Coconut revival: new possibilities for the 'tree of life'

Proceedings of the International Coconut Forum held in Cairns, Australia, 22–24 November 2005

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Australian Centre for International Agricultural Research
Canberra
2006

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Members of the program committee were Dr Yohannes Samosir (University of Queensland) (Chair), Mr Mike Foale (CSIRO), Mr Sisunandar (University of Queensland), Dr Steve Adkins (University of Queensland) and Ms Cherri Buffett.

The administrative support of Mrs Christine Brown, Mrs Jane Gilpin, Mrs Melissa Anderson and Mrs Dianne Waters is gratefully acknowledged.

The papers in these proceedings were peer reviewed for their scientific content and merit, and the reviewers are thanked for their constructive comments.

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Adkins, S.W., Foale, M. and Samosir, Y.M.S. (eds) 2006. Coconut revival—new possibilities for the ‘tree of life’. Proceedings of the International Coconut Forum held in Cairns, Australia, 22–24 November 2005. ACIAR Proceedings No. 125, 103 pp.

ISBN 1 86320 514 4 (print)
ISBN 1 86320 515 2 (online)

Technical editing: Jo Mason, Mason Edit, Adelaide, Australia
Typesetting and layout: Clarus Design Pty Ltd, Canberra
Printing: PIRION Pty Ltd

From: Adkins, S.W., Foale, M. and Samosir, Y.M.S. (eds) 2006. Coconut revival—new possibilities for the 'tree of life'. Proceedings of the International Coconut Forum held in Cairns, Australia, 22–24 November 2005. ACIAR Proceedings No. 125.

Foreword

Coconut (*Cocos nucifera*) is one the most important crops grown in the humid tropics. More than 11 million farmers, mostly smallholders with low income, grow the palm in 90 countries. More than 80% of the total world production comes from the Asia–Pacific countries, which are near neighbours of Australia. Coconut also grows well in moist tropical regions of Australia, particularly northern Queensland. Plantations have been established in the past but the palm is now mostly used for ornamental purposes. Coconut is still used as the symbol of the Australian tropics to attract tourists from around the world to come on holiday in these regions.

Through the Australian Centre for International Agricultural Research (ACIAR), Australia actively supports and is involved in coconut research and development (R&D), in collaboration with its neighbouring coconut producing countries. Some business-related work has also occurred on coconut tree maintenance, processing and trading. Such a broad range of interests puts Australia in a unique position to make an important contribution to the future of coconut in the Asia–Pacific region.

The idea of holding an International Coconut Forum in Australia evolved from extensive discussions with a number of coconut specialists, businesses and agencies. This forum, which was co-sponsored by ACIAR, the Australian Agency for International Development (AusAID), the University of Queensland (UQ), African Pacific Pty Ltd, Asian and Pacific Coconut Community (APCC), Secretariat of the Pacific Community (SPC), Coconet Pty Ltd and Kokonut Pacific Pty Ltd, was the first of its kind to be held in Australia. Appreciation is expressed to Mr Luke Bice (Sunrise Coconuts) and Mr Paul Richardson (Cocotap) for their help in organising the event; and to Councillor Kevin Byrne, Mayor of the City of Cairns, for his address and the opening of the forum.

These proceedings not only document the majority of the papers and posters presented at the forum, but also present several papers by authors who, for various reasons, could not attend the meeting. The topics covered in the forum were diverse, reflecting the vast range of interests and expertise of the participants, and included R&D, business and government, and regional and international agency interests.

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Unpresented papers

Posters

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Summary

The International Coconut Forum was planned with several objectives in mind:

- to highlight Australia's support for coconut R&D in the Asia–Pacific region over 20 years
- to discuss past, current and future international support for coconut R&D
- to identify strategic issues in the development of coconut industries of the region, especially those relating to new products and markets
- to discuss the potential benefits to Australia of increased interest in coconut as a health food, and possible collateral benefits to producers elsewhere through increased product recognition and status.

The forum was supported by the University of Queensland (UQ) with major and minor sponsorships from AusAID, ACIAR, the Asian and Pacific Coconut Community (APCC), the Secretariat of the Pacific Community (SPC), Kokonut Pacific Pty Ltd, African Pacific Pty Ltd, Coconet Pty Ltd, Sunrise Coconuts, Cocotap and other private sponsors. In the first 2 days of the forum the delegates shared experiences and views, and discussed the future of coconut R&D, processing and marketing, as well as the potential of coconut in Australia. The forum was also a showcase of publications, fresh tender-coconut drinks and high-value products, particularly virgin coconut oil (VCO), and other Australian inventions. On the third day the delegates visited some remnant coconut plantations and the Queensland Department of Primary Industries (QDPI) South Johnston Research Station. The forum was well covered by both the local and national media.

Councillor Kevin Byrne, Mayor of the City of Cairns, opened the forum. He welcomed the 50 delegates from 14 different countries (viz. Fiji, France, French Polynesia, India, Indonesia, Malaysia, Marshall Islands, the Philippines, Papua New Guinea, Singapore, United States of America, Vanuatu and Australia). His remarks were apposite in highlighting the interest and challenges of growing coconut, as well as the fast-growing tourism of the Cairns region.

It was acknowledged at the forum that Australia, through ACIAR, has supported coconut R&D for more than 20 years, helping to understand some major diseases of the plant, particularly foliar decay in Vanuatu and cadang-cadang in the Philippines. Australia has also assisted in the recognition and collection of coconut varieties in order to conduct breeding for improvement in yield and resistance to natural threats. More recently, ACIAR renewed its support for coconut tissue culture research. The latest project involved Australia (UQ), Vietnam, the Philippines, Papua New Guinea and Indonesia. Continuing support from ACIAR and other donors was solicited at the forum to further help in addressing the strategic issues identified by the delegates.

Achievements and challenges in coconut R&D, processing, marketing and community development were shared by the speakers through oral and poster presentations. Despite the various technologies, including high-yielding varieties, that have been developed through past R&D investment in various countries, coconut farmers are still faced with many problems. Besides new research, particular importance needs to be given to the enhancement of technology transfer, quality control and marketing. Expansion of export markets for value-added and high-value products like geotextiles and VCO requires intense effort. The potential of elite fruit types, such as 'makapuno' and 'aromatic', should soon be widely realised using the more advanced embryo culture technique developed during the latest ACIAR-funded project.

The role of regional and international bodies (i.e. APCC, SPC and Coconut Genetic Resources Network (COGENT)) was also highlighted, with expectation of more collaborative activities to be undertaken in the near future among the member countries. The assertion was made that 'coconut farmers should not be poor', challenging all coconut stakeholders, including private enterprise, to ensure this is the case. Stronger support from respective countries is needed to tap growing market interest in products with high value. Likewise, the realisation and utilisation of national and international gene banks to develop high-yielding and more secure

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planting materials deserve greater support in the future.

The future of coconut biofuel in the Pacific countries was addressed, noting government taxation policies and the need for new initiatives to make the fuel more competitive and reliable. A policy challenge was identified in Vanuatu, for example, where the government collects a levy on imported diesel fuel that would diminish as in-country coconut oil began to take over from diesel.

Dr Bruce Fife from the Coconut Research Center in the USA attended as a special guest. He noted that there are many scientific papers in the medical research literature describing the benefits of coconut oil in the diet for health problems including diabetes, heart disease and many infectious diseases. He pointed out that, even though coconut oil is chemically a saturated oil, its molecular components are very different from animal fats, being known as 'medium-chain triglycerides'. This is the technical name for small molecules that are able to move freely into the bloodstream and enter active tissue cells, thus boosting the turnover of energy to the extent that other energy sources are also used up. As a consequence, coconut oil helps those who are trying to lose weight. It also stabilises the HIV/AIDS condition in many sufferers, and the forum called for more research into this and other health responses.

Three aspects of the potential of coconut and its products in Australia were discussed, namely its continuing use as an ornamental plant in cityscapes and resorts, 'Coconut World'—a theme park, and coconut as a plantation crop in sugarcane growing regions (hereafter referred to as sugarcane lands). There is no doubt that coconut palms make parks, beaches and streets beautiful and more attractive to the tourist seeking a tropical holiday in Australia. However, ongoing management of the palm is needed to avoid possible injury to unsuspecting visitors by falling nuts and fronds.

The Coconut World concept, similar to such agriculture-based theme parks as Tropical Fruit World and the Big Banana, was presented by Dr Yohannes Samosir of UQ. In the tourist-rich region of far northern Queensland, a Coconut World theme park could be another attraction alongside the reef, rainforest, Sky Rail, tablelands and so on. The park would provide the visitor with a good insight into the growing, harvesting and processing of coconut, and the diverse end products available, especially the wonderful range of attractive foods and artefacts. Coconut World could also provide a showcase of coconut-related technologies from around the world, including some Australian inventions such as the Direct Micro Expelling (DME) technique for oil extraction, the Coconet, the Cocotap, the kernel extraction knife and others.

Sugarcane farmers are generally very reliant on the one crop for their income, and they suffer from the uncertainties of the world sugar market. Coconut could provide a stabilising component in such a farming system as it produces a crop product month by month, all year round, and there are now some high-value end products from coconut (e.g. VCO) that would ensure a reasonable return on investment. Research is just beginning on this possibility, and could lead to a modest industry in Australia producing coconut oil and other products in the long term. If coconut had greater recognition in Australia its products would likely become more accepted and researched, especially in the diet and health area. In the future Australian markets might grow sufficiently that the developing economies of, in particular, our Asia–Pacific neighbours could benefit by increasing their exports and therefore becoming less reliant on aid grants.

The Australian delegates expressed their interest in establishing an association (proposed name: 'Australian Coconut Association') as a body or group that would engage in active communication both within the Australian coconut community, and also facilitate outcomes to align with coconut communities around the globe. Nearly 90% of the global area occupied by coconut palms is located in the Asia–Pacific region, which is geographically close to Australia. As a crop, coconut could reasonably be expected to grow well in selected locations in Australia and become a 'successor' to the old plantations that were established up to 100 years ago but were abandoned due to economic depression.

At the closing session of the forum all delegates, comprising representatives in national, regional and international coconut agencies, leaders in coconut R&D, coconut business leaders and scientists, talked about the future priorities for research and support. The following list was compiled to assist future consideration of research needs:

1. clinical research on HIV/AIDS and the general effects of VCO on the immune system
2. raising farmers' real incomes from coconut production

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3. market research in Australia for existing major and potential coconut products
4. new possibilities for value-adding to VCO
5. scaled-up development of elite coconut types such as makapuno and kopyor
6. Coconut World including a collection of germplasm
7. strengthening of the International Coconut Genebank (ICG) for the Pacific region
8. collaborative work on phytoplasmas
9. pheromones for rhinoceros beetles and other pests
10. intensification of the search for biocontrol agents for *Brontispa* spp.
11. training to increase researcher capacity
12. VCO quality control—detecting adulteration
13. somatic embryogenesis—seeking a breakthrough for clonal propagation
14. organic farming technology
15. refinement of biofuel technology
16. emerging coconut pests.

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From: Adkins, S.W., Foale, M. and Samosir, Y.M.S. (eds) 2006. Coconut revival—new possibilities for the 'tree of life'. Proceedings of the International Coconut Forum held in Cairns, Australia, 22–24 November 2005. ACIAR Proceedings No. 125.

The International Coconut Genetic Resources Network (COGENT): its history, achievements and future plans

P. Batugal

Abstract

The Coconut Genetic Resources Network (COGENT) was established in 1992 by the International Plant Genetic Resources Institute (IPGRI) under the aegis of the Consultative Group on International Agricultural Research (CGIAR). To date it has made some modest achievements. It has successfully developed and disseminated worldwide the International Coconut Genetic Resources Database (CGRD) containing passport and characterisation data and images of 1,416 accessions which are conserved by national programs in 28 sites in 23 countries. To provide double security for the conserved germplasm and a more effective mechanism for access and safe germplasm movement, it established the COGENT multisite International Coconut Genebank (ICG), which conserves, evaluates and shares about 200 important accessions in each of five geographic regions. Coconut varieties with multipurpose uses are being identified, documented, conserved and promoted in 15 countries. The performance of high-yielding hybrids and farmers' varietal preferences in nine countries are being evaluated. To strengthen the coconut research capability of member countries of COGENT, 39 country needs assessment missions were conducted. Also, 41 workshops and meetings involving 994 coconut researchers, 40 training courses involving 765 participants from 41 countries, and 274 research and training and capacity-building activities in 30 countries were supported. To enhance the efficiency of global research, COGENT helped establish and is currently coordinating the Global Coconut Research for Development Programme (PROCORD), a global coconut research alliance with the Asian and Pacific Coconut Community (APCC) and Bureau for the Development of Research on Tropical Perennial Oil Crops (BUROTROP), Centre de Coopéracion Internationale en Recherche Agronomique pour le Développement (CIRAD).

In the near future COGENT plans to upgrade its CGRD, rationalise its coconut conservation strategy, and upgrade its embryo in-vitro culture and somatic embryogenesis technologies. It will also identify, test and share germplasm with resistance to phytoplasma-caused diseases, and support a globally coordinated coconut breeding program. To enhance incomes of poor coconut farmers and conserve germplasm in situ and on farm, it will continue its 'poverty reduction in coconut growing communities' project and expand it in the African and Latin American and Caribbean regions. It will accelerate its capacity-building activities and strengthen its partnership collaboration with developing and developed countries.

History

COGENT is a global research network established under the aegis of the Consultative Group on International Agricultural Research (CGIAR). The international initiative on coconut (*Cocos nucifera*) research was first discussed at the 1989 meeting in Bangkok of the Asian and Pacific Coconut Community (APCC).

In 1989 the Technical Advisory Committee (TAC) of CGIAR commissioned studies to identify:

- priority problems that affect coconut production
- problems that could be addressed through research

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- new approaches to address those researchable issues that are international in character and beyond the capacity of any one country to resolve.

Based on these studies, the problems identified by CGIAR as suitable for international research support are:

- germplasm collecting, conservation, evaluation and enhancement
- pest and disease control, especially lethal diseases
- improving the productivity and sustainability of coconut-based farming systems
- increasing efficiency and added value in post-harvest handling and utilisation
- addressing socioeconomic issues such as the factors that influence farmers' varietal choices in replanting coconut land.

These studies revealed that higher incomes for poor coconut farmers could result from investment in international coconut research.

With the encouragement and support of the International Plant Genetic Resources Institute (IPGRI), a workshop involving 15 countries was held in 1991 in Cipanas, Indonesia. The participants recommended the establishment of an international network of coconut genetic resources. Dr Gabrielle Persley, then working with the Australian Centre for International Agricultural Research (ACIAR), devoted a great deal of time and effort to convince CGIAR and other donors to support international coconut research, and in 1992 CGIAR decided to include coconut in its research portfolio. Shortly thereafter, IPGRI organised COGENT and included coconut in its research program. Starting with 15 member countries, COGENT membership has grown to include 38 coconut producing countries to date (Table 1).

The goals of COGENT are to improve coconut production on a sustainable basis and to increase incomes in developing countries through improved cultivation of the coconut and efficient use of its products and by-products. The objectives of COGENT are to:

1. establish an international database on existing and future coconut germplasm collections
2. encourage the protection and use of existing germplasm collections
3. identify and secure additional threatened diversity by developing and adopting suitable conservation technologies and strategies
4. promote greater collaboration among research groups in producer countries and advanced technology sources in the exchange of germplasm and the development of new conservation techniques
5. secure necessary funding for network activities
6. conduct appropriate training and information dissemination.

To achieve the above-mentioned goals and objectives, IPGRI established a COGENT Steering Committee (SC) that decides on priority activities and provides oversight during implementation. The SC consists of two representatives in each of five geographical regions plus the Executive Director of the APCC and the COGENT Coordinator, with the last two serving as non-voting members. COGENT has five regional subnetworks, a Country Coordinator in every member country and Country Project Leaders designated to manage each country project.

