*Xanthosoma* sp); molecular diagnostics based on polymerase chain
  reaction (PCR) technique for the detection of Gemini viruses, lethal yellowing (LY), phytoplasma and citrus tristezia virus (CTV).
- **Plant molecular pathology:** use of plant growth promoting bacteria as a bio-control agents to protect hot peppers against tobacco etch virus (TEV) and potato virus Y (PVY).
- **Plant metabolism/biochemistry:** post-harvest physiology to seek ways to enhance shelf life of harvested yams; isolation of secondary metabolites from yams for medicinal purposes; investigation starches for cholesterol-lowering properties and industrial application.

Research at the SRC focuses on:

- **Germplasm conservation**: conservation of food and orchard crops, ornamentals and medicinal plants.
- **Micro-propagation**: small-scale production of micro-propagated plants principally bananas; protocol development for mass production of coffee, mangosteen, breadfruit and jackfruit; development of techniques for

somatic embryogenesis of protocorms of orchids; development of temporary immersion systems for *in vitro* plantain.

- **Mushroom production**: development of fruiting substrate using agricultural wastes, certain grasses; production of spawn for growth of mushrooms, primarily *Pleurotus* sp.

Research at the Coconut Industry Board is focussed on:

- Genetic characterization of phytoplasmas causing lethal yellowing of coconut palms; screening coconut germplasm using micro-satellite markers and AFLP for resistance genes.

Barbados

Research in biotechnology in Barbados is conducted principally at the Cave Hill campus of the University. A Government tissue culture laboratory is in operation and some work is carried out at the Caribbean Agriculture Research and Development Institute (**CARDI)** Station in the nation.

Table 1 below gives details of work in progress:

Table 1: Biotechnology capacity and capability in Barbados

Capacity			Capability			Funding
Human Resources		Facilities	Area	Species	Objective	
Professional	Support					
2	2	Fully equipped University-based Facilities	Reverse transcriptase technology	Breadfruit, soursop and avocado	Delay ripening in fruits	External and local funding
2	5	Fully equipped University-based Facilities	Characterization of pathogen and plant disease resistance genes	Pepper, tomato, Yam, anthurium and papaya	Plant disease genetic control	External public; regional and local private and public sectors
3	4	Fully-equipped hospital and University-based Facilities including DNA sequencer	Genetic typing of diabetes and hypertension	Barbadian human population	Better management of obesity	Local and external public sectors
3	1	Fully equipped university and hospital-based facilities, including animal cell culture incubators and containment cabinets	Molecular typing of obesity	Barbadian human population	Better management of obesity	Local and external public sectors
3	2	Fully equipped university-based facilities	DNA finger printing	Barbados Black Belly sheep	To establish taxonomic distinction	Local public sector
2	1	Fully equipped university-based facilities including DNA sequencer	DNA finger printing	Caribbean hot pepper	To establish taxonomic distinction	Local and external public sectors
3	4	Fully equipped university-based laboratory and extensive private field testing facilities	Identification of genetic markers using DNA probes	Sugar cane	Marker-assisted breeding for sugar content and new products	Local and external public sectors
3	4	Fully equipped university-based facilities	Fermentation Technology	Mutacin-producing microbes	Bio-prospecting for anit-microbial agents	Local and external public sectors
2	6	Fully equipped Government laboratory	Micro-propagation	*Anthurium*	Commercial	Local public

Organisation of Eastern Caribbean States (OECS)

In the nations that comprise the OECS, biotechnology activity focuses principally on micro-propagation. There is a level of germplasm conservation in some of the islands. With assistance from the Chinese Government and to a lesser extent form the Taiwanese, tissue culture facilities have been set up in Grenada, St. Vincent and St. Lucia. These are run by the Ministries in each of the islands. In St. Vincent, in addition to the government funded laboratory, there is a private laboratory at which the focus is on production of horticultural species. Governmental support of science and technology is strongest in Grenada and the laboratory in that country, run by a professional at the doctorate level, has begun work on molecular biology and genetic engineering in addition to the micro-propagation begun some years ago.

Trinidad and Tobago

The Republic of Trinidad and Tobago has for years been involved in fermentation technologies in the rum industry. Work on other aspects of biotechnology began in the late 1970s, with the establishment of a small tissue culture facility at the St. Augustine campus of the University of the West Indies, principally for the training of personnel in the discipline. In the early years of the 1980s the laboratory was expanded and put on a firmer footing through a grant of one hundred and fifty thousand dollars (TT$150,000.00) from NIHERST. This expansion allowed for a larger intake of research students and the establishment -on the site- of a small semi-commercial facility. Grants from the Organisation of American States (**OAS)** through the 'Biotechnology and Food Programme' run in the late 1980s to early 1990s allowed for an upgrade in the facilities at the laboratory. The first phase of work concentrated on developing expertise in micro-propagation and the development of protocols for the mass production of plants of economic importance in the region; then on a change from organogenesis to embryogenesis. In a later phase, with the laboratory better equipped in an upgrading exercise on the part of the University through a loan from the Inter-American Development Bank, work involving aspects of molecular biology were initiated.