Table 1. COGENT member countries from the five major coconut-growing regions of the world

South-East and East Asia	South Asia	South Pacific	Africa and Indian Ocean	Latin America and Caribbean
China	Bangladesh	Cook Islands	Benin	Brazil
Indonesia	India	Fiji	Cote d'Ivoire	Colombia
Malaysia	Pakistan	Kiribati	Ghana	Costa Rica
Myanmar	Sri Lanka	Papua New Guinea	Kenya	Cuba
The Philippines		Solomon Islands	Madagascar	Guyana
Thailand		Tonga	Mozambique	Haiti
Vietnam		Vanuatu	Nigeria	Honduras
		Samoa	Seychelles	Jamaica
			Tanzania	Mexico
				Trinidad–Tobago

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Table 2. COGENT's international coconut genetic resources database

Site	No. of accessions	25<P75[a]	25<E75[b]	With images[c]	With molecular data[d]
CNRA Marc Delorme Research Station, Port-Bouët, Côte d'Ivoire	99	92	71	73	67
Coconut Programme, OPRI, Sekondi, Ghana	16	–	4	15	14
CRC, Sémé Podji, Benin	4	4	4	4	3
National Coconut Development Programme, Dar es Salaam, Tanzania	72	71	69	35	33
African region	191	103	148	127	117
Centro de Investigacion Cientifica de Yucatan, Merida, Mexico	20	20	1	1	2
Coconut Industry Board, Kingston, Jamaica	60	16	58	32	36
EMBRAPA, Aracaju, Betume-Brazil	16	16	16	10	10
Latin American – Caribbean region	96	52	75	43	48
BARI, Gazipur, Bangladesh	40	18	37	–	–
Coconut Research Institute, Lunuwilla, Sri Lanka	78	78	64	5	10
CPCRI, Kasaragod, India	212	141	211	76	52
RS, Islamabad, Pakistan	32	–	–	–	–
South Pacific region	362	237	312	81	62
Cocoa and Coconut Institute, Rabaul, Papua New Guinea	3	–	3	5	30
Stewart Research Station, Madang, Papua New Guinea	54	31	54	3	2
Ministry of Agriculture, Nuku'alofa, Tonga	7	–	1	2	2
Saraoutou Research Station, Santo, Vanuatu	79	71	11	48	53
Taveuni Coconut Centre, Taveuni, Fiji	11	8	7	5	5
Olomanu Coconut Seed Garden, RS, Apia, Samoa	9	–	9	4	3
RS, Yandina, Solomon Islands	21	4	21	10	11
South Asian region	184	114	106	77	106
Coconut Research Institute, Wenchang, China	17	15	17	–	14
Department of Agriculture, Sabah, Malaysia	45	23	30	23	19
MARDI, Hilir, Perak and Terengganu, Malaysia	44	34	39	40	38
Bone Bone Experimental Garden, Manado, Indonesia	41	35	41	–	–
Mapanget Experimental Garden, Manado, Indonesia	74	74	45	14	17
Pakuwon Experimental Garden, West Java, Indonesia	25	22	25	8	10
Sikijang Experimental Garden, Pekanbaru, Indonesia	30	30	30	3	5
Philippine Coconut Authority, Zamboanga, the Philippines	224	221	219	194	51
Chumphon Horticultural Research Centre, Chumphon, Thailand	52	42	52	9	8
Dong Go Experimental Center, Ben Tre, Vietnam	31	30	16	9	8
South-East Asian region	583	526	514	300	170
Total for all regions	1,416	1,032	1155	628	503

[a] number of accessions with 25–75% of full passport data
[b] number of accessions with 25–75% of full evaluation data
[c] number of accessions with images
[d] number of accessions with molecular marker data generated using micro-satellite kits

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Achievements

In the last 15 years COGENT has made some modest achievements thanks to the support of its member countries, partner institutions, CGIAR and donors; and to the effective administrative and technical backup provided by IPGRI, the executing agency for the network (Batugal et al. 2005). It has successfully developed and disseminated worldwide the International Coconut Genetic Resources Database (CGRD), containing passport and characterisation data and images of 1,416 accessions which are conserved by national programs in 28 sites in 23 countries (Table 2). To provide double security for the conserved germplasm and a more effective mechanism for access and safe germplasm movement, it established the COGENT multisite International Coconut Genebank (ICG), which will conserve, evaluate and share about 200 important accessions in each region. The regional gene banks are managed by the national coconut programs of India, Indonesia, Papua New Guinea and Côte d'Ivoire, with Brazil recently agreeing to host the ICG for the Latin American and Caribbean region. Coconut varieties with multipurpose uses are being identified, documented, conserved and promoted in 15 countries. The performance of high-yielding hybrids and farmers' varietal preferences in nine countries was evaluated in collaboration with APCC and the Bureau for the Development of Research on Perennial Tropical Oil Crops (BUROTROP); and the performance of 38 promising high-yielding hybrids was evaluated in four African and three Latin American/Caribbean countries to identify suitable varieties and hybrids for resource-poor farmers.

To promote in-situ and on-farm conservation of farmers' varieties, COGENT has been implementing a diversity-linked poverty reduction project in 54 coconut growing communities in 15 countries. This strategy has demonstrated that farmers' incomes can be increased three to five times. The effect on women was particularly significant, with formerly destitute and underemployed women now earning up to US$3/day. Families are now working together, which contributes to social cohesiveness, social recognition and self esteem, especially for women. Food security and income can be enhanced and precious coconut genetic resources can be conserved (Batugal and Coronel 2004; Batugal and Oliver 2004, 2005). Protocols are being developed, tested and upgraded for in-vitro embryo culture, cryopreservation, morphometric and molecular marker-based methods for locating and characterising diversity, pest risk assessment and germplasm health management. Strategies and techniques for farmer participatory research, collecting, characterisation, and ex-situ and in-situ conservation are being refined.

To strengthen the coconut research capability of COGENT member countries, 39 country needs assessment missions were conducted. Also, 41 workshops and meetings involving 994 coconut researchers, 40 training courses involving 765 participants from 41 countries, and 274 research and training and capacity-building activities in 30 countries were supported. To enhance the efficiency of global research, COGENT helped establish and is currently coordinating the Global Coconut Research for Development Programme (PROCORD), a global coconut research alliance with APCC and BUROTROP – Centre de Coopéracion Internationale en Recherche Agronomique pour le Développement (CIRAD).

Plans for the future

To further enhance its achievements in the last 15 years, COGENT plans to undertake the following priority activities:

1. ***International Coconut Genetic Resources Database (CGRD)***—COGENT will enhance the generation of more morphometric and molecular maker data for the 1,416 accessions conserved in 23 countries; release the CGRD in the public domain; and link with System-wide Information Network for Genetic Resources (SINGER), the CGIAR genetic resources database.
2. ***rationalisation of coconut conservation***—COGENT will develop and implement more harmonised global, regional and national conservation strategies to make conservation efficient and cost-effective. These strategies will be developed by and promoted in COGENT member countries.
3. ***International Coconut Genebank (ICG)***—COGENT will enhance the full development of the ICG by formally establishing the Latin American – Caribbean ICG to be hosted by the Government of Brazil; conserving a total of about 200 representative accessions in each of the five ICG host countries; characterising these conserved germplasm; and sharing both data and germplasm with coconut growing countries of each region.

4. ***complementary conservation***—COGENT will further develop and refine complementary conservation technologies and strategies to make them efficient and cost-effective, i.e. field gene banks, in-vitro and in-situ/on-farm.
5. ***embryo culture and somatic embryogenesis***—To increase the efficiency of embryo culture techniques for germplasm collecting and embryo rescue in high-value soft-endosperm coconut varieties, COGENT will provide further support to improving embryo culture technology. To enhance efficiency of propagation and provide parental materials to breeders in adequate numbers and at affordable cost, it will support research to increase somatic embryogenesis efficiency.
6. ***disease resistant germplasm***—COGENT will identify germplasm with resistance to phytoplasma-caused diseases, e.g. lethal yellowing, root wilt.
7. ***globally coordinated coconut breeding—***To accelerate the development of improved coconut varieties which are acceptable to farmers, COGENT will support the breeding efforts of national programs and develop suitable breeding networks for countries with similar objectives.
8. ***poverty reduction in coconut growing communities***—To enhance the conservation of farmers' varieties and improve the incomes and livelihoods of resource-poor coconut growing communities as a strategy for in-situ/on-farm conservation, COGENT will expand its diversity linked poverty reduction project from 15 to 25 countries worldwide in the next 5 years.
9. ***capacity building***—To further enhance the research capacity of member countries, COGENT will continue to provide training, technical assistance missions and strategic publications and public awareness materials to national research programs worldwide.
10. ***regional subnetworks and partners—***To increase research collaboration at the regional level, COGENT will continue to strengthen its five regional networks and continue its collaboration with APCC, the Secretariat of the Pacific Community (SPC) and similar regional organisations in the African and Latin American – Caribbean regions.
11. ***PROCORD***—To increase the deployment of conserved diversity in the programs of partner institutions, COGENT will enhance the full implementation of PROCORD in collaboration with APCC and CIRAD.

To support the above activities, new funding has been generated from the Global Crop Diversity Trust, the International Fund for Agricultural Development (IFAD), the Department for International Development of the United Kingdom (DFID) and the Government of Brazil. COGENT will continue to effectively liaise with and seek support from COGENT member countries, partner institutions and donors.

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Asian and Pacific Coconut Community activities, achievements and future outlook

P. Rethinam[1]

Abstract

The Asian and Pacific Coconut Community (APCC) comprises a loose alliance of both large and small coconut-producing countries which have the broad objective of promoting communication that would benefit particularly the coconut producers and processors within those countries. The emphasis is on technical meetings and the dissemination of printed material across a great range of topics related to productivity (e.g. genetic improvement and soil management), protection (especially against new insect pests) and processing to develop higher value commodities such as virgin coconut oil. APCC has become a valuable clearinghouse for information, especially about innovations that have made a significant impact on the profitability of coconut production. Its efforts to liberate coconut from the false image bestowed on it by marketers of rival food oils in the marketplace have been particularly important.

Introduction

The Asia and Pacific Coconut Community (APCC) is an intergovernmental organisation of 15 full member countries, namely: Federated States of Micronesia, Fiji, India, Indonesia, Kiribati, Malaysia, Marshall Islands, Papua New Guinea, the Philippines, Samoa, Solomon Islands, Sri Lanka, Thailand, Vanuatu and Vietnam. Established in 1969 as the first commodity-based organisation in the region, the APCC is tasked to promote, coordinate and harmonise all activities in the coconut (*Cocos nucifera*) industry, which sustains the lives of millions of coconut farmers as well as those engaged in the processing, marketing and other sectors of the industry.

Vision

The vision of the APCC is to improve the socioeconomic conditions of coconut growers, processors, traders and all those who depend on this crop and associated industries in the member countries through proper promoting, collaborating and harmonising of various coconut-related activities (Anonymous 2005a).

Mission

APCC's mission is to assist the member countries to develop, provide and exchange technologies to make the coconut industry more vibrant in the years to come by:

- increasing productivity
- reducing the cost of production
- adopting integrated coconut-based cropping farming systems
- encouraging organic farming
- promoting farm-level processing
- promoting product diversification/value-adding and by-product use
- improving quality standards
- increasing market promotional activities, surveying and research
- helping in trade-related issues
- developing human resources for effective transfer of technology.

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From: Adkins, S.W., Foale, M. and Samosir, Y.M.S. (eds) 2006. Coconut revival—new possibilities for the 'tree of life'. Proceedings of the International Coconut Forum held in Cairns, Australia, 22–24 November 2005. ACIAR Proceedings No. 125.

Activities

In order to achieve their objectives, the APCC undertakes a range of activities which includes organisation of COCOTECH meetings, seminars/workshops and training programs; execution of projects, studies and links with other agencies; information networking; publication of books and production of video documentaries, CDs etc. A brief description of each activity is given below.

COCOTECH meetings

The COCOTECH meeting is organised usually once a year but has been changed to become a biennial feature from 2004. This is an open forum that facilitates the exchange of knowledge and transfer of technology and identifies research gaps and needs.

Seminars/workshops

APCC provides a forum for experts and interest groups to meet and discuss subjects of special interest to the industry, leading to the formulation of future programs and projects.

Studies

APCC undertakes studies on different aspects of the industry, namely production, processing and marketing. This also aims to develop future programs and projects.

Project formulation and execution

This aspect includes identifying thrust areas as well as gaps in research and development, processing and marketing etc; formulating projects to tackle problems; seeking donor funds; and implementing the projects/studies through member countries.

Human resource development

APCC organises training programs using the expertise available within the community, and arranges study tours for participants from coconut-producing countries to acquaint them with various aspects of the coconut industry not familiar to them.

Transfer of technology

The APCC Secretariat also serves as a centre for the transfer of technology. APCC prepares resources such as posters and charts, video films, DVDs, CDs etc. on coconut production, processing technologies, and the nutrient and health benefits of coconut products; and distributes these resources to all member countries for their use. APCC also participates in exhibitions/fairs/expos in different countries, organises exhibitions and buyers' and sellers' meetings for effective transfer of technology, and popularises and promotes the marketing of coconut-based products.

Technical consultancy

The APCC Secretariat provides technical advice to and assists member countries in identifying qualified experts in the relevant fields of production, processing and marketing.

Networking

The APCC Secretariat serves as a regional centre for a coconut information network. Linked to the national coconut information centres of individual member states through electronic mail, the regional centre assists in collecting, organising and exchanging information relating to all aspects of the coconut industry. Material is disseminated in various forms such as journals, proceedings of meetings, country studies, technological sheets, directories, statistical yearbooks and video documentaries. The national information centres, in turn, through their participating agencies, disseminate information to end-users in their respective countries.

Cooperation/linkage

In fulfilment of its aims and objectives, APCC cooperates and collaborates with the appropriate agencies relating to the coconut industry. Participation in meetings and exchange of information and personnel create closer collaboration with these organisations. Among them are United Nations agencies such as United Nations Development Programme (UNDP), Food and Agriculture Organization (FAO), United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP), United Nations Industrial Development Organization (UNIDO) and International Trade Centre (ITC); other international organisations such as the Common Fund for Commodities (CFC), Department for International Development (DFID), International Fund for Agricultural Development (IFAD), Bureau for the Development of Research on Tropical Perennial Oil Crops

(BUROTROP) (replaced by Centre de Coopéracion Internationale en Recherche Agronomique pour le Développement, CIRAD) and Coconut Genetic Resources Network (COGENT); and national agencies such as International Development Research Centre (IDRC), Natural Resources Institute (NRI) (United Kingdom), CIRAD (France) and the Australian Centre for International Agricultural Research (ACIAR) (Anonymous 2005a).

Major achievements

APCC over a period of 36 years has undertaken yeoman services to promote, coordinate and harmonise various activities of the coconut industry through projects, COCOTECH meetings, information dissemination and publications (Anonymous 2005a, b). Fifty-five projects/activities have been accomplished on:

- market studies on coconut products
- collection and dissemination of coconut production and processing technologies
- development and setting up of agriculture-based industries
- a coconut information system
- a survey on performance of varieties and hybrids and farmers' preferences
- integrated pest management (IPM) for coconut—rhinoceros beetle and *Eriophyid* mite.

It has also conducted 41 COCOTECH meetings, of which 16 are theme related as listed below:

1. coconut production and productivity
2. coconut-based farming system
3. small-scale processing of coconut products
4. coconut trade and marketing
5. product diversification as a strategy for market development for coconut products
6. coconut industry into the 21st century
7. global competitiveness of the coconut industry
8. technology transfer and application in relation to the coconut industry
9. environment-friendly coconut and coconut products
10. coconut production, product diversification, processing and marketing
11. promoting coconut product in a competitive global market
12. sustainable coconut industry in the 21st century
13. health and wealth from the 'tree of life'
14. strategic agenda to make the coconut industry globally competitive
15. new approaches to product diversification, value-adding and global marketing of products
16. strategies for enhancing productivity and income of coconut farmers

Other APCC activities include:

1. organisation of 42 APCC sessions which facilitated policy-making decisions, directions, discussions among member countries and exchange of information/knowledge between countries
2. strengthening of information network by establishing a coherent and sustainable information system
3. dissemination of information through the COCOMUNITY—a monthly newsletter, COCOINFO INTERNATIONAL—a semi-annual magazine, and CORD—a scientific half-yearly journal
4. more than 50 publications on coconut—17 monographs, nine on marketing of coconut product series, eight on experiences with new varietal performance, eight on bibliographies, eight on processing technologies etc.
5. 16 proceedings of COCOTECH meetings
6. many ad hoc publications
7. annual year book of statistics (up to 2004)
8. directory of coconut traders and equipment manufacturers (1995, 1998, 2002)
9. development of guidelines for organic coconut production
10. technical bulletins on the eriophyd mite *Aceria guerreronis* and the leaf beetle *Brontispa longissima*
11. approval and circulation for adoption of standards for virgin coconut oil
12. coconut processing information series—technology sheets: generation of technologies of coconut product diversification for small-scale industry
13. promotion of coconut oil for health and nutrition
14. promotion of coconut and its products for health and nutrition
15. marketing of coconut and its products
16. directory of international coconut workers
17. catalogue on coconut handicrafts and furniture
18. catalogue on coir-based products
19. video documentaries / CDs/DVDs
20. posters
21. human resource development
22. promotion of the farmers field schools concept

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Global scenario of the coconut industry

Coconut is grown in more than 93 countries in the world in an area of 12.19 million ha, with an annual production of 61,165 million nuts or 13.59 million t of copra equivalent. Indonesia is the largest coconut producing country, with an area of 3.8 million ha and annual production of 3.77 million t of copra equivalent, followed by the Philippines with an area of 3.3 million ha and annual production of 2.49 million t of copra equivalent. India, with 1.9 million ha and annual production of 2.74 million t copra equivalent, occupies third place. The production increase in coconut is mainly due to an increase in area over the years. However, the productivity rate has remained almost static, i.e. around 1.0 t/ha/year copra equivalent. This is a major setback, which needs to be addressed by every coconut-growing country (Rethinam 2004a).

Global export of coconut products exceeds US$1.2 billion annually. Even though more than 50 coconut products are being exported, only 10, namely copra, coconut oil, desiccated coconut, coconut milk, milk powder, cream, coco chemicals, shell charcoal, activated charcoal and coir-based products, are being exported on a larger scale. The Philippines is the largest exporter of coconut products, earning US$841 million/year, followed by Indonesia, Sri Lanka, Malaysia, India and Thailand. Indian exports are mainly coir and coir products including geotextiles, coir pith compost and grow bags.

Among the products exported, coconut oil remains the largest in quantity (1.8 million t), but in terms of growth rate it is fluctuating. The copra export has been reduced considerably because the copra-producing countries have started processing coconut oil and other value-added products. Global export of desiccated coconut has increased from 127,000 to 280,000 t in the last 25 years, while India imports desiccated coconut from Sri Lanka. In the last 15 years export of coco chemicals increased from 17,389 to 59,400 t, activated carbon from 22,147 to 110,500 t and coir products from 108,200 to 250,745 t. India and Sri Lanka are the major coco fibre producing countries (Rethinam 2004a, b, c; Rethinam 2005a; Rethinam and Amrizal 2005a).

Recent international prices for coconut products have fluctuated widely. In November 2005 the global price for coconut oil was US$650/t, while Indian coconut oil fetched US$1,200/t. Coconut water, which is mostly wasted by us, was US$800/t. Coconut milk was US$800/t, milk powder US$2,800/t, fatty alcohol US$1,125/t, coir bristle fibre US$460/t and activated carbon US$945/t.

Outcomes

The APCC started with six member countries in 1969 and has grown to 15, seven of which are Asian and eight are Pacific countries. Projects are implemented in the member countries from time to time with donor funding. COCOTECH meetings, organised every year, and more particularly theme-based COCOTECH meetings and publications brought out from time to time, have delivered to member countries effective transfer of technology, human resource development and capacity building.

The member countries could prioritise their research activities to increase productivity and production. Some member countries, such as the Philippines, Indonesia, Sri Lanka, Thailand, Malaysia, India and Vietnam, are also exporting diversified products. Copra export has been considerably reduced, more particularly in Pacific countries since they have introduced value-adding of copra to coconut oil, soaps, cosmetics etc. Biodiesel and biolubricants from coconut are also being produced. Many of the member countries have started revitalising their coconut industries. Coir-based products are also gaining importance in the other countries which were so far neglecting this sector. In general, in APCC countries, the area under coconut has increased from 6.25 million ha (1965) to 10.68 million ha (2004), and production has increased from 4.4 million t copra equivalent (1969) to 9.62 million t copra equivalent (2004). The annual export earnings of coconut and coconut-based products has increased from US$374 million in 1969 to US$1.39 billion in 2003 and US$1.8 billion in the year 2004 (Anonymous 2005b).

Emerging new applications

Organic foods

Health conscious people throughout the world, and specifically in Europe and the USA, prefer their food to be free from pesticides and chemicals. Organic foods are niche products which are produced by certified organic farms, processed and sold in authorised

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shops and certified by state registered certification bodies.

The largest organic markets in terms of global revenue distribution are the European Union (EU) (53% market share) and North America (40%). In the USA the growth rate for the sale of organic products is 17% to the present level of US$12.7 billion, compared to 3% annual sales growth for the USA food industry as a whole. Organic products account for 2.3% of total food sales in the USA. World consumption of organic oil is 95,000 t, which is only 0.1% of the total oil consumption. Organic coconut oil and organic virgin coconut oil can be produced easily compared to other oils since the bulk of coconut plantings are managed without the application of inorganic fertilisers and pesticides (Rethinam 2004d).

Virgin coconut oil

Virgin coconut oil (VCO) processed from the copra kernel and coconut milk is gaining popularity as a healthy nutritive oil, and has wider uses in pharmaceuticals, nutriceuticals and cosmoceuticals. Natural VCO and organic all-natural VCO may be exploited in niche health markets for premium prices. A large number of small-scale production units of VCO have been set up in many countries using different methods. It is necessary to strictly follow quality standards in order to sustain demand. This market seems to be a fast-growing one for functional foods, pharmaceutical, nutriceutical and cosmoceutical applications.

The export quantity of VCO from the Philippines has increased significantly in recent years. In 2001 the total export was only 1.8 t to the USA, including Hawaii, but this figure jumped to 176.6 t in 2004 to countries such as the USA, Korea, Japan, Netherlands, Singapore, Malaysia, South Africa and Australia. For the first quarter of 2005 the Philippines exported VCO amounting to 159.32 t, and countries in the Pacific region such as Fiji and Samoa are exporting VCO to Australia. Indonesia is also producing VCO and the domestic demand for this commodity is booming, with about 200 small and medium manufacturers in the country. Most of this production is going to the domestic market but some producers are exporting into world markets such as Malaysia and Singapore.

The export value of VCO to all markets from the Philippines was about US$553,469 in 2004, significantly higher than US$19,810 in 2001. The export value for the period January–March in 2005 was US$504,377, which was a 24.1% increase over the export value of the whole year in 2003 and about 91.1% of the total export value in 2004. It is estimated that the export value for 2005 will be US$2.0 million (Rethinam and Amrizal 2005a, b).

Functional foods

The market is attracting health conscious groups with functional food buzz words like designer foods, medical foods, longevity foods, hyper nutritional foods, super foods, pharma foods, perspective foods, phyto foods, therapeutic foods and others. These foods contain biologically active components thought to enhance health and wellbeing. While the conventional food sector has an expected growth rate of 1–3%, functional foods are catching up and surpassing this market with a growth rate of 7–8%. Between 1998 and 2003, global value sales of functional food increased by almost 60% and are further set to rise by 40% by 2008 (Global Market Analyst Euromonitor). By 2010 the most industrialised countries, Western Europe (34%), the USA (34%) and Japan (25%), will account for 90% of the total estimated market.

A high level of new product activity is continuing to stimulate growth in the fast growing global confectionery market, which was worth US$95 billion in 2002 with a total volume of 15 million t. The perceptive consumption is 17 kg/year in Denmark, 16 kg in Sweden, 13 kg in Norway and in Europe and North America (8.8–10.7 kg).

Coconut milk, milk powder and desiccated coconut provide lauric acid which can help build up resistance/immunity against viral, fungal and bacterial diseases. Coconut oil and its medium-chain fatty acid derivatives have an increasing role to play in the fast-developing functional foods market, particularly baby foods, nutriceuticals and pharmaceuticals.

Functional drinks from coconut

This area concentrates on value-added products. The functional drink market continues to be healthy—the sports drink, energy drink, wellbeing drink and welcome drink markets are continuously growing. Beverage markets showed strong growth between 1998 and 2003, expanding by a compound annual growth rate of almost 11%. Functional juices markets also showed good growth, with value-added sales up by an estimated 73% between 2003 and 2008. One reason behind the success of functional

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beverages is convenience—they can be consumed on the move and therefore tap into the key consumer demand pattern of health, convenience and portability. The global functional food drinks market, defined as 'soft drink with added health benefits', was valued at US$13.86 billion in 2000. This is expected to double to US$24 billion by 2005. Sports drinks are mainly isotonic and hypotonic, and are based with leading brand names. Energy drinks, including glucose-based products, had a market value of US$3.5 billion in 2000. Most of the energy drinks contain caffeine, vitamins and minerals, but caffeine is problematic in some countries.

Young coconut water (tender-nut water) and mature coconut water, in both a pure form and with various added minerals and vitamins, could have wider domestic and international markets with well-directed marketing.

Cosmoceuticals

Production of cosmetics and personal products in Asian and Pacific countries is just developing, with emerging popularity of skin-whitening products. With growth of 10% for cosmetics and personal care products, and 5–19% for soap in Asia and the Pacific, the requirement is enormous. Many of the Pacific countries are importing all products. Coconut oil, which is rich in C12 and C14 fatty acids (lauric and myristic), is good for skin care when applied as a pure product and also as manufactured cleaning products that have wide acceptance.

Oleochemicals

The long-term trend for oleochemicals is favourable, with world capacity expected to rise to 12 million t and production to 10.8 million t by 2010. Consumer trend is increasing towards the application of oleochemicals in detergent, soap and personal care products, and hence there is good scope for coconut-based oleochemicals.

Biofuels/biolubricants

Energy security perspectives have become a driving force for the use of vegetable oil-based biodiesel fuels. Numerous countries are in the process of making biofuels. However, there are three challenges the biofuel sector must overcome: price considerations, lack of awareness of the fuel and negative impact on the glycerine supply to existing markets.

Biolubricants are functional fluids made from vegetable oils and downstream esters. For example, coconut oil as a biolubricant has been used in India for three-wheeler vehicles. The overall global usage of renewable raw materials in lubricants and related functional fluid applications is about 250,000 t, comprising about 0.7% of the total lubricant marketed and 0.25% of the total oils and fats produced annually. The Philippines is moving forward followed by Thailand, Vanuatu and Marshall Islands. Double-filtered coconut oil is used directly in Marshall Islands to run cars, fishing boats, trucks etc, while in the Philippines a mixture of diesel and methyl ester from coconut oil at a 99:1 ratio is used, with plans to increase this to 95:5.

Premium grade monolaurin and HIV/AIDS

Over a period of 22 years, 42 million people in the world have been affected by HIV/AIDS. This viral disease affects 7.2 million people in Asian and Pacific countries, while India is reported to have 3.5–5.0 million sufferers. Coconut oil, with 48% lauric acid, is a potential source for producing monolaurin (lauricidin), which has been experimentally found to reduce the virus. Dr Jon Kabara, a scientist from the USA, has undertaken some preliminary work but pilot-scale testing with a large number of AIDS patients needs to be undertaken. The Philippines has also done some basic studies and would like to expand. If a small amount of the donor funds received for the Global AIDS Awareness campaign could be spent on this research, it should be possible to develop a cost-effective control measure. If this happens, the coconut currently produced throughout the world may not be adequate to meet the needs of all sufferers.

Coir and coir pith

For environmental friendliness, cost and low weight, natural fibres are now considered to be important. Natural fibres used as reinforcements in industrial products have made considerable inroads into the production of automotive interiors, especially in Europe. Several European firms are testing whether coir pith can play a role in the growing automotive market for 'biocomposites' or as thermal insulation in home construction. It is also used as a filler to replace talc and calcium carbonate in certain household products.

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Coir fibre matting products for soil protection along roadside cuttings and bare patches have been shown to be effective and are becoming popular under the label 'geotextile'. In the horticulture sector, natural fibre pith can play a vital role as it has a short life (disposability) and reasonable strength for transporting flowers, vegetables and fruit and for bulking up potting mixtures. The Netherlands produces about 1,850 million plant pots annually, consuming about 30,000 t of synthetic plastics. It is anticipated that the use of biodegradable pots using natural fibres could replace these synthetic plastic pots within 10 years.

Rubberised coir used to be the material of choice for car seats but recently it has lost out to competition from synthetic foams. Yet, the remaining use of coir in several up-market European car models is an example of how natural fibre products can remain competitive and possibly regain ground. When compared to high-end foams, seat covers made from rubberised coir provide better feel and support. Manufacturing these covers used to be a multistep labor intensive process, but in 2000–01 two major German automotive suppliers jointly developed a novel one-step injection process offering shorter cycling times, higher productivity, more consistent quality and, ultimately, lower production cost. The process requires that the used twisted coir fibre is virtually free of pith and very consistent in the weight per unit length of twisted strand.

Wall panels produced from blast furnace slag cement and coir fibres have been developed in Brazil using a low-cost environmentally friendly technology. This technology is available from the Institute de Pesquisas Technologie do Estado de Sao Paulo S.A., Brazil. High-tech production of industrial textiles is possible and needs to be exploited by importing coir fibre.

Future strategies

In order to make the coconut industry globally competitive, time-targeted mission-mode approaches have to be made by APCC member countries. The APCC Secretariat will provide technical assistance either from its own team or help to obtain it from countries where such help is available. APCC can also identify gaps in research and development as well as marketing, and in the formulation of collaborative projects under the newly launched Global Coconut Research for Development Program (PROCORD) jointly with BUROTROP (now under CIRAD) and COGENT. APCC can identify donors for funding the implementation of those projects in member countries. There is scope to build up human resources by exposing research and development capacity to promote farming methods, and by making available modern processing techniques to develop profitable high-value products.

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Past, present and future coconut research in Indonesia

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Abstract

During the last four decades coconut management in Indonesia has been focused on traditional farming systems that have an inherent low productivity and limited product diversity, and that cater for the direct needs of the household alone. Some advances in coconut technology, such as the development of new methods for cultivation of superior varieties, were made before 1980 but most have been more recent. In the 1981–90 period advances were made in germplasm collection, crop replanting, intercropping, pest and disease control, and better product processing. In the next period, 1991–2000, efforts were focused upon processing technology and integrated farming systems. Future research is likely to make use of molecular and biotechnological approaches for the production of resistance varieties (e.g. to control Kalimantan wilt disease) and clonal propagation of elite palms. Other developments might include improved biocontrol for pests such as *Oryctes* and *Sexava*, the expansion of organic farming, the improvement of virgin coconut oil quality and the establishment of an International Coconut Genebank for the South-East and East Asian region in North Sulawesi province. These and other strategies will be used to build self-supporting coconut farming communities, develop coconut agribusiness and value-add to traditional coconut products to raise the living standards of Indonesian coconut farmers.

Introduction

Coconut (*Cocos nucifera*) is a strategic commodity for both estate and smallholder enterprises in Indonesia in terms of its social, economic and cultural function in the daily life of the people. In 2004 Indonesian coconut areas occupied 3.84 million ha or around 30% of the total world coconut producing area. At least 3 million farmer households were involved in coconut farming. Today Indonesian coconut production is around 15.5 billion nuts, which is 28% of the world's total production. The value of coconut products exported in 2003 was worth about US$250 million or 18% of global trade. (Ditjebun 2005).

The following weaknesses of the coconut industry in Indonesia need to be acknowledged:

- Unimproved coconut palms are still grown that embody traditional characteristics. These palms need to be replaced by superior types. The country's true potential productivity remains unknown.
- Downstream processing is still lacking in industrial operations and this restricts the coconut farmer to only producing raw materials, which provide a low income.
- The coconut palm produces less oil and income per ha than oil palm. Coconut produces 0.53 t/ha of oil (averaged over the total area of palms in Indonesia), valued at US$423/ha, while oil palm produces 3.17 t/ha, valued at US$1,729/ha. Coconut oil export is now only half of that exported prior to 1970.
- Indonesia lacks appropriate research and development procedures to allow coconut to be integrated into viable agribusiness activities.
- The strong need for advanced technology cannot be met from current government resources.

The following points concerning the implementation of a coconut agribusiness system need to be considered:

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- Advanced coconut technology is yet to be efficiently applied under subsistence farming conditions. For example, the limited number and high cost of superior coconut seedlings make them unavailable to the subsistence farmer.
- Although the coconut palm can produce many products (more than 100 including foods, housing materials, medicines, chemical substances for industry and handicrafts), only 10 of these are presently exported.
- The traditional western industry processing of coconut oil has recently been devolved to a number of developing countries, including Indonesia. This move has provided a boost to the local coconut industry, as local business enterprise takes a hold.
- Coconut research has been undertaken in Indonesia since 1856 when copra was first exported from the Minahasa district to the Netherlands. Coconut research started at Mapanget (near Manado, North Sulawesi) with the establishment of the 'Klapperproof Station' in 1927. This station has now evolved to become the Indonesian Coconut and Other Palmae Research Institute (ICOPRI). By establishing this Institute, Indonesia gave coconut the status of a major crop, thus further boosting research activity considerably.

Some goals in the Indonesian development of coconut are:

- to improve copra productivity from 1.1 t/ha/year to 3.0 t/ha/year (or from 40 to 120 nuts/palm/year)
- to use more of the coconut raw materials through sharing between the coconut processing industries, and thus maximise the farmers' incomes
- to adopt cheaper, efficient, effective and more environmentally friendly coconut processing technologies in order to sustain or improve the production of highly competitive coconut products
- to develop collaboration between researchers, technicians and management to accelerate the adoption of new technologies and products from coconut.

Technology innovation to solve some problems in the development of coconut as a modern commodity is a key factor in analysing the strengths, weaknesses, opportunities and threats in the industry. As a research institute, ICOPRI must generate innovation that is commercially and scientifically sound.

Coconut genetic resources

Genetic diversity of germplasm is very important to the Indonesian coconut breeding program. The exploration of Indonesian coconut germplasm started in 1927 and continues today; so far, 131 accessions have been collected and conserved. However, only a part of this collection has been used for breeding and other research purposes.

Initial exploration and collection of coconut genetic resources

Research on coconut palms was given considerable attention during the Dutch colonial period. Formal research was institutionally started in 1911, involving the collecting of coconut populations from Java. From 1926 to 1927 Dr Tammes identified and selected 100 high-yielding Tall palms from the populations of coconut growing in the Mapanget District of North Sulawesi, and planted them in the Experimental Garden of ICOPRI. From 1956 to 1961 the Government of Indonesia contracted the services of a German FAO expert to characterise, select and cross the coconut germplasm previously collected by Dr Ihne, with the aim of producing high-yielding hybrids.

In the 1990s the International Coconut Genetic Resources Network (COGENT) of the International Plant Genetic Resources Institute (IPGRI) identified the problem of genetic erosion through germplasm loss. In an attempt to prevent this in Indonesia, coconut germplasm was collected and conserved in field gene banks. This work was funded by the Asian Development Bank (ADB) and implemented from 1996 to 1997. Coconut populations were specifically collected from East Nusa Tenggara and Moluccas Province and conserved at the International Coconut Genebank for the South-East and East Asian region (ICG-SEA) located at Sikijang, Riau, Indonesia.

Further exploration, collecting and evaluation of coconut germplasm

Further exploration, collecting and evaluation of coconut germplasm took place with the help of 20 COGENT member countries and using ADB funding in a project entitled 'Coconut genetic resources network and human resources strengthening in Asia and the Pacific region'. The project collecting activities in Indonesia involved the Moluccas, North and Central Sulawesi and West Nusa Tenggara. Fifteen coconut accessions were characterised in situ and

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collected for ex-situ conservation at ICG-SEA. In addition, 107 existing accessions from ICOPRI's research stations (Mapanget—54 accessions, Pakuwon—0 accessions and Sikijang—33 accessions) were characterised and their passport and characterisation data submitted to the French Centre Internationale de Recherche Agronomique pour le Development (CIRAD) and entered into the CGRD (Coconut Genetic Resources Database). Descriptive information on 60 accessions was documented and submitted to COGENT for the catalogue of conserved germplasm.

Coconut breeding

The main objective of the Indonesian coconut breeding program has been to produce planting material on a large scale with the characteristics of high yield of copra/oil and early fruit production. Consideration has been given to the following traits, with the ultimate goal of incorporating one or more of them into the gene pool: high copra oil content, resistance to bud rot *(Phytophthora)* or wilt diseases (a phytoplasma), high yield of copra per unit area with conservative management input, tolerance to drought, a high content of protein in kernel, and a high proportion of lauric acid in the oil.