Concurrent with the commencement of research in molecular biology at the Biotechnology laboratory, similar work was initiated at the Cocoa Research Unit (**CRU**), also located at the St. Augustine campus, in collaboration with CIRAD (France).

Work in other areas of biotechnology was initiated or strengthened with time and the campus became the focal point of biotechnological research in the Republic. It must not be thought however that the University (including the schools of the Eric Williams Medical Complex at Mount Hope) is the only institution involved in work on aspects of biotechnology. The Caribbean Epidemiology Centre (**CAREC**) -a regional organisation located in Trinidad, the Caribbean Agriculture Research and Development Institute (**CARDI**), La Reunion Propagation Station (Centeno) of the Ministry of Agriculture, land and Marine Resources, the Institute of Marie Affairs (**IMA**) and the Sugarcane Feeds Centre (**SFC)** have all been engaged in one aspect of biotechnology or another.

Listed below are the main areas and projects of ongoing research in the Republic:

Fermentation techniques: production of wines and vinegars from local fruits; development of protocols for the production of cheeses, yoghurt and butter from buffalyso milk.

Plant tissue culture: micro-propagation of tropical crops and ornamentals including banana, breadfruit, plantain, pineapple, yam bean, carambola, aloes, Heliconia, anthurium, orchids and bromeliads; development of protocols for somatic embryogenesis in anthurium.

Plant genetic transformation: developing transformation protocols and systems for bioengineering tropical ornamentals (novel characteristics and an increase in the colour range in anthurium), and other crops of commercial value - tomato, cocoa, pepper.

Molecular biology: identification and characterization of genes of interest**:** isolation of flavanoid biosynthetic genes from anthurium; identifying the genes involved in tuberization in tropical root crops with a view to elucidating the role of light in the process; identifying genotypes of the germplasm in the International Cocoa Genebank and fingerprinting of all cacao types in the Americas (in collaboration with USDA) for the development of a molecular data base.

Molecular characterization of genetic biodiversity of forest species; characterization of genetic diversity of indigenous and introduced plants; biotechnology-assisted breeding using markers (markers have been developed for blackpod disease of cacao and work is currently on identification of markers for witches' broom.)

Plant metabolism/biochemistry: investigating the starch composition of yam beans and attempting to increase starch content in the crop.

Biological control: development of bi-control agents as part of a pest management programme; use of Bt as a pesticide; use of other microorganisms in the control of frog hopper in the sugarcane industry, ticks in animal husbandry and weevils in legumes. Exploring the bacterial and fungal biodiversity for bio-agents against white fly.

Bioremediation: use of microorganisms in the abatement of pollution, particularly that caused by petroleum and petroleum products.

Germplasm collection and characterization: cacao and pepper.

Medical biotechnology: studies on diabetes – identification of novel diabetes-associated
Mutations; characterization of rabies virus isolates; studies on dengue and other ailments occasioned by mosquito- borne pathogens, leptospirosis, and West Nile.

Aquaculture: protocols for intensifying production in Tilapia and other fresh water species of animals; sex reversal and production of super males in Tilapia. Production systems for fresh water conch.

Animal husbandry: improving the buffalypso stock for greater milk production; identifying the time of heat; artificial insemination and embryo transplant in buffalypso (planned).

Medicinal plants: I am informed (Dr. C.E. Seaforth personal communication) that research on medicinal plants is to be initiated at the University of Trinidad and Tobago (**UTT**) in collaboration with Johns Hopkins University.

Discussion

There are disparities in the levels of technological advance in biotechnology among the islands of the Caribbean: the larger countries of Cuba and to a lesser extent the Dominican Republic are at the upper end of the scale, with the islands of the OECS, with the possible exception of Grenada, at the lower end. Trinidad and Barbados occupy a position somewhat to the higher end of the mid- region, with Jamaica slightly higher.

The level of competence achieved in the field appears to be less related to the GDP of the country than to the size of population and ease of facility to a tertiary education (hence size of critical mass of scientific personnel) and to the political will of the government to establish a firm foundation for science and technology and provide funding to drive the sector.