Evaluation and selection

The characterisation and evaluation of these palms has involved recording morphological, physiological, biochemical and molecular marker data. Evaluation has been done on the following traits: high oil production (Pandin et al. 1992), high fat content (Akuba et al. 1997), resistance to bud rot and nut fall diseases (Runtunuwu 2000), drought tolerance, high protein content (Tenda et al. 1998), big nuts, and use as ornamental objects or use in medicines (Novarianto and Miftahorrachman 2000). The specific characteristic information useful for coconut genetic resource analysis is presented below (Table 1). ICOPRI has released four Tall varieties, namely Bali Tall, Mapanget Tall, Palu Tall and Tenga Tall, in 2004, all of which have a high copra production of between 2.8 and 3.3 t/ha/year (Tenda et al. 2004).

To overcome the problem of insufficient seed–nut production and improve overall coconut production, the development of large-scale seed gardens generating coconut hybrids (Dwarf by Tall and Tall by Tall hybrids) has been achieved.

Several selected local Mapanget Talls have been crossed with each other to produce an elite Tall population that will contribute to high-yielding hybrids, primarily for copra production. Some of these hybrids were released in 1984 by the Ministry of Agriculture.

Tall by Dwarf coconut hybrids achieve high and early fruit production. The copra yield of three such hybrids is around 4–5 t/ha/year when they are 10 years old with high management inputs (Novarianto et al. 1984).

These Khina hybrids were released in 1984 by the Ministry of Agriculture and distributed to farmers. Hybrids have also been tested with medium management input, yielding 2.5–3.0 t/ha/year of copra. Coconut composite varieties are being developed by random mating of 15 Tall by Tall intervarietal hybrids in 5 ha plots at three agroecosystems.

Cultivation techniques

New planting strategies that give more space between the rows allow for the introduction of both annual and perennial intercropping plants, and this is highly advisable for farmers to do if they are to obtain the best income.

The distance between the rows is normally much greater than the distance between the trees in each row, creating excellent space for intercropping. This system could be developed with the same total palm population as the traditional approach but with an option for intercropping. Research done by ICOPRI has shown that the combination of 6 m by 16 m (within and between rows respectively) is an appropriate arrangement to allow successful intercropping.

Pest and diseases

Pests and diseases which attack the coconut palm in localised regions of Indonesia are *Oryctes rhinoceros*, *Sexava* sp., *Brontispa longissima*, bud rot and nut-fall diseases caused by *Phytophthora palmivora* (which is quite widespread), and wilt disease caused by a phytoplasma.

Pesticides are used to help combat some of these issues. However, the risk of acquired pesticide resistance has led to the development of a strategy of integrated pest management (IPM). IPM not only helps prevent pest resistance but keeps pest populations below the economic threshold level using ecologi-

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cally sound approaches. Host plant resistance, in combination with natural, biological and cultural control measures, are the basic components of the IPM system used in Indonesia.

Recently, biological control has been recognised as one of the most promising and effective tools in the management of the most important pests of coconut. There are several natural enemies such as *Tetrastichus brontispae* (a pupa parasitoid) and *Ooencyrtus podontiae* (an egg parasitoid) that parasitise *Plesispa reiche* and *Brontispa longissima*; *Leefmansia bicolor* (an egg parasitoid) that parasitises *Sexava* sp.; and *Apanteles artonae* (a larval parasitoid of *Artona*). Insect pathogens that are considered as promising natural enemies of some coconut pests are *Metharizium anisopliae* and *Beauveria bassiana,* the first being highly effective in *Oryctes rhinoceros* control while the second can control *Brontispa longissima*.

Table 1. Description of several specific characters of Indonesian coconut accessions

Specific characteristics	Accessions	Origin	Planting date	Performance
Early bearing (years after planting)	Salak Dwarf Sawarna Tall	South Kalimantan West Java	Aug. 1980 Aug. 1980	1.5 to 2.0 3.5
High copra production (t/ha/year)	Mapanget Tall Tenga Tall Bali Tall Palu Tall	North Sulawesi North Sulawesi Bali island Central Sulawesi	1927–1928 Nov. 1987 Nov. 1987 Nov. 1987	3.3 3.0 3.0 2.8
Resistant to bud rot and nut fall diseases	Raja Brown Dwarf Jombang Green Dwarf Nias Green Dwarf Sagerat Orange Dwarf Tebing Tinggi Dwarf Salak Dwarf	North Moluccas East Java North Sumatra North Sulawesi North Sumatra South Kalimantan	Aug. 1980 Nov. 1978 Nov. 1978 May 1987 Dec. 1979 Aug. 1980	Nut inoculation Nut inoculation Nut inoculation Nut inoculation Nut inoculation DNA analysis
High oil content of copra (%)	Sagerat Orange Dwarf Paslaten Tall Mapanget Tall Pandu Tall	North Moluccas North Sulawesi North Sulawesi North Sulawesi	May 1987 Nov. 1987 1927–1928 May 1983	67 67.5 68 67
High lauric acid of oil (%)	Mapanget tall Bali Tall Palu Tall Khina-1 hybrid	North Sulawesi Bali island Central Sulawesi North Sulawesi	1957–1958 Nov. 1987 Nov. 1982 1976–1977	45 44 44 44
High protein content of fresh kernel (%)	Sea Tall Pungkol Tall Tontalete Tall Marinsow Tall	North Sulawesi North Sulawesi North Sulawesi North Sulawesi	Jan. 1982 Nov. 1981 Nov. 1981 Nov. 1981	4.55 4.28 4.51 4.20
Big fruit and nut weight (kg)	Bali Tall Palapi Tall Dobo Tall	Bali island North Sulawesi North Sulawesi	Nov. 1987 May 2001 May 2001	2.2 2.2 3.5
Abundance of nuts (nuts/bunch)	Takome Tall Sangtombolang Tall	North Moluccas North Sulawesi	May 1977 Oct. 2000	>100 >100
Semi Tall, high production	Bitunuris Solo Tall	North Sulawesi Central Sulawesi	May 2001 May 2001	Early bearing Early bearing
Young tender coconut	Nias Yellow Dwarf Salak Dwarf	North Sumatra South Kalimantan	Nov. 1978 Aug. 1980	Sweet coconut water Sweet coconut water
Toddy and sugar	Jombang Green Dwarf Nias Green Dwarf	East Java North Sumatra	Nov. 1978 Nov. 1978	High yield of toddy High yield of toddy
Ornamental (fruit colour)	Sagerat Orange Dwarf Waingapu Red Dwarf	North Sulawesi East Nusa Tenggara	May 1987 May 1999	orange red
Medicine	Pink husk coconut	North Sulawesi	2000	Massage oil and fever

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Recent advances in biotechnology, particularly cellular and molecular biology, have opened new avenues for controlling pests and diseases. Biotechnological approaches are now available for the identification or diagnosis of disease-causing organisms such as Kalimantan wilt (a phytoplasma). Molecular techniques are likely to play an important role in the identification of strains, races or biotypes of some species of pest or disease-causing organisms.

Post-harvest research

Coconut farmers' incomes have fluctuated over time due to the instability of the price of copra and coconut oil. The price of these products has declined greatly over the past 50 years due to competition from vegetable and palm oil. The coconut fruit contains many nutrients and minerals which make it a promising raw material. The aims of post-harvest research at ICOPRI are to improve the processing technology for existing products and to develop new products.

The technologies for processing some products are already available, such as those used for the production of virgin coconut oil, nata de coco, ketchup, soft drink, coconut snack food, preserved young tender coconut, coconut wine, coconut candy and coconut water concentrate. However, these technologies are often not made available to the farmers in cooperative groups or for small-scale operations.

Husk decorticator

An example of new technology is the husk decorticator for the extraction of fibre from the husk. ICOPRI's husk decorticator has a processing capacity of 250 husks/hour or 70,000 husks/month, yielding 15,500 kg dry coconut fibre when three operators are used. The cost of such a unit is Rp23 million, and the life span is expected to be 10 years with a benefit-to-cost ratio of 1.44 (16% discount rate) and internal rate of return (IRR) of 100.2%. The financial break-even point occurs after only 1 year and 3 months.

Coconut embryo culture

Embryo culture is an important technique for coconut germplasm collecting, exchange and conservation. Embryo culture would also satisfy most phyto-sanitary requirements that presently preclude any coconut germplasm transfer (Ashburner and Thompson 1993). Different protocols have been published for embryo culture in vitro and ex vitro, but the success rate varies among laboratories. The most difficult problem that faces use of the in-vitro technique is culture contamination and death of cultures. Since 2003–05, ICOPRI has collaborated with ACIAR in a coconut tissue culture research program to improve the hybrid embryo protocol. This project is coordinated by a University of Queensland team, and the other project member countries are Papua New Guinea, the Philippines and Vietnam.

Indonesia has undertaken four research activities regarding coconut embryo culture, namely:

1. the effect of sterilisation of the embryo plug to help reduce culture contamination
2. promoting root growth of plantlets in vitro using plant regulators NAA and IBA
3. the effect of vermiculite on in-vitro plantlet growth and development, especially to improve foot growth
4. coconut embryo transplantation.

Improvements resulting from this technique have been transferred to estate crops of East Java and are now important in producing their high-value kopyor coconut.

Future research and development (2005–09)

There are a number of areas where future coconut research and development should take place in Indonesia, including:

- improvement of coconut cultivars through the use of biotechnology and DNA marker selection techniques
- improvement of the efficiency of the embryo culture technique ex-vitro steps
- improvement of the embryo transplanting technique using kopyor and local Talls
- improvement of the biocontrol of *Oryctes* and *Sexava*
- identification of resistance to Kalimantan wilt disease in some coconut varieties
- encouragement of the development of coconut organic farming systems
- improvement of processing techniques to control the quality of virgin coconut oil

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- establishment of the International Coconut Genebank for South-East and East Asia (ICG-SEA) in North Sulawesi province in combination with an ecotourism-based 'Coconut World' theme park.

Conclusion

Coconut research in Indonesia is focused on increasing coconut palm and farm productivity, which hopefully can increase coconut farmers' incomes. From early 1980 until 2005, ICOPRI was involved in the development of many kinds of coconut technologies that included high-yielding varieties, coconut cultivation methods, integrated farming systems, pest and disease management, tissue and embryo culture research, post-harvest research, equipment processing and social economy studies. Establishment of the International Coconut Genebank for South-East and East Asia (ICG-SEA) and the use of these technologies will be future goals, as will the development of coconut agribusiness.

Acknowledgments

We wish to thank AusAID, Canberra, Australia, for providing travel funds to attend the forum. Thanks also to the PAATP Project of the Indonesian Agency for Agricultural Research and Development (IAARD), Jakarta, Indonesia, which provided the funding for registration fees and the field trip following the forum. Finally, thanks to the organising committee from the School of Land and Food Science, University of Queensland, Brisbane, for arranging travel to Brisbane and Cairns.

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The coconut in the Pacific: the role of the Secretariat of the Pacific Community

L. Guarino[1]

Abstract

The coconut (*Cocos nucifera*) is an essential part of life and cultural identity, as a food item and for its many products, in the Pacific. It played a pivotal role in the economic development of the region during colonial times, but, although there has been much research on the coconut in the Pacific, it has been somewhat neglected of late. The objectives of the Land Resources Division (LRD) of the Secretariat of the Pacific Community (SPC) are to improve nutritional security and health, and incomes, through sustainable management of forestry and agriculture systems and improved biosecurity and trade facilitation. Work on coconuts has therefore been an important component of its work over the years, through partnerships with international, regional and national players. The resurgence of interest in the coconut generated by recent initiatives in the Pacific in biofuels and other value-added products presents an opportunity for intensifying and building on past research and development work. SPC-LRD stands ready to work together with partners to reverse the trend of neglect and usher in a new era of coconut-fueled economic development in the Pacific. Research and extension interventions are much needed to revitalise the industry.

Introduction

The coconut (*Cocos nucifera*) is an essential part of life and cultural identity in the Pacific, not only as a food item but also for its many other products. The coconut contributes directly to food security (in some areas up to 25% of the production is consumed locally), and its timber, leaves and roots are used to provide shelter and tools. There are also significant environmental benefits to growing coconut palms in the fragile ecologies of the Pacific islands, including prevention of soil and beach erosion, nutrient recycling, protection from wind and provision of shade. In addition, the Pacific island countries and territories, which comprise 8 million people spread out over a third of the Earth's surface, are collectively one of the major producers and exporters of copra, which makes a vital contribution to both national coffers and family income (Osborne 2005).

The coconut played a pivotal role in the economic development of the region during colonial times, with early trade and investment in the region largely based on copra. Not surprisingly, there has been much research on the coconut in the Pacific: indeed, the first controlled hybridisations were apparently made in Fiji in 1926. More recently, however, the crop has been somewhat neglected. Many plantations are not well maintained, with senile trees not being replanted. There has been limited adoption of hybrids and other improved materials, and a shift to other cash crops in places. Many national marketing boards are in crisis. However, copra remains the sole source of cash in many remote islands, which has meant declining incomes and living standards for many Pacific coconut smallholders. Research and extension interventions are therefore much needed to revitalise the industry.

The Secretariat of the Pacific Community

The Secretariat of the Pacific Community (SPC) is a regional technical advisory, training and research organisation with a vision for a 'prosperous Pacific

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community whose people are healthy and manage their resources in an economically and environmentally sustainable way'. Its Land Resources Division (LRD), based in Suva, Fiji, has the objectives to improve nutritional security and health, and incomes, through sustainable management of forestry and agriculture systems and improved biosecurity and trade facilitation. Work on coconuts has therefore been an important component of SPC-LRD's work over the years, through partnership with ACIAR, Centre de Coopération Internationale en Recherché Agronomique pour le Développement (CIRAD) and Coconut Genetic Resources Network (COGENT), as well as regional players such as the Cocoa and Coconut Institute (CCI) in Papua New Guinea, the Vanuatu Agricultural Research and Training Centre (formerly a research station of France's Institut de Recherches pour les Huiles et Oléagineux (IRHO)) and others.

Examples of SPC-LRD's recent activities on coconut include:
- germplasm conservation including research on tissue culture and in-vitro conservation at the Regional Germplasm Centre (SPC-RGC)
- plant health including integrated pest management, incorporating biological control, of rhinoceros beetle (*Oryctes rhinoceros*)
- value-adding through a training workshop on the use of oil in the biofuels project (SPC Renewable Energy Unit)
- health and nutrition education including food leaflets (SPC Lifestyle Section).

Coconut projects

Previously, considerable regional resources (European Union funding through the Pacific Regional Agricultural Programme, PRAP) went into the development of and research work at the IRHO Center on Espiritu Santo, Vanuatu. The research included the gathering and planting of various Tall varieties from around the region and collection of production data on the hybrid crosses. Unfortunately, due to the Vanuatu foliar decay disease, the germplasm could not be disseminated but the results continue to be documented and used by other countries. SPC was a close collaborator in this important regional project.

As with other crops such as taro, banana and yams, SPC-LRD has also been a focal point for networking on coconut, both within the region and beyond. A COGENT subnetwork meeting for the Pacific, held in 2000 in Apia, Samoa, developed regional priorities for coconut research and development (R&D). A number of projects have been implemented by COGENT in the Pacific region to address these priorities, including:
- the formation of a coconut genetic resources network and human resources strengthening activity in the Asia and Pacific region (Asian Development Bank)
- the sustainable use of coconut genetic resources to enhance the incomes and nutrition of coconut smallholders in the Asia and Pacific Region (IFAD)
- the development of sustainable coconut-based income-generating technologies in poor rural communities (Asian Development Bank).

Through these projects there has been significant work in the following areas:
- in-vitro collecting and characterisation of germplasm
- enhancement of the national capacity in participatory technology development in coconut conservation and utilisation
- research on improving the income-generating potential of coconut production systems and on increasing the yields of local varieties and hybrids
- enhancing incomes from high-value alternative coconut products and suitable varieties
- evaluation of intercropping options.

An important development has also been the establishment of the International Coconut Genebank – South Pacific (ICG-SP) at the Stewart Research Station of the Cocoa Coconut Institute (CCI) in Madang, Papua New Guinea. Some 500 ha have been set aside which will hold 200 accessions selected by South Pacific countries as being the most important to the region. It is hoped that it will become a centre to facilitate germplasm exchange and use through the region, in partnership with the SPC-RGC, and complement the conservation activities of national gene banks (Table 1). In this context, the coconut is one of the crops included in Annex 1 of the Food and Agricultural Organisation's (FAO) International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA), and as such will form part of the multilateral system for access and benefit sharing being set up by parties to the ITPGRFA. This should have important consequences for the facilitated exchange of germplasm among countries.

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Table 1. National and regional coconut gene banks in the Pacific (Guarino 2004)

Place	Country	Type	Number of accessions
Totokoitu Research Station	Cook Islands	Field	6
Taveuni Coconut Centre	Fiji	Field	14
Wainigata Research Station	Fiji	Field	14
Central Nursery, Bikenibeu	Kiribati	Field	7
CCI	PNG	Field	49
CCI	PNG	In-vitro	22
Olomanu Research Station	Samoa	Field	13
Russell Islands Plantation	Solomon Islands	Field	17
Estate	Vanuatu	Field	60
VARTC[a]	Regional	In-vitro	8
SPC-RGC, Suva, Fiji			

[a] Vanuatu Agricultural Research and Training Centre

Summary and prospects

The resurgence of interest in the coconut generated by recent initiatives in the Pacific in biofuels and other value-added products presents an opportunity for intensifying and building on past research and development work. Better, more varied products are still needed, including those from the wood of senile trees and for improved human health (e.g. a sports drink based on coconut water). Market studies will be crucial to this enterprise, including targeting the tourism sector in countries such as Fiji as well as the export sector. Also needed are better coconut trees and better use of coconut land.

Better coconuts will come from more effective use of conserved germplasm through more participation by farmers in hybridisation, selection (including within local Tall populations) and improvement, coupled with decentralisation of the process of dissemination of seedlings of improved materials. The ICG-SP and the SPC-RGC will be crucial in facilitating the necessary exchange of genetic resources among countries and regions. Work on pests and diseases will also need to continue and intensify, and quarantine vigilance must not abate. Better use of the land on which coconuts are grown will involve research on intercropping and farming systems, but also investigation of the possibilities for organic certification in the region, and on the possible role of coconut plantations in carbon credit schemes.

SPC-LRD stands ready to work together with national, regional and international partners on these key issues of coconut research and development to reverse the trend of neglect and usher in a new era of coconut-fueled economic development in the Pacific.

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Strategic issues and research and development priorities in sustaining the Vanuatu coconut industry

D. Burnett and D. Kenneth[1]

Abstract

This paper focuses on the strategic issues and priorities currently identified for achieving the sustainability of the Vanuatu coconut industry, and how research and development (R&D) should be targeted. Following a brief history of Vanuatu's coconut industry to date, the paper outlines constraints to industry development, the main issues to be resolved, R&D priorities and achievements to date, and recommendations for the future development of the industry. The paper proposes that it is essential for Vanuatu to move away from production of copra, crude coconut oil and copra meal that are used in the manufacture of basic foodstuffs, animal feeds and industrial products; and look towards a future in the high-value and niche coconut product markets, which are geared to health and nutrition.

Introduction

This paper focuses on the background to the strategic issues and priorities identified in ensuring the sustainability of the Vanuatu coconut industry, and how research and development (R&D) should be targeted to achieve key objectives. Topics covered in this paper are:

- a brief history of Vanuatu's coconut industry and its current status and key features
- constraints to industry development
- the main issues to be resolved
- R&D achievements and priorities
- recommendations for the future development of the industry.

The presentation emphasises the role of the Vanuatu Department of Agriculture and Rural Development (DARD) and the Vanuatu Agricultural Research and Training Centre (VARTC) in implementing the European Union (EU) – Government of the Republic of France (GoF) funded Producers Organization Project 2 (POP 2) and its Coconut Development Programme (CDP).

POP 2 is a rural development project funded jointly by the EU, under the 8th European Development Fund (EDF), and the GoF. The Government of Vanuatu (GoV) contributes to the project through the provision of local staff and office facilities. The project, originally scheduled to run for 3 years from 2002, has been extended by the EU and now has a current expiry date of the end of 2007. The day-to-day implementation of the project is being undertaken by a project management team reporting to the Director of DARD.

The three key priorities of POP 2 are as follows:

1. the support of existing, and the creation of new, Producers Organizations (POs)
2. improved agricultural extension and applied research
3. the commercialisation of agricultural crops.

POP 2 comprises the following four key components:

1. support and strengthening of identified existing POs, and the creation of new POs through capacity building, training, and technical and financial assistance

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From: Adkins, S.W., Foale, M. and Samosir, Y.M.S. (eds) 2006. Coconut revival—new possibilities for the 'tree of life'. Proceedings of the International Coconut Forum held in Cairns, Australia, 22–24 November 2005. ACIAR Proceedings No. 125.

2. support of agricultural research and extension through training and technical assistance to the DARD and VARTC
3. improvement of marketing efficiency and enhancement of domestic and export marketing opportunities through the dissemination of marketing information and improved producer organisation
4. project management.

From its inception POP 2 has operated seven specific product development programs, namely coconuts, cocoa, coffee, spices, root crops, beef cattle and fishing. The current focus is on the coconut, cocoa and beef cattle development programs.

POP 2 supports the Vanuatu coconut industry through its CDP, which to date has undertaken the following initiatives:

- studies on the feasibility of coconut oil biofuel production at the village level, and the development and marketing of Vanuatu coconut products
- infrastructure developments for copra drying and transport for copra
- PO capacity building in the area of management and administration, including bookkeeping and accounting
- marketing, rural credit/collection/grouping/negotiation with buyers
- support and identification of new value-adding initiatives such as virgin coconut oil (VCO) and biofuel
- development of synergies and cross-cutting impacts with beef cattle and cocoa production
- support to coconut extension and R&D through budgetary assistance, training and technical advice to DARD and VARTC.

Vanuatu coconut industry—background

From time immemorial, in common with other Pacific islands countries, the coconut has played a key role in the livelihood of the peoples of Vanuatu, providing them with food, building materials and ingredients for local medicines. The coconut is also used in custom ceremonies and is integral to the culture and lifestyles of Ni Vanuatu society. Around 130 years ago, in the 1870s, coconuts began to be used for the production of copra. This was exported primarily to Europe for crushing into oil and meal, mainly for use in the soap, cooking oils and animal feedstuff industries.

From the latter part of the 19th century coconut plantations geared to copra production were developed, mainly by European colonialists. They transformed the Vanuatu landscape, economy and way of life of the people. As the plantation sector developed, beef cattle were introduced and grazed beneath the palms, and coconuts were interplanted with cocoa. From 1923 to Independence (1980) foreign indentured labour, mainly from former French colonies in Indochina, were employed. The smallholder sector of the industry also developed rapidly and by the 1930s accounted for about 30% of copra production. This figure had increased to 73% by Independence and is currently in excess of 90%.

Production of copra had reached 4,000 t by 1919, 15,000 t by 1930 and 46,000 t at the time of Independence, accounting for 76% of export earnings. Since Independence production has fluctuated between 47,800 t (1984) and 25,000 t. The variations in production have been attributed to the impact of cyclones, fluctuations in the copra price, competition from more profitable crops and cattle, and declining yield. There has been a slow but steady decline in production, with copra and coconut oil currently accounting for only about 25% of export earnings.

While coconuts grow throughout the Vanuatu archipelago, production is now concentrated in the northern geographic zones of Malekula, Santo–Malo, Ambryn, Ambae–Maewo and Banks–Torres, which account for around 97% of the total output.

The last nationwide agricultural census in 1994 did not attempt to measure the area under coconuts, but rather concentrated on the variety of coconuts planted, household consumption and marketing concerns. Therefore, the latest detailed area figures available are those of 1983, which estimated some 18,839 ha planted for commercial plantations and 72,452 ha for smallholders, totalling 93,291 ha. This figure, particularly for plantations, has since declined. Current average yield is low, at around 630 kg/ha, and declining.

Two copra crushing mills are operational in Luganville, exporting crude coconut oil (CNO) and manufacturing CNO products (oils/soaps), and together they have the capacity to handle all the copra produced in Vanuatu. However, copra is still being exported while also being imported from small Pacific neighbours, a situation which does not make economic sense.

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The coconut industry is regulated by the Vanuatu Commodities Marketing Board (VCMB), a statutory body which issues export licences to private sector exporters and levies what is in effect an export tax on copra and coconut oil. The role of the VCMB, established 25 years ago, and its cost to coconut growers is currently a sensitive issue in the industry, and should be reviewed in the light of current domestic and global realities in the coconut sector.

Development constraints and key issues

A question often posed in relation to Vanuatu's coconut production is: 'Does Vanuatu have unique problems, for example cyclones, customs, lack of large-scale commercial agricultural enterprises, poor infrastructure, lack of rural credit, high transaction costs?' The answer is probably no.

The following key constraints have hindered development of Vanuatu's agriculture in general and are, for the most part, all applicable to the coconut sector:

- a wide variety of taxes, policies and regulations, including high trade taxes
- lack of competition in markets for credit, shipping, utilities and other inputs
- inefficient and loss-making state farming and marketing bodies, e.g. VCMB
- traditional land tenure that has been a barrier to commercial investment
- land, air and sea transport that are both unreliable and expensive
- domestic markets that are small and export markets that are distant and difficult to penetrate
- excessive utility charges
- an exchange rate that tends to be overvalued by capital inflows from aid donors and trade taxes
- investors who are discouraged by uncertain government policies and excessive bureaucracy
- labour that is relatively high cost and has generally low productivity
- high age profile and low productivity of existing coconut stands, and lack of a comprehensive and extensive replanting program
- Melanesian garden farming systems that discourage smallholder specialisation in commercial agriculture.

Coconut research and development

Background

In 1962 Saraotou Research Station, Santo, was established under the management of the Institut de Recherches pour les Huiles et Oléagineux (IRHO). In 1985 management of the station passed to the Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD). Since 2002 the station has been part of VARTC.

From the 1960s research was focused on increasing productivity in a coconut monoculture context, exclusively geared to copra production, by improving the yield potential of planting materials and developing modern and cost-effective management techniques. The research involved coconut plant breeding and agronomy together with improved livestock grazing under coconuts.

In recent years VARTC's R&D focus has been on the optimum use of local genetic material resources, intercropping with food crops, and the economic and technical aspects of smallholder farming systems involving coconuts. Key achievements to date have included:

- development of best practice techniques adapted to Vanuatu conditions in nurseries: planting, fertilisation, crop production and protection, and copra drying
- discovery of coconut foliar decay, a viral disease endemic to Vanuatu, in conjunction with CIRAD, the Australian Centre for International Agricultural Research (ACIAR) and the University of Adelaide
- coconut genetic diversity evaluation supported by the International Plant Genetic Resources Institute – Coconut Genetic Resources Network (IPGRI-COGENT).

Currently the VARTC coconut field gene bank comprises 14 Dwarf varieties and 32 Tall varieties, including a population of 20 Vanuatu Talls. All data on morphological characteristics, flowering and production are regularly gathered and are included in the International Coconut Genetic Resources Database (CGRD). VARTC's coconut palms occupy an area of 212 ha.

Current research and development operations undertaken by VARTC

The objectives of the current VARTC R&D programs are as follows:

- the creation and selection of improved genetic materials using the Vanuatu Tall (VTT) variety
- the association of coconuts and food crops, particularly within Melanesian farming systems
- depollution and carbon sequestration by coconut plantations
- development of coconut oil biofuel
- soil fertility assessment.

Current activities

The following specific activities are being undertaken:

1. Germplasm conservation—management of the collection of 46 coconut varieties by maintaining and observing the VARTC field gene bank and undertaking:

- the collection of Dwarf varieties and hand pollination to replace palms pulled down by cyclones and those attacked by DFMT (decay foliar disease transmitted by the leafhopper *Myndus taffini*)
- the collection of exotic Talls and the recording of first flowerings
- the collection of local Talls and the recording of first flowerings and yield, and fruit component analysis.

2. Improvement of coconut cultivars for Vanuatu and their dissemination—the only genetic trial currently being undertaken is the hybrid trial of VTT by RIT (Rennell Island Tall). During the 5th and 6th years after planting, the hybrids are showing an average yield of copra of 3.8 t/ha against 2.9 t/ha for VTT (an increase of 31%). A comparative trial between four different populations of VTT will be planted by the end of 2005. It will be regularly monitored in the future and the speed of germination recorded. R&D results in the context of coconut cultivar improvement have been published internationally (Labouisse et al. 2004, 2005).

3. Coconut breeding for the Pacific region—from 1989 to 1999 VARTC was the implementing agency of the project 'Production and dissemination of improved coconut cultivars' in the framework of the Pacific Regional Agricultural Programme (PRAP) funded by EU and coordinated by the Secretariat of the Pacific Community (SPC). Eight trials were established between 1992 and 1999 and around 9,000 palms placed under ongoing individual observation.

4. VARTC priorities for 2006 and beyond—VARTC has identified the following priorities and focus for its R&D program in the future:

- maintenance of VARTC field gene bank genetic resources
- continuation of the breeding selection program of hybrids adapted to Vanuatu conditions
- ecophysiology studies
- studies of coconut-based farming systems
- diversification of coconut products, particularly in the coconut oil biofuel and carbon markets
- maintenance of regional activities of VARTC in coconut breeding
- maintenance and observation of PRAP hybrid trials and the publication of results
- training of national staff
- maintenance of close links with local partners (DARD, POP 2, the Vanuatu Cultural Centre) in the dissemination of improved planting material; and, with regional and international organisations [SPC, IPGRI, International Fund for Agricultural Development (IFAD), COGENT, Asian and Pacific Coconut Community (APCC), CIRAD, EU and Asian Development Bank (ADB)] in funding projects and exchanging information, training and technical advice.

Strategic issues and R&D priorities

It is considered essential for Vanuatu to move away from production of copra, crude CNO and copra meal used in the manufacture of basic foodstuffs, animal feeds and industrial products; and look towards a future in the high-value and niche coconut product markets, which are geared to health and nutrition. The development of coconut oil biofuel for domestic use, although used for more industrial purposes, is probably a special case in view of escalating world mineral fuel prices and the high cost of imports into small island states. It is believed that this policy is also the stated objective of APCC for the industry. Such a change of focus is particularly important for Vanuatu in view of its disadvantages in terms of low economies of scale, its small island status and its high transaction costs.

Therefore, in order to achieve objectives, the main constraints to development and sustainability need to be addressed as priorities as follows:

- Low productivity should be addressed through new planting and replanting with suitable varieties geared to product development; for example, VCO is said to need traditional varieties rather than hybrids.

- Melanesian farming systems should be addressed through integration of Vanuatu smallholder systems into commercial coconut farming through intercropping and cattle.
- Labour shortages and high costs should be addressed through mechanisation of harvesting, nut cracking, product processing and packaging.
- Low profitability should be addressed through the phasing out of copra production and processing, with support going to new value-adding initiatives with benefits shared by farmers.

In order to address the above strategic issues R&D should be prioritised as follows:

- New product development should concentrate on VCO, coconut shell charcoal and activated carbon/ pith for the horticultural sector; coconut wood; and coconut oil biofuel. Organic certification should also be a priority in order to take advantage of premium markets for health and nutrition products. The development of desiccated coconut, coir products, soaps and oils as branded products for export probably has little chance of success in Vanuatu due to high labour costs and availability, low economies of scale, high transaction costs leading to a lack of economic comparative advantage, and international competition.
- Market research and product promotion into regional and global niche and premium (e.g. organic, fair trade) market development should be undertaken, with particular emphasis on compliance with international rules and regulations regarding environmentally friendly products and technologies.

Recommendations

Vanuatu has limited research and agricultural capability and must avoid duplication of research through underfunded programs. Therefore, it is necessary and essential for Vanuatu to seek closer cooperation and links with other R&D institutions and extension services, particularly in the Asia–Pacific region.

Acknowledgments

The authors acknowledge with thanks the contribution of the management and staff of VARTC in preparing this paper.

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From: Adkins, S.W., Foale, M. and Samosir, Y.M.S. (eds) 2006. Coconut revival—new possibilities for the 'tree of life'. Proceedings of the International Coconut Forum held in Cairns, Australia, 22–24 November 2005. ACIAR Proceedings No. 125.

Australian involvement in coconut research and development

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Abstract

Despite a low level of input to its economy, Australia is actively involved in coconut research and development (R&D). Australia is one of the few developed countries that has taken an active interest in coconut production and its products, particularly since 1984 when the Australian Centre for International Agricultural Research (ACIAR) started to work on coconut. To date ACIAR has funded 11 collaborative projects that include coconut as one of the target crops. These 11 projects have involved 12 countries with a total budget of more than AUS$4.5 million.

The Australian Government has also supported international initiatives such as those of the Consultative Group on International Agricultural Research (CGIAR), through which coconut R&D has also been directly or indirectly supported. Over a longer period of time, since 1963, coconut R&D has been supported by a number of Australian institutions, particularly universities. To date a total of 33 higher degree theses have been produced on coconut, covering a number of aspects of R&D. The main universities that have worked on coconut include the University of Queensland (10 higher degree theses), the Australian National University (seven theses) and the University of Adelaide (five theses). Many of these studies were undertaken by overseas postgraduate students supported by scholarships from the Australian Government. The active involvement of Australia in coconut R&D is also reflected by the high number of scientific journal publications produced from its institutes, with 67 papers listed in the CABI database. The universities are the main source of these publications but Commonwealth Scientific Industrial and Research Organization (CSIRO) has also been an important contributor.

The support of the Australian Government for coconut R&D is part of the Australian international aid program directed at its neighbouring developing countries, particularly those in the Asia–Pacific region. Coconut fits well into ACIAR's mission because nearly 90% of the global total of 12 million ha of coconut plantations are to be found in this region. Continuing support on R&D from the Australian Government is needed to realise the potential of coconut in this region and to raise the living standard of the millions of smallholder coconut farmers living here.

Introduction

Coconut (*Cocos nucifera*) is one of the most important tropical tree crops in the world. Presently there are 12 million ha grown by 11 million smallholder farmers in 90 countries (APCC 2004). Nearly 90% of this coconut production is in the Asia–Pacific region (APCC 2004), close to Australia. Coconut is the most important export earner for many countries in this region, for example the Philippines and some South Pacific countries. Coconut also plays an important role in the local economy and culture of these countries. Here the palm is widely known as the 'tree of life' because it provides a large number of products that can be used to support the local economy. More than 100 products have been made from the coconut palm.

Despite the potential of the coconut palm in the local economy, copra (and hence coconut oil) has been facing financial difficulties for decades. Nearly two-thirds of the palms that are being harvested for copra

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From: Adkins, S.W., Foale, M. and Samosir, Y.M.S. (eds) 2006. Coconut revival—new possibilities for the 'tree of life'. Proceedings of the International Coconut Forum held in Cairns, Australia, 22–24 November 2005. ACIAR Proceedings No. 125.

are now becoming too old and, as a consequence, are becoming unproductive. In addition, there are a number of serious new pests and diseases and nutritional deficiencies that are also reducing yield. A further issue is that any new seedlings being planted are coming from unimproved germplasm with inherent low productivity. In many traditional coconut production areas fruit harvesting is not being undertaken and only the fallen fruit are collected and sold for a very low price. The farmers undertaking collection have limited access to the new fruit-processing technologies and are unable to make any attempt to value-add to the traditional copra production.