A comparison of the research conducted in the countries deemed to be midway along the scale shows a great deal of overlap in both techniques used and objectives; in instances even in respect of species under investigation. This might be due in part to the fact that campus presences in these countries are all units of a regional University. Much of this can thus be explained on the basis of collaborative effort on the part of the scientists.

There are areas in which Trinidad and Tobago seem to lack a competitive edge, but four areas show promise on account of possible clusters of competences, natural resources and the potential for generation of IP through the existing expertise in plant breeding and aquaculture. Among the natural resources that hold promise are cocoa and the buffalypso. Expertise in which the country holds some advantage is in plant breeding and in the development of aquaculture production systems.

A case for a 'fine' chocolate industry

In or about 1525, Criollo cocoas were introduced to Trinidad, probably from Venezuela. Much of this was destroyed by 'the blast', either a hurricane of disease, in 1727. Sometime later, dark-beaned cocoa of the Forestero type was introduced from the Amazon region. These latter types hybridized with the remnants of the earlier Criollo types to produce what are known as the Trinitario cocoas. Trinitario cocoas are regarded in the trade as being a 'fine' cocoa,[5] and is used as a component of all brands of fine chocolate produces world-wide. At present demand for cocoa from Trinidad outstrips supply. The flavour of the beans determines whether a cocoa is classified as 'fine' or not.

Although these clones have been exported to the major cocoa growing countries, Trinidad and Tobago has an edge on these regions, for flavour which is genetically determined, is enhanced by soil type and fermentation regimes.

The soil in Trinidad, particularly on some estates, is formed from marine sediments containing calcium carbonate and glauconite rich is potassium and phosphorus and ideally suited to enhance flavour. Fermentation regimes have been developed at the **CRU** (see Appendix 11) that further enhance the attribute**.**

One of the problems currently facing cocoa growing regions of the world is the high incidence of disease. 'Cocoa production has suffered from a number of diseases worldwide that annually destroy approximately 40% of the total crop in 12 major producing countries.'[6] Work is in progress on the development of clones that are resistant to or tolerant of the major diseases. The CRU has had some measure of success in developing techniques for the screening of clones for resistance to the two major diseases (Witches broom and blackpod) that occur here.

It is thus not far fetched to suggest the development of an industry for the production of 'fine' chocolate and drinking chocolate. A recent initiative in this direction was taken 'to honour the Soca Warriors' participation in the 2006 World Cup.' Scharffen Berger Chocolate Maker (Berkely, California) has produced a limited edition of chocolate bar ('*Danse le cacao* – BitterSweet') of single origin from beans produced on selected estates in Trinidad. The confection – described as 'a flavourful chocolate with fruity and floral tones and hints of coffee and vanilla' (see Appendix 111), is on the market in London and Germany.

Experts from the CRU have suggested that an industry might be started in collaboration with an established factory of 'fine' chocolate makers, under a specific label (as has been done with *Danse le cacao*. When the label is sufficiently well known on the international market the country might consider going it alone.

A case for the development of an industry for the production of value-added diary products of buffalypso milk origin.

In Trinidad and Tobago, research towards the development of good beef producers was carried out on the Indian water buffalo (*Bubalus bubalis)*. Various breeds of the animal were crossed and crossbred allowing for genetic recombination and expression of variability in the population. Selection was made for the progeny of the crosses. The resulting population, called buffalypso, possesses most of the characteristics of a new breed specifically suited for beef production in the tropics;[7] the type has been exported to Venezuela and to the USA.

A herd was maintained by the now defunct Caroni (1975) Ltd., but was decimated by *Brucella* and fewer than 1000 animals of the herd exist. The Animal Breeding Centre (ABC) of the Ministry of Agriculture, Land and Marine Resources, at Aripo, also maintains a herd with is *Brucella*- free. The **ABC** has facilities for freezing semen and no doubt embryos and highly trained professional in the field of *in vitro* fertilization and embryo transplant. A training course in embryo transplant for technicians has been designed and is due to be offered at the Veterinary School (EWMSC) in July next.

The **SFC** has plans to resuscitate the Caroni herd and breed for greater milk production.

Rapid increase in population size can be achieved if embryos are supplied by the ABC.

It is claimed that a yoghurt and mozzarella of very good quality are produced from buffalpso milk. Both the Department of Chemical Engineering, Faculty of Engineering, the University of the West Indies, and the Biotechnology Unit of CARIRI have worked on, and successfully produced, protocols for production of both these commodities.

On the basis of the pacts presented above, and industry for the production of value-added products form buffalypso milk is proposed.