Most of the problems listed above are being addressed by research-driven activities undertaken at the international, national or regional level. However, very few successful outcomes have been achieved so far. Coconut research has been poorly supported and the need for international support was acknowledged by the Consultative Group on International Agricultural Research (CGIAR 1986). Unfortunately, this international support has been slow in coming, and, unlike the oil palm (*Elaeis guineensis*) where productivity has been raised significantly, coconut productivity has not been helped.

Australia, through the activities of its scientists working on Australian Centre for International Agriculture Research (ACIAR) funded projects, has been an important contributor to the region's coconut research and development effort. The present paper discusses the outcomes of this Australian effort and argues for the need for continued support for coconut research and development from the Australian Government.

Coconut—the crop in crisis

The decline in the coconut industry has been recognised for decades (Wright and Persley 1988) but little significant effort has been made to prevent further decline. The productivity potential of coconut has not been increased and now more than half of the existing plantations are becoming too old for continued copra production. The area around the world planted to coconut has, however, increased slightly due to non-systematic replanting with unimproved varieties. Some high-yielding hybrids of Tall by Tall and Dwarf by Tall have been available for many years but farmers are reluctant to replant with these materials due to a lack of confidence and knowledge of this kind of germplasm. In addition, hybrid seedlings are not easily available to the farmer and, when available, the seedlings are too expensive for the average farmer to buy.

Thus, the typical coconut farmer continues a zero or low input management practice and, under such conditions, the palms are performing well below their full potential. Selected Tall types or hybrids are known to produce up to 4.5 t/ha/year copra equivalent but the world average yield remains at a very low 0.9 t/ha/year (Rethinam 2004). The lack of farmer understanding of intercropping and mixed farming systems has also contributed to low productivity of the coconut farming system. Although coconut is well adapted to these production systems, the use of poor planting techniques and agronomic practices results in poor plant production.

Devastating coconut diseases (e.g. cadang-cadang, lethal yellowing and bud rot) are also affecting the coconut industry in many locations. Cadang-cadang (a viroid disease), first identified in the early 1930s in the Philippines, has since killed many millions of palms. Lethal yellowing, caused by mycoplasma-like organism(s), is a major disease in South and Central American countries, and other similar diseases are found elsewhere, including East Africa, the Philippines and India. As there have been no economic measures available to control these devastating diseases, the development of resistant varieties is an important requirement for the future.

Coconut producers are not only facing declining fruit production but are also fighting a low, and often fluctuating, price for copra (coconut oil). Global supplies of coconut oil are facing strong competition from vegetable and palm oil whose markets are rapidly expanding. As a consequence of this competition, the coconut farmer is reluctant to replant their land to coconut and may replant with oil palm or even just abandon the land.

Other products from coconut have yet to be popularised and marketed on a large scale. So far more than 100 valuable products have been produced from coconut but up to now farmers have only seriously produced copra and some fresh nuts for the local markets. It is widely believed that these farmers must now turn their attention to the production of other, more diverse products which have a high economic return. Such products will include virgin coconut oil (VCO), shell charcoal and tender-nut water packaged in containers for wider marketing. Unfortunately, farmers have limited knowledge of such products and access to the technology that can produce the prod-

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ucts. They also lack access to the markets where such products can be sold. In addition, quality control is always difficult where a small-scale production system is developed involving many smallholder producers in a local community group.

The Australian contribution in coconut R&D

Coconut is not an important crop in Australia. Some plantations were established in the early part of the 20th century but they were abandoned long ago due to the low price of copra and the high cost of labour, and only a few remnant palms remain. Coconut, however, maintains its significance as an ornamental tree, particularly in tropical regions of Australia, and can be found on the coast in small numbers as far south as latitude 30 degrees. Australian involvement in coconut R&D is therefore driven by its mission to help developing countries, particularly those in the Asia–Pacific region. There is a sociological as well as economic motivation behind this mission because most coconut farmers are smallholders with low incomes and nearly 90% of the global coconut production areas are geographically near Australia. In addition, coconut has been labelled an 'orphan crop' by home country researchers because it has attracted little international funding support in spite of its potential for great rewards in both its economic and community impacts. Advances made in coconut technology will require special effort in the transfer to the wider producing community because most of the millions of farmers are smallholders.

ACIAR is the main Australian agency that has been providing assistance for coconut R&D. Since its establishment in the early 1980s ACIAR has supported collaborative research projects involving Australian institutions as the commissioned agency together with nominated overseas institutions. This approach generates interactions and promotes team building among Australian scientists and their overseas counterparts. ACIAR also supports coconut R&D through international agencies like CGIAR. International support for coconut R&D has been extensively reviewed elsewhere (see Persley 1992).

To date ACIAR has provided AUS$4.5 million of funding for 11 research projects (Table 1). A number of these projects, however, were not solely dedicated to coconut. Three disciplinary areas (namely crop improvement, crop protection and socioeconomics) were the subjects of the research projects. No research projects have so far been funded to look at the development of processing technology or new products from coconuts. Research on germplasm collection and exchange, including embryo culture, was started in 1986 involving the Cocoa and Coconut Institute of Papua New Guinea, the Victorian Department of Agriculture and CSIRO. A recent project on crop improvement, aiming to develop tissue culture techniques for germplasm exchange and clonal propagation, was begun in 2002 and involved the University of Queensland and four collaborating institutions from Indonesia, the Philippines (2), Papua New Guinea and Vietnam. In this later project the protocol for embryo culture has been much improved, while a program on somatic embryo genesis showed that this technique is possible. Pioneering research within this project also shows that embryo transplantation is possible, and this could be a new way of establishing transferred germplasm. In addition, the project involved a training component to further improve the capacity of overseas institutions in coconut biotechnology.

Research on coconut virus and viroid diseases was initiated in 1973 at the University of Adelaide with support from the Food and Agriculture Organization (FAO). ACIAR continued support for this project from 1984 to 1992 involving the Federated States of Micronesia, the Philippines, Solomon Islands and Vanuatu (Table 1). It was shown that viroids similar but not identical to the entity associated with cadang-cadang disease (in the Philippines) are widely distributed in symptom-free coconut palms and other palms in the Pacific region. The project has terminated but further work undertaken at the University of Adelaide has resulted in a new highly specific methodology to be developed that is able to accurately identify these viroid entities in palms (Randles, pers. comm.). Such viroid identification methods can be integrated into any new tissue culture work that may be developed for palm production or exchange programs.

Other work on coconut supported by ACIAR includes the publication of books, working papers and articles (Table 2).

Finally, in addition to ACIAR's contribution there have been a number of other research activities undertaken and supported by Australian institutions (mainly universities) that have become the subject of postgraduate study research (Table 3). In fact, some of this later research occurred well before the exist-

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Table 1. Coconut research projects funded by ACIAR

Project code	Project/activity title	Discipline	Date	Commissioned institution	Countries involved	Budget (AUS$)
ADP/2000/072	Improving resource use efficiency in the coconut industry of North Sulawesi and its national implications	Socioeconomic	2004–06	University of Sydney	Indonesia	396,157
SFS/2001/068	Technical support for regional plant genetic resources development in the Pacific	Crop improvement	2002-–06	International Plant Genetic Resources Institute, Malaysia	Fiji, Kiribati, Malaysia, PNG, Samoa, Tuvalu, Solomon Islands, Vanuatu	585,000 (% for coconut unclear)
CS1/1998/061	Coconut tissue culture for clonal propagation and safe germplasm exchange	Crop improvement	2002–05	University of Queensland	Indonesia, The Philippines, PNG, Vietnam	711,309
ASEM/1998/068	Socioeconomic evaluation of supervised cattle distribution under coconuts in the Philippines	Socioeconomic	1999–2002	University of Queensland	The Philippines	151,158 (% for coconut unclear)
ASEM/1997/118	Socioeconomic monitoring and evaluation of research and development of the PNG cocoa and coconut smallholder sector	Socioeconomic	1998–2000	University of Western Australia	PNG	149,886 (only 20% for coconut)
CS1/1992/021	Nucleotide sequence determination of cadang - cadang-like viroids in the Pacific area	Crop protection	1993–95	University of Adelaide	The Philippines, Vanuatu	244,707
CS1/990/025	Coconut improvement	Crop improvement	1991–94	Victorian Department of Agriculture and Rural Affairs	Papua New Guinea	645,407
CS1/1988/031	Virus-like diseases of coconut palm	Crop protection	1989–92	University of Adelaide	The Philippines, Solomon Islands, Vanuatu	734,769
CS1/1984/042	Coconut improvement	Crop improvement	1986–90	Victoria Department of Agriculture	Papua New Guinea	504,939
CS1/1984/002	Studies on cadang-cadang disease of coconut in the Philippines and Micronesia	Crop protection	1984–87	University of Adelaide	Federated States of Micronesia, The Philippines	176,348
CS1/1984/003	Etiology, distribution and control of virus-like diseases of coconut palm in the South Pacific	Crop protection	1984–87	University of Adelaide	Vanuatu	221,197
4 on crop improvement (including 1 on technical support) 4 on crop protection 3 on socioeconomic matters		since 1984		5 Australian institutions, 1 international institute	12 countries	*c.* 4.5 million

ence of ACIAR, with the first study being undertaken in 1963.

Nine universities have been involved in such research covering a wide range of topics. Most of this research was undertaken by postgraduate students supported by scholarships obtained from the Australian Government, particularly through the Australian Agency for International Development (AusAID, formerly AIDAB) scheme.

Active involvement of Australian scientists in coconut R&D can also be demonstrated by the publications listed in reference databases such as CABI and Agricola. A simple search undertaken using both databases and compiled into a single electronic file using EndNote™ lists 67 publications published by 24 different Australian institutions in the past 30 years. The most frequently listed institutions were the University of Adelaide, the University of Queensland, CSIRO, the Australian National University, ACIAR and AusAID. More than half of the publications produced have been on pre-harvest aspects, notably protection from pest attack, germplasm and breeding, and productivity.

Benefits and impact of the Australian contribution

Like most research projects, it is difficult to assess the impacts of the Australian coconut R&D effort at the community level. ACIAR funded coconut projects have not yet had a major impact at the community level because of the slow growth of the palm, requiring 10–15 years to mature. This has caused problems for any 3-year-long project to be able to take any new developments to community level. Benefits from the coconut germplasm work supported by the ACIAR, for example, are expected to take decades to make an impact at the farmer level, and this will only come after extensive breeding programs have been put into place and propagation systems have been established. The poor capacity of coconut farmers to adopt new technologies will also delay the transfer of the research results to the field. This implies a need for technology transfer schemes to be developed to aid the uptake of the new coconut technologies.

Australia has become one of the few developed countries to support and undertake coconut R&D. Other countries have also been heavily involved, including France which has been actively involved through the Centre de Cooperation Internationale en Recherché Agronomique pour le Developpement (CIRAD, formerly IRHO), the Institut de Recherche pour le Développement (IRD, formerly ORSTOM) and the Bureau for the Development of Research on Tropical Perennial Oil Crops (BUROTROP – now inoperative). The direct involvement of Australia in coconut R&D has made an impact, particularly in developing the research capacity of institutes in the producing countries. For example, the capacity to successfully undertake tissue culture in Indonesia, the Philippines, Papua New Guinea and Vietnam has been greatly refined as a result of a recent ACIAR funded project (Samosir and Adkins 2005).

The involvement of Australia in coconut R&D has not only benefited the producing countries but also the ornamental palm industry of Australia. Collaborative research activities on coconut also provide opportuni-

Table 2. List of publications on coconut published by ACIAR

No	Title	Year	Note
1	The coconut odyssey: the bounteous possibilities of the tree of life	2003	Monograph
2	A guide to the zygotic embryo culture of coconut palms	1995	Technical paper
3	Coconut improvement in the South Pacific: proceedings of a workshop held in Taveuni, Fiji Islands, 10–12 November 1993	1994	Proceedings
4	Replanting the tree of life: towards an international agenda for coconut palm research	1992	Published by CABI in association with ACIAR
5	Forages for plantation crops	1991	Proceedings; some papers on coconut
6	An annotated bibliography on the coconut palm	1990	Working paper
7	Potential Australian market for coconut and coconut products	1988	Working paper
8	An annotated bibliography on coconut research relevant to the Pacific islands	1988	Working paper
9	Coconut germplasm in the South Pacific islands	1987	Technical paper

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Table 3. Theses produced by Australian Universities since 1963 on aspects of coconut production

University	Pre-harvest		Post-harvest		Socio-economic	Total
	Plant	Others	Edible	Non-edible		
The University of Queensland	3	4			3	10
The Australian National University	1				6[a]	7
The University of Adelaide	1	1	2		1	5
The University of Melbourne	1			1	1	3
The University of New England	1				2	3
La Trobe University	1				1	2
Flinders University		1				1
Macquarie University					1	1
The University of Newcastle					1	1
Total: nine universities	8	6	2	1	16	33

[a] including subthesis (M.A.D.E)
A simple search using Kinetica™ was undertaken to access the theses database in Australia

ties to Australian scientists to be employed and to broaden their experience in tropical agriculture.

The established link with overseas partners enhances coconut related business in Australia as it gives some sense of 'ownership' of coconut technology to Australian participants. Some useful coconut technologies have been developed in Australia including the mechanical virgin oil extraction method using the Direct Micro Expeller (DME™), the removal of the coconut kernel by the coconut meat extractor (CME) water jet, the coir-pith-shell beater and separator, and the photoautotrophic system for embryo culture. The latter technique was developed within the recent ACIAR funded research project. In fact, the DME and CME are now being transferred to coconut producing countries in the Asia–Pacific region.

The knowledge and experience gained from collaborative research involving Australia will also be beneficial to a possible future Australian coconut industry, especially if some coconut plantations are established on land traditionally used for sugarcane (see paper by Foale and Roebeling in these proceedings). In addition, coconut palms will continue to play an important role in beautifying streets and parks to retain the tropical ambiance of these regions for tourists, particularly in northern Queensland.

Conclusion

Coconut producing countries have limited capacity to undertake R&D, and because the palm is regarded as an orphan crop, it demands continuing international support for R&D. Australia has been actively involved in supporting and undertaking coconut R&D for decades, particularly through the efforts of ACIAR. Many Australian agencies, including universities and research institutes, have worked collaboratively with their counterparts from the South-East Asian and Asia–Pacific regions on coconut R&D. Collaborative research activities benefit both Australia and the coconut producing countries. Any future development of a coconut production system in Australia will benefit greatly at the outset from the links that have grown between Australian coconut science and its research partners. Continuing support, especially for delivery of new technologies, is needed to make a strong impact at the community level and to stimulate coconut related business.

Acknowledgments

Thanks are extended to Professor John Randles, University of Adelaide, and Dr Tony Fischer, ACIAR, for the information they provided.

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From: Adkins, S.W., Foale, M. and Samosir, Y.M.S. (eds) 2006. Coconut revival—new possibilities for the 'tree of life'. Proceedings of the International Coconut Forum held in Cairns, Australia, 22–24 November 2005. ACIAR Proceedings No. 125.

Revealing the potential of elite coconut types through tissue culture

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Abstract

Low income, smallholder coconut farmers have been facing difficulties for decades due to the falling price of copra, their traditional cash product from coconut. These farmers are now looking towards new, higher value products from coconut to make their industry viable over the longer term. There are a number of elite coconut types that have either a soft, jelly-like endosperm or a flavoursome, aromatic drinking water. They have a high commercial value in the confectionary and ice cream industries (soft endosperm types) or the soft drink market (aromatic types). The soft endosperm types ('makapuno') are naturally occurring mutants which cannot germinate in nature as their endosperm cannot support the germination of the embryo. They are known from a number of countries and are called makapuno (the Philippines, Vietnam and Thailand), kopyor (Indonesia), garuk (Papua New Guinea) or dikiri pol (Sri Lanka), depending on their origin. For propagation, the embryo has to be removed from the fruit and grown in vitro to produce a seedling. The aromatic types are also thought to be naturally occurring mutants which can only germinate in nature at a very low rate. They are known from a number of countries including Thailand and Vietnam. For propagation, the same kind of embryo culture procedure has to be used.

The first attempt at the embryo culture of these mutant coconut types was by De Guzman in the Philippines in the early 1960s (for the makapuno coconut). Subsequent studies have led to the commercialisation of a technique so it is now possible to mass produce seedlings of the Filipino makapuno. Other countries are now attempting to use the same or modified embryo culture techniques to develop their own soft-endosperm or aromatic coconut production industries. The common problems these projects encounter are the low rate of conversion of the isolated embryos to plantlets and the duration of the protocol, which can be as long as 1 year. These issues ultimately lead to high production costs for the elite seedlings, well above that possible for subsistence farmers. However, a recent collaborative project funded by the Australian Centre for International Agricultural Research (ACIAR) has made some impressive improvements to the standard embryo culture protocol. These improvements include the use of a CO_2-enrichment step within a photoautotrophic culture system and the application of plant regulators NAA or IBA to promote seedling rooting. By using this protocol on the embryos of normal coconuts the in-vitro stage can be reduced from 10–12 months to 3–4 months and the success rate in transferring embryos to seedlings in the field can be improved from about 50% to 100%. The new improved protocol now needs to be refined and applied to the different mutant coconut types that are found around the world.

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From: Adkins, S.W., Foale, M. and Samosir, Y.M.S. (eds) 2006. Coconut revival—new possibilities for the 'tree of life'. Proceedings of the International Coconut Forum held in Cairns, Australia, 22–24 November 2005. ACIAR Proceedings No. 125.

Introduction

Despite the huge potential of coconut (*Cocos nucifera*) as a tropical crop, producers are suffering from low productivity and the low price for copra, the main traditional product from coconut. Most of the trees that are presently harvested are old specimens of unimproved, low-yielding varieties. In some countries financially unsound coconut palms are being replaced with other crops such as oil palm *(Elaeis guineensis*). Thus, there is a need to revitalise the coconut industry, particularly in the countries where coconut plays an important role in the local economy. In the rebuilding of this industry it is imperative that other, high-value products from coconuts be developed and used to replace the traditional copra-based industry. Fortunately there are several elite coconut types that produce high-value fruit. Such types have fruit with a tasty, jelly-like endosperm or a refreshing, flavoursome aromatic water.

The coconut types that have the jelly-like endosperm are widely known as the 'makapuno-types'. The name makapuno comes from the Filipino word 'makapuno' which means 'almost full'. Such coconut types were first identified in the Philippines more than 40 years ago and similar types are now known to exist in several other countries, for example kopyor (Indonesia), dikiri (Sri Lanka), garuk (Papua New Guinea) and makapuno (Thailand and Vietnam). Makapuno-type fruit are used in the production of flavoursome foods and can be priced up to 10 times higher than ordinary, hard kernel fruits. Their value can be even higher on special occasions like Christmas and Idul Fitri when they are purchased in larger numbers and given as gifts.

Aromatic-type coconuts have a distinctive flavoursome liquid endosperm (water) and solid kernel which can give a refreshing effect when consumed. This coconut type is popular in Thailand and recent interest has grown in Vietnam. The nuts are sold fresh in local as well as export markets and can fetch prices up to five times those for standard fruits.

The future potential for both makapuno- and aromatic-type coconuts, however, still needs to be developed and this is hampered by the lack of planting stock availability. The makapuno-type coconut cannot germinate in nature because of the inability of its soft endosperm to nourish its own embryo. While the aromatic-type coconut can germinate in nature, they do so at a very low rate. In addition, there is a belief in Vietnam that those nuts that are able to germinate have only a weak aromatic flavor. To produce planting stock of both elite types, an embryo culture technique is needed to rescue the embryos and take them to full seedlings using an in-vitro procedure.

The successful embryo culture of the makapuno-type coconut was first reported in the 1960s (De Guzman and Del Rosario 1964). Since then the technology has been transferred to a number of tissue culture laboratories in the Philippines, particularly at the Philippine Coconut Authority (PCA), and in Indonesia for the kopyor variety. The coconut embryo culture technique is also used for other purposes, such as germplasm collection, and therefore research on this technique has also been conducted in other countries including Papua New Guinea, Vietnam, France and Australia. This paper aims to highlight recent developments in embryo culture technology as well as discuss future applications of the technique to the large-scale production of elite coconut seedlings.

The potential and challenge of elite coconut types

Despite the high commercial value of the elite coconut types (makapuno and aromatic), their potential has not yet been fully realised. There are only about 31,000 makapuno-bearing palms (out of 300 million coconut trees) in the Philippines (Rillo and Rillo 2001). The demand for their fruit is increasing as the makapuno food and drink industries grow. In 2003 the export of products from Filipino makapuno coconuts reached 1,200 million t, which was about 44% more than that exported in the previous year (Rillo 2005). A survey in the Philippines in 1999 revealed that the gap in supply to meet demand was about 4 million kg/year of makapuno endosperm, equivalent to about 8 million makapuno fruit (Rillo 2005) or at least 120,000 trees.

In Indonesia there has been a growing interest in the local makapuno-type coconut, the kopyor. To date there has been no comprehensive study undertaken on the number of kopyor palms present in Indonesia or what the local demand for this fruit is. Nevertheless, in 2004 a total of 378 ha (equivalent to 47,000 trees) of kopyor were reported to be growing in Pati district, East Java (Syariefa 2005), and some kopyor production had been reported from the Lampung and Madura districts for many years. The

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present Indonesian production of kopyor fruit is for the local market or is sent to the cities of Jakarta or Surabaya for fresh consumption. In the cities the endosperm is also used for ice cream manufacture.

In Thailand about 2,000 makapuno trees are known to have been planted in the 1970s from embryos imported from the Philippines (Sarian 2001). A recent survey in Vietnam has shown the existence of 237 makapuno- and 70 aromatic-type coconut palms in smallholder fields near Ho Chi Ming City (Lien 2005); however, large scale production is not possible from so few trees. In other countries such as Sri Lanka and Papua New Guinea there have been no reports of the large-scale planting of their makapuno- or aromatic-types.

As mentioned above, makapuno-type coconut fruit are popular for the manufacture of various foods including ice cream, cakes, pastries and syrup. Other potential markets are within the pharmaceutical and microchip industries as the makapuno-type fruit is rich in galactumanan, a form of cellulose that is used in the creation of materials used in encapsulation procedures.

Since the embryos from the makapuno-type fruit cannot germinate in situ, farmers cannot produce new palms. The embryos, however, can be rescued through tissue culture and nurtured to produce seedlings. The planting of these seedlings in close proximity (and away from normal palms to reduce pollen contamination) will give rise to palms producing a high proportion of makapuno fruit. A success rate of up to 95% has been achieved in the Philippines (Rillo 2005).

Mass propagation of makapuno seedlings is yet to be achieved, although some tissue culture laboratories have started producing seedlings for commercial purposes in the Philippines and discussions are underway to do something similar in Vietnam.

The current process of embryo culture for makapuno- and aromatic-type coconuts is long and tedious, making the production costs for seedlings very high. However, recent research funded by ACIAR has made some significant improvements to this protocol, which should now be applied to the commercial production of makapuno.

An embryo culture technique for elite coconut types

Coconut embryo culture was first attempted in the early 1960s at the University of the Philippines, Los Banos (UPLB). This early work was able to successfully culture makapuno embryos and grow them into mature palms at a low success rate (De Guzman and Del Rosario 1964). From this early start, the Philippines has now developed an industry based on the tissue culture of makapuno coconut. In addition to a number of private and university laboratories, six PCA laboratories are now providing tissue-cultured plantlets to farmers (Rillo 2005). Other countries are also showing an interest in this procedure, including Vietnam, Indonesia and Thailand. For the makapuno industry to establish elsewhere, a more widely applicable embryo culture protocol is needed. With the help of ACIAR, a recent project may have developed such a technique.

Today there are a number of methods described in the literature for undertaking coconut embryo culture. However, in most cases, these protocols have been developed for local coconut types and have little applicability to other kinds grown elsewhere. The need for a uniform, highly efficient embryo culture protocol is indicated by the low rates of success achieved when using these methods in other areas of the world. Rates of success can be as low as zero (Ashburner et al. 1994) but can reach 80% (Engelmann and Batugal 2002) in the hands of an expert. A common problem encountered by many is the low rate of conversion of plantlets established under in-vitro compared to ex-vitro conditions. This transfer step is always going to be difficult as most seedlings grown in vitro have a poorly developed root system and a low photosynthetic capacity (Triques et al. 1998), making establishment in soil very difficult. In addition, these seedlings are highly susceptible to infection when first transferred to soil and take a very long time to develop further, with the whole process of embryo culture taking up to 12 months to complete.

Thus, there is a need to develop a more widely applicable and reliable embryo culture technique that can be applied to a wide range of germplasm types and used by inexperienced technicians. Such a technique would have great applicability for commercial production of the makapuno- and aromatic-type seedlings as well as for germplasm collection. Through a collaborative research program linking several countries, Coconut Genetic Resources Network (COGENT) has investigated various forms of the embryo culture technique (Batugal 1998; Engelmann and Batugal 2002), and have proposed a new 'hybrid embryo culture' protocol (Engelmann and Batugal 2002; Rillo et al. 2002) which is being

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used as a platform onto which further improvements are being proposed.

At the present time major improvements to this protocol are being considered, some of which were identified and discussed at the most recent review of the ACIAR funded coconut project held in Manado, Indonesia, 10–14 October 2005. This new information includes the following observations.

At the Cocoa and Coconut Institute (CCI) it has been found that mature embryos (aged 10–11 months after fertilisation) are the best ones to be used for embryo culture. However, younger embryos can also be used if mature ones cannot be found or nuts cannot be aged correctly, for example, when collecting germplasm in remote areas. In terms of culturing costs, about 20% savings can be made if an embryo-culling step is included to remove unresponsive embryos 6 weeks after the start of the culture period.

An attempt to improve germination in cultured embryos was undertaken at UPLB. However, the application of spermidine, silver thiosulphate or polyethylene glycol, to the culture medium did not increase the germination percentage. In another experiment it was found that the collective acclimatisation method applied to new ex-vitro seedlings, using a wooden box covered with a transparent plastic sheet, produced better quality seedlings than was possible using the older plastic bag method of the hybrid protocol.

At the Indonesian Coconut and Other Palmae Research Institute (ICOPRI) coconut seedlings treated with auxins (plant growth regulators, either NAA or IBA) grew better in vitro. Their ex-vitro survival rate was also much greater than was achieved with the hybrid protocol method, which does not use auxins. The amount of auxin needed was determined by the method of application. For plantlets that were dipped once into the auxin, 200 mM NAA was needed, while prolonged application needed only 100 mM NAA. The benefit of adding NAA and/or IBA to the culture media is thought to be the promotion of root initiation. At the Oil Plant Institute of Vietnam (OPI) good in-vitro and ex-vitro growth were possible when using 0.5 mg/L of the auxin IBA. When combined with 0.5 mg/L NAA, not only was the embryo germination percentage increased but ex-vitro survival was also improved.

At Albay Research Centre (PCA), it was found that seedling growth could be improved and the rate of seedling establishment increased by reducing the medium carbohydrate load (from 45 to 25 g/L) at the last seedling subculture step. Coconut dust and fibre has been shown to be a superior potting mixture when compared to soil and sand for growing seedlings ex vitro. It has been also shown that 3-month-old seedlings previously grown in vitro can survive at higher rates ex vitro when maintained with a Hoagland mineral solution. This shortens the in-vitro stage and therefore reduces the cost of seedling production.

Work undertaken at the University of Queensland (UQ), Australia, has shown that enriching the gaseous environment around the in-vitro culture with CO_2 produced much more vigorous seedlings than using the hybrid embryo protocol. This vigour could be achieved at a much lower sucrose level (5 g/L compared to 45 g/L in the hybrid embryo protocol) or without sucrose at all (Samosir and Adkins 2005a). This approach has significantly improved the success rate of transferring the in-vitro plantlets to ex-vitro conditions (about 50–100%), as well as shortening the time in vitro, from the normal 12 months down to 4 months.

Another important improvement coming out of the work at UQ involves an embryo transplantation step. If this improvement were to be fully incorporated into the protocol, the need to undertake any aspect of in-vitro culture would be bypassed. In this improvement embryos are aseptically removed from the donor nut and transferred to their proposed destination. At the recipient laboratory a surrogate fruit is prepared to receive the isolated embryo or the endosperm plug carrying the embryo. The surrogate nut, with the transplanted embryo, is then allowed to germinate naturally under protected environmental conditions. The first batch of embryo-transplanted coconut seedlings using this technique has now been established in soil at UQ (Samosir and Adkins 2005b).

Commercial production of elite coconut seedlings

So far it has taken about 4 decades to transfer the technology of coconut embryo culture from the research laboratory to commercial production of makapuno seedlings. Currently, the Philippines is the leading country in the production of the makapuno-type seedlings. To date there are 11 tissue culture laboratories (six PCA-based, two private, two within the Department of Agriculture and one university-based) working on the production of makapuno seedlings using embryo culture. Each PCA laboratory has at least a 1 ha demonstration plot used to produce

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embryos for their work. The price of a single seedling (300–1000 pesos), however, is still too expensive for most farmers. Nevertheless, nearly 100 ha have been planted with makapuno-type coconuts obtained from in-vitro culture.

Some tissue culture laboratories have been developing embryo culture of kopyor coconut in Indonesia, including Indonesian Coconut and Other Palmae Research Institute (ICOPRI), University of Gajahmada and the Indonesian Biotechnology Research Institute for Estate Crops (IBRIEC). But only the latter laboratory is producing seedlings for commercial purposes and this is still at a low level. The ready-to-field plant seedlings are sold at US$10 each. A new tissue culture laboratory at Jombang town has been established with technical assistance from ICOPRI.

There has been no production of seedlings of elite coconut types for commercial purposes in Thailand, Sri Lanka, Vietnam and Papua New Guinea. Nevertheless, OPI Vietnam has been able to produce seedlings of aromatic-type coconuts for planting of about 4.5 ha, which could later act as the source of embryos for mass production of seedlings.

Future work direction

It has been shown that the embryo culture technique can reveal the potential of elite coconut types, particularly makapuno which cannot germinate in nature. However, the demand for embryo-cultured seedlings of these elite types is increasing. The problem is that they are too expensive and not widely available to farmers. Thus, there is a need to lower the cost of seedling production and speed up the production rate. The new protocol, developed during the ACIAR funded project, still requires further development, particularly in its modification for elite types and how it can be scaled up for more production.

The number of embryos available for culturing is limited, and often it is difficult to meet the needs of the nearby laboratory. In the future the program should include the establishment of seed gardens of elite coconut types near the tissue culture laboratory to act as the main source of embryos. In addition, the garden may also be a home for the germplasm collection of elite coconut types. To date very little work has been done in the selection and breeding of such types. There is a potential to combine the two traits to form 'aromatic–makapuno' nuts.

Despite the high demand for both aromatic and makapuno coconuts and the availability of the embryo culture technique in the public domain (not patented), private industry has not shown a great interest in exploiting the potential of elite coconuts so far. The bad image of coconut oil, although wrongly claimed, in advanced countries may have contributed to this slow uptake. In addition, the decreasing coconut industry in general may also have caused the private sector to 'wait-and-see' on the makapuno and aromatic coconut business. Respective governments therefore should provide incentives and develop programs to enhance the elite coconut industry in their countries.

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From: Adkins, S.W., Foale, M. and Samosir, Y.M.S. (eds) 2006. Coconut revival—new possibilities for the 'tree of life'. Proceedings of the International Coconut Forum held in Cairns, Australia, 22–24 November 2005. ACIAR Proceedings No. 125.

Coconut oil and health

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Abstract

Because of its high saturated fat content, coconut oil has been blindly criticised by the medical community and laypersons alike for contributing to the development of heart disease. Coconut oil, however, is not like other fats. It is composed predominately of a special group of saturated fats known as medium-chain triglycerides (MCT). Over the past 40 years research has shown that MCT, derived from coconut oil, posses unique properties with important nutritional and medical applications. Although MCT are classified as saturated fats they do not contribute to heart disease; rather, evidence shows they actually protect against it. Coconut oil has a long history of use throughout the world as both a food and a medicine. It has traditionally been used to treat a wide variety of health problems ranging from burns to influenza. Studies have shown that those populations that use coconut oil as their primary source of fat have the lowest heart disease rates in the world. These populations also have a low incidence of chronic disease. Recent medical studies have shown that both coconut oil and MCT can help protect against many common illnesses including heart disease, cancer and diabetes, and numerous infectious diseases including HIV/AIDS.

Introduction

For the past 3 decades coconut (*Cocos nucifera*) oil has been criticised by the medical community and laypersons alike for contributing to the development of heart disease. Because of its high saturated fat content it is assumed that it has a negative effect on blood cholesterol and, therefore, promotes heart disease. However, after years of study researchers have been unable to link coconut oil consumption with an increased risk of heart disease. In fact, the evidence shows that coconut oil may actually protect against heart disease (Fife 2005).

Research to date has shown that coconut oil has the potential to protect against not only heart disease but a wide variety of chronic health problems including diabetes and cancer. It is also showing promise as a means to prevent and even treat infectious diseases.

Because of a general prejudice against saturated fats, the knowledge about coconut oil has been kept buried in medical journals. It is only recently that the truth about coconut oil has begun to emerge. With this renewed interest in coconut oil, researchers are now actively studying it more intently in regards to its effect on health. An increasing number of health-care professionals are recognising coconut as not only one of the 'good' fats but perhaps the healthiest of all the dietary fats.

Although awareness of the health benefits of coconut oil is becoming better known, many people still mistakenly think of it as an artery-clogging saturated fat. I did too at one time. But then I had an experience that changed the way I look at fats and oils and particularly coconut oil.

Some years ago I was in a meeting with a group of nutritionists and a member of the group stated that coconut oil was one of the good fats, that it did not cause heart disease and that it provided many health benefits. We were all stunned! For years we've been told that coconut oil promotes heart disease. We were skeptical.

This nutritionist, however, backed up her statements and referred to several studies in leading medical journals. I learned that coconut oil in one form or another is used in hospital intravenous (IV) solutions and in baby formula and is recommended for those with cystic fibrosis and digestive problems. I was amazed! And I began to wonder: if coconut oil has so many medical and nutritional uses, why is it

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labelled a dietary nightmare? And, if it really did cause heart disease, why is it given to seriously ill patients and newborn infants? It just didn't make sense. I had to find the answer.

Since everyone seemed to know that coconut oil caused heart disease, I was sure that there must be many magazine articles written on the topic, outlining the dangers of coconut oil. Some of these I was sure would include references to medical studies to prove this, so I began looking for articles on coconut oil. I searched everywhere but couldn't find any. At that time there weren't any articles written specifically on coconut oil, at least that I could find. I did find many articles on fats and oils and almost all of them included one sentence on coconut oil, which was almost exactly alike in every article I read. That sentence was 'Coconut oil is a saturated fat and causes heart disease.' I saw this statement repeated over and over again. Although almost every author would include this statement, not one of them ever backed it up with any facts, figures or references to the medical literature. When I started this search, I expected to read horror stories where people began eating coconut oil as little children and by the time they were 30 years old they had raging heart disease, but there were no such stories.

It became obvious to me that none of these authors who were writing about fats and oils knew anything at all about coconut oil. They had never bothered to research the matter. All they were doing was simply repeating what someone else had said, who in turn had repeated what others had said before them, and so on.

It was apparent that I would never find the truth about coconut oil from popular books and magazines. If I was going to learn the truth, I was going to have to search through the medical literature and see what researchers were learning about it. And that's exactly what I did. When I started searching the medical journals I found a large amount of information on coconut oil and what I found shocked me!