A case for the development of elite types of horticultural species.

A major focus of the plant breeding unit of the Department of Life Sciences, UWI, has bee the improvement of *Anthurium andraeanum* for resistance to bacterial blight (*Xanthomonas)* and leaf spot (*Acidovorax*), through traditional techniques. Recently these efforts have been enhanced by the use of molecular markers. To date varieties resistant to the diseases have been produced and in the process a few novel spathe colours have been obtained. Additionally the genetics of colour in the species has been worked out and the pathway to colour change by gene manipulation is now known. The potential for producing new colours thus exists.

An anthurium bloom of standard colour goes for US$ 0.30 on the international market, but if a novel variety is produced the blooms sell for US$1.00 – roughly a three-fold increase in revenue (Dr. P. Umaharan, personal communication).

The orchid industries of many of the countries that produce the species commercially is often build around a single genus. For example, the industry in Thailand is centered on the genus *Phalaenopsis*. The centre of origin of the genus *Epidendrum* is the Americas. No one has to date developed an industry based on the genus. Work in progress at the UWI is centered on collection of species of the genus, broadening the genetic base through a breeding programme and producing elite types upon which an industry can be based.

The region is also the centre of diversity of *Capsicum chinense.* This species is truly adapted to the tropics, is resistant to *Phytophthora* and is very pungent. The aim of the breeding programme is to produce new varieties with improved yield potential that can be competitive with the varieties of *Capsicum annuum,* a temperate crop. Apart from being grown at the commercial level as a crop for production of seed for sale to farmers, the species can be used in the production of medicines, sprays and in the food industry.

It is not proposed that Trinidad goes into the growing of any of these crops for export of the end product, for the country lacks the land required for large-scale production The suggestion is that novel varieties of the species in question be developed, licensed and sold to seed producers in the case of pepper and to other countries in the region for production of the volume of blooms required for sustaining a viable industry. The benefits to Trinidad and Tobago will accrue from Intellectual Property.

A case for the development of an aquaculture industry for the production of Tilapia

Research on Tilapia production has been carried ongoing at The University of the West Indies, The Institute of Marine Affairs and at the Sugar Feeds Centre for some time. Greatest progress has been made at the UWI. An intensive production system that allows for many crops per year has been developed. Consideration is currently being given to the development of aquaponic systems in which the water from the fish ponds is circulated through a hydroponic system, whereby the plants receive nutrients from the water while ‘cleaning’ it for return to the ponds. In this way crops of fish and of vegetables can be obtained from one system.

The equipment required for set up operations is not expensive. Large areas of land are no longer required, since the move is away form mud ponds to concrete tanks. These latter require less space; provide for better security of the operation; are less

labour intensive, since one man can manage 4 tank systems of 20X20 m^2 whereas the equivalent mud pond area would require more hands.

There is a great demand for fresh water fish Tilapia is at the top of the list on the world market. In addition to fillets of the fish, value added products such as breaded slabs and sausages have been produced. This opens opportunities for our food technologists.

References

1. ACP Policy Brief 1. ACP Region must harness Biotechnology for a better future.
   Approved and adopted by the Advisory Committee on Science and Technology for ACP Agricultural and Rural Development on November 11, 2005 during their 4th meeting held at CTA Headquarters Wageningen, The Netherlands, Nov. 07-11, 2005. pp11

2. NTI: Country Overviews: Cuba: Biological Facilities. Biological Facilities: Centre for Genetic Engineering (Centro de Ingenieria Genetica Biotechnologia)
   http://www.nti.org/e-research/profiles/Cuba/Biological/3487_3514 pp 3.

3. Biotechnology and Development in the Dominican Republic. Presentation made at a workshop 'Developing a Regional Roadmap for Commercialization of Biotechnology.' Kingston, Jamaica, December 2004.

4. McLaughlin W., Burrell, P. and Barnett, A. (2006) applications of Biotechnology In Jamaica and the Caribbean.
   http://www.science.oas.org/components/quito/Biotechnology.

5. Purseglove, J. W. (1968) *Tropical Crops: Dicotyledons.* Longmans Scientific & Technical, Longmans Group U.K. Ltd., Longman House, Honslow, Essex, U.K. pp717.

6. Saunders, James A. (2002) The USDA Program for *Theobroma cacao:* Molecular Geonomics, Disease Resistance and IPM Strategies. *The Manufacturing Confectioner* September 2002, 109-119.

7. Duncan, E. Julian (1988) Germplasm manipulation and Conservation. In Reay and Steward edited *Science applied in the Caribbean.* Macmillan Caribbean,
   London. pp 362.