I found out why coconut oil, in one form or another, is included in IV solutions (Chen et al. 2005; Lai et al. 2005), and in baby formula (Klenoff-Brumberg and Genen 2003). I learned why it is recommended for those with cystic fibrosis and those with digestive problems (Calabrese et al. 1999). I also learned that there is absolutely no truth, whatsoever, in the belief that coconut oil causes or even contributes to heart disease. In fact, I learned that if you want to avoid heart disease you should be using coconut oil (Bourque et al. 2003; Dayrit 2003; Mensink et al. 2003; Sircar and Kansra 1998).

Historical use as a medicine

In my research I found that coconut oil has a long history of use throughout the world as both a food and a medicine. It holds a high place of respect in the Ayurvedic medicine of India. In Central America and East Africa the people drink it by the cup whenever they are sick. Over the centuries they have learned that coconut oil is a safe, natural remedy for many common illnesses. In the Philippines it has a long history of use as an all-purpose medicine and topical ointment. Among the Pacific islanders coconut oil is considered the cure for *all* illnesses. The coconut palm is so highly regarded that it is called the 'tree of life'.

In traditional forms of medicine around the world coconut oil is used for a wide variety of health problems, ranging from the treatment of burns and constipation to gonorrhea and influenza (Duke and Wain 1981). Modern medical research is now confirming the use of coconut oil for many of these conditions. I began using it myself and recommending it to others. I've seen it clear up hemorrhoids, stop bladder infections, remove cancerous skin lesions, help people lose excess weight and improve digestion, among other things.

After doing all this research I realised that few people outside the research community knew about the healing miracles of coconut oil. I felt an obligation to share this knowledge with others, so I wrote a book titled 'The Healing Miracles of Coconut Oil' (Fife 2003). All the information in this book came directly from published medical studies as well as from my own experience.

Medium-chain fatty acids

If coconut oil is high in saturated fat, why doesn't it contribute to heart disease? How can a saturated fat have so many health benefits? What makes it different from other oils?

The difference is found in the fat molecule. All fats and oils are composed of fat molecules known as fatty acids. The fatty acids found in coconut oil are unique and possess properties that are different from other fats. They are called medium-chain fatty acids (MCFA), also known as medium-chain triglycerides (MCT).

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The fatty acids in our diet can be classified into three categories based on their size or the length of the carbon chain. There are short-chain fatty acids (SCFA), MCFA and long-chain fatty acids (LCFA). The vast majority of the fats and oils in our diet, both saturated and unsaturated, from plants or animals, are composed of LCFA. Some 95–100% of the fats you eat are made of LCFA, unless you eat a lot of coconuts or coconut oil. Coconut oil is composed predominately of MCFA.

The length of the carbon chain is extremely important. Our bodies respond to and metabolise each fat differently depending on its size. Therefore, the physiological effects of MCFA from coconut oil are significantly different from those of the LCFA more commonly found in our foods.

Since the 1950s research has shown that MCFA derived from coconut oil possess unique properties with important nutritional and medical applications (Kaunitx et al. 1958). For this reason, they are added to IV solutions and baby formula and are recommended for use with a variety of health concerns.

Until recently MCFA have not received much attention outside the research community because of prejudice against saturated fats. Although all MCFA are saturated fats, they are not like the long-chain saturated fats we find in meats and other vegetable oils. There are only a few good natural sources of MCFA in our diet, and the best source is coconut oil.

The anti-tropical oils campaign

At this point you may be wondering: 'If coconut oil is so good, why does it have a reputation as an artery clogging fat that causes heart disease?' You can give most of the credit to the soybean (*Glycine max*) industry. The attack on coconut oil was a cleverly designed publicity campaign sponsored by the vegetable oil industry in an effort to take over the tropical oils market. In the 1970s and early 1980s saturated fats in general were being scrutinised because of their tendency to raise cholesterol. The vegetable oil industry saw an opportunity to capitalise on this and capture the tropical oils market. They spent millions of dollars in an aggressive publicity campaign that extended across the world, flooding the media with reports about the dangers of saturated fats. In North America the wives and families of nearly half a million soybean growers were encouraged to fan out across the country promoting the benefits of soybean oil and the dangers of saturated fat and coconut oil. Many well-meaning, but misguided, special interest groups joined in the battle and produced alarming news stories about saturated fats and labelled coconut oil a dangerous 'artery-clogging fat'. Before long, everyone believed coconut oil caused heart disease. A few researchers who knew the truth about coconut oil finally came forward to set the record straight. But by this time, everyone had become so brainwashed that they wouldn't listen, and these researchers were severely criticised and ridiculed, so they backed off and remained silent.

Restaurants and food manufacturers, sensitive to customer fear of saturated fats, began removing coconut oil from their foods and replacing it with soybean oil. By the early 1990s coconut oil had virtually disappeared from the diets of people in Australia, North America and Europe. It was even disappearing from the diets of Asians who had been using it for generations.

Because of the negative publicity campaign sponsored by the vegetable oil industry, today most people believe coconut oil contributes to heart disease.

Heart disease

The primary concern most people have about coconut oil is its effect on blood cholesterol levels. Being highly saturated it is assumed that it has a negative effect on cholesterol. Studies, however, have shown that it does not have a harmful effect but improves cholesterol levels.

When people add coconut oil to their diets their total blood cholesterol levels may fluctuate either up or down slightly, but in either case their HDL (good) cholesterol increases. HDL cholesterol is believed to protect against heart disease and the higher it is the better. Total cholesterol is not a very accurate measure of heart disease risk because it includes both LDL (bad) and HDL (good) cholesterol and you don't know how much of the good or the bad makes up the total. This is why nearly half of those people who die of heart attacks have normal or below normal total cholesterol levels. A much more accurate proven indicator of heart disease risk is the cholesterol ratio (total cholesterol/HDL cholesterol), which takes into account the amount of good cholesterol in the total cholesterol value.

Researchers consider a cholesterol ratio of 5.0 mg/dL to be normal or average. A ratio above 5.0 mg/dL indicates a high risk of heart disease, while below 5.0

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mg/dL is low risk and 3.2 mg/dL or lower is optimal or very low risk.

Let's look at an example. A total blood cholesterol level of 200 mg/dL is considered to be average. If a person has a total cholesterol value of 180 mg/dL this would be considered low risk. But if their HDL (good) cholesterol were only 32 mg/dL, the cholesterol ratio would be 5.6 mg/dL, which indicates high risk. So in this example total cholesterol is not accurate.

Here is another example. Let's say a person has total cholesterol of 240 mg/dL, which is considered high risk. However, if their HDL is 75 mg/dL, the cholesterol ratio would be 3.2 mg/dL, which is in the very low risk or optimal range. Here again the total cholesterol level gives an erroneous indication of heart disease risk.

Conversely, sometimes those people with high total cholesterol also have a high cholesterol ratio and those with low total cholesterol have a low cholesterol ratio. So total cholesterol does not always correlate with the cholesterol ratio. If you only look at total cholesterol values, as most people do, you could come to the wrong conclusion about the person's true risk of heart disease.

There have been several studies that compared cholesterol values after subjects consumed coconut oil, corn oil (*Zea mays*), soybean oil and other vegetable oils. It has been found that vegetable oils reduce total cholesterol more than coconut oil. Many people have interpreted this to mean that vegetable oils protect against heart disease while coconut oil doesn't. However, even though the vegetable oils decrease total cholesterol more than coconut oil, coconut oil improves the cholesterol ratio more than the other oils. Therefore, coconut oil has a more favorable overall effect on cholesterol values than all other oils.

An interesting study was done by Mendis and colleagues on Sri Lankan male volunteers (1989). Coconut oil is commonly used throughout Sri Lanka, and cholesterol levels were measured in subjects whose normal diet included coconut oil. The subjects were given corn oil to replace the coconut oil in their diets and cholesterol levels were measured again. Their total blood cholesterol on average decreased from 179.6 to 146.0 mg/dL, and their average LDL (bad) cholesterol decreased from 131.6 to 100.3 mg/dL. Both of these changes are considered good and, if taken by themselves, would suggest that corn oil is superior to coconut oil as far as heart health is concerned. However, when the HDL (good) cholesterol values are included, the picture changes entirely. The HDL cholesterol in volunteers decreased from 43.4 to 25.4 mg/dL, and the cholesterol ratio increased from 4.14 to 5.75, which is not good. Keep in mind that a ratio greater than 5.0 is considered high risk. When volunteers ate coconut oil they were at a low risk value of 4.14 but when they switched to corn oil the ratio was propelled into the high-risk range at 5.75. Even though coconut oil increased total cholesterol relative to corn oil, it lowered the cholesterol ratio and thus reduced the risk of heart disease. According to this study coconut oil protects against heart disease while corn oil (a polyunsaturated fat) promotes it.

Common sense

A little common sense illustrates the fallacy behind the coconut oil scare. If coconut oil really did cause or even contributed to heart disease it would be very easy to prove. How? All you would have to do is go to the coconut growing regions of the world and examine the health of the people there. If coconut oil caused heart disease, these people should be riddled with heart attacks and strokes. But when you go to Thailand, the Philippines and the islands of the Pacific what do you find?— that heart disease is relatively low compared to the rest of the world. In fact, the people who eat the most coconut oil have the lowest heart disease rates in the world!

In Sri Lanka coconut has been the primary source of dietary fat for thousands of years. In 1978 the per capita consumption of coconut was equivalent to 120 nuts/year. At that time the country had one of the lowest heart disease rates in the world. Only one out of every 100,000 deaths was attributed to heart disease. In the United States of America, where very little coconut is eaten and people rely more on polyunsaturated oils, the heart disease death rate at the same time was at least 280 times higher.

Since 1978 coconut consumption in Sri Lanka has declined. By 1991 per capita consumption dropped to 90 nuts/year and has continued to fall. In place of coconut oil the people have begun to eat more corn and other polyunsaturated vegetable oils. As coconut consumption has decreased, heart disease rates have increased! If coconut oil really did cause heart disease the heart disease rate should have decreased as people consumed less coconut oil, but just the opposite has happened. Another interesting fact is that heart disease occurs almost entirely in the urban

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population that eats the least amount of coconut oil and the most imported polyunsaturated oil. In populations that live outside the cities and continue to depend on coconut oil as a major source of fat, heart disease is essentially non-existent (Mendis 1991). In the coconut-growing regions of India, people were told to stop eating coconut oil because it caused heart disease. So they started eating more processed vegetable oils and margarine. As a result, within just 10 years the heart disease rate tripled! Are you beginning to see a pattern develop here? You should. In those areas of the world where people eat lots of coconut oil, heart disease is relatively rare. Where people eat very little coconut oil and depend on processed vegetable oils and margarine, heart disease is a major health problem.

In areas of the world like the Philippines and Fiji where people have been eating coconuts for thousands of years, there had not been a single case of heart disease reported until the mid 20th century. Then suddenly people started dying from heart disease, assumedly because they ate coconut oil. Doesn't that sound strange? Why would coconut oil be harmless for thousands of years and then suddenly become deadly? It makes no sense. Heart disease did not exist in these areas until after processed vegetable oils were introduced and people switched from coconut oil to these imported oils. For example, in Papua New Guinea coconut has traditionally been the primary source of fat in the diet. People have been eating coconut oil for thousands of years yet the very first heart attack death didn't occur until 1964 (Misch 1988), which was after they started using imported vegetable oils. When you go outside the cities into rural populations that still rely on coconut oil as their primary source of dietary fat, heart disease does not exist (Lindeberg and Lindh 1993). In these populations signs of heart disease are completely absent even in the older members of the population who can live up to 100 years of age.

Obviously, coconut oil does not cause or contribute to heart disease. If anything, it helps protect against it.

Diabetes

Diabetes is characterised by poor circulation and a tendency to develop atherosclerosis (hardening of the arteries). For this reason, heart disease is a major cause of death in diabetics. Because of poor circulation, diabetes is the most common cause of non-traumatic amputation of the legs and feet. It is also one of the leading causes of blindness and kidney failure.

Diabetes occurs when the body is unable to properly regulate blood sugar. When we eat a meal, much of our food is converted into glucose and released into the bloodstream, so glucose is commonly called 'blood sugar'. Our cells use glucose as food to fuel metabolic processes. Every cell in our bodies needs a continual supply of glucose in order to function properly and, if glucose is not available, the cells can literally starve to death. Blood vessels and capillaries degenerate, circulation is hindered and nerves become damaged, leading to the many complications associated with diabetes.

Insulin is a vitally important hormone that escorts glucose from the bloodstream and into the cells. Even if the bloodstream is saturated with glucose, our cells cannot get what they need without the aid of insulin. Fatty acids from fats can also feed our cells. But, like glucose, they too need insulin in order to enter the cells.

There are two types of diabetes, Type 1 and Type 2. In Type 1 the body is unable to produce the amount of insulin needed. In Type 2 the body may be able to produce a normal amount of insulin but the cells have become unresponsive or resistant to it, so a much higher amount of insulin is required to accomplish the job. This condition is called insulin resistance. In both types of diabetes cells are deprived of nourishment.

Coconut oil can be of great benefit to diabetics. The MCFA in coconut oil are small enough that they don't need the aid of insulin in order to enter cells. They can provide the cells with nourishment regardless of insulin status. It doesn't matter if there is not enough insulin available or if the cells have become insulin resistant.

Studies have also shown that coconut oil helps regulate blood sugar because MCFA improve insulin production and insulin sensitivity (Garfinkel et al. 1992; Han et al. 2003). In other words, coconut oil helps the body produce insulin and reverses insulin resistance, thus relieving many of the symptoms associated with diabetes.

For example, after the publication of my first book on coconut oil I received a call from a man who was a diabetic. He had lost the feeling in both his feet due to a lack of circulation caused by his diabetes. He read my book and started using coconut oil. After less than 2 weeks he told me 'My feet came alive!'—his circulation improved so much that feeling returned to his feet. Since then several others have reported

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similar experiences to me after they began using coconut oil.

Another diabetic told me his feet had been numb for 6 years, starting with his big toe and gradually moving down his foot and up his leg. He had received a scratch on his lower leg, but because of his poor circulation it wouldn't heal, persisting for several months. He began eating three to four tablespoons of coconut oil a day, and within 10 days the injury was completely healed and feeling was returning to his feet and toes.

One of the characteristics of diabetes is high blood sugar, particularly after a meal. Because insulin production is insufficient or the cells are unresponsive to it, blood sugar can remain elevated for an extended amount of time and cause many health problems, one of which is death. This is why it is important for diabetics to monitor their blood sugar levels and take insulin injections to lower it when it gets too high.

Coconut oil can be helpful in lowering blood sugar when it gets too high. Many people have reported that it can reduce high blood sugar almost immediately.

One man explained to me that his wife and daughter are both diabetics and measure their blood sugar levels at least three times a day. When they eat the wrong types of food and their blood sugar levels are too high, they don't inject themselves with insulin any more but eat two to three tablespoons of coconut oil. Within half an hour their blood sugar levels are back to normal.

Cancer

Cancer is one of the five leading causes of death worldwide. Every year over 10 million people are diagnosed with the disease. The incidence of cancer continues to increase year after year and currently causes 12% of all deaths.

The good news is that coconut oil can help protect you from cancer, or at least some forms of it. Medical studies have shown that coconut oil possesses potent anti-cancer properties.

In one study (Reddy and Maeura 1984) colon cancer was chemically induced in a group of rats. The animals were fed diets containing different types of fat to determine their influence on tumour development. The oils tested included coconut oil, corn oil, safflower oil (*Carthamus tinctorius*), olive oil (*Olea europaea*) and others. Tumours developed in the animals at different rates depending on the type of oil they were given. The largest and greatest number of tumours occurred in the animals fed corn and safflower oils. In fact, the authors stated that these oils seemed to promote the growth of the tumours. Tumours developed in all the animals except those that were given coconut oil. Researchers concluded that coconut oil protected the animals against tumour development.

Several studies have shown that coconut oil may help protect against breast cancer. In one study (Cohen et al. 1984) mammary cancer was induced in test animals which were fed different types of oils. All the animals developed tumours except those fed MCT from coconut oil. Researchers stated that in these animals there was no detectable tumour-promoting effects even though they were given potent cancer-causing chemicals.

In a study on skin cancer researchers applied cancer-causing chemicals to the skin of test animals and tumours developed within weeks. However, when coconut oil was applied to the skin along with the cancer-causing chemicals, there was a complete absence of tumour development (Nolasco et al. 1994).

These and many other studies suggest that coconut oil can protect against colon cancer, breast cancer, skin cancer and other cancers.

Research has demonstrated several means by which coconut oil protects against cancer. One of these is that MCFA in coconut oil inhibit tumour growth. Another is that they stimulate the production of white blood cells, specifically T-cells, which attack and kill anything that the body perceives to be harmful, including cancerous cells (Ling et al. 1991; Wanten 2006; Witcher et al. 1996). So coconut oil not only blocks the growth of cancer but aids the immune system in fighting it.

Case reports show that coconut oil can not only prevent cancer but treat it as well (Fife 2005). For instance, one woman had an aggressive form of breast cancer that was so severe it spread to her skull. Doctors operated but they couldn't remove it all and 20% of the cancer remained in her skull. They couldn't do anything more for her and basically sent her home to die. She learned about the healing properties of coconut oil and began eating coconut and coconut oil daily. After 6 months she went back to her doctors and to their amazement they could find no trace of the cancer. Instead of dying she was completely healed.

Melanoma is the most deadly form of skin cancer. It causes death in about one in every four cases, and because it is highly malignant it often spreads to other parts of the body. I have seen melanomas fade away with the daily application and consumption of coconut oil.

Traditionally, in the islands of the Pacific the people rub coconut oil over their entire bodies from head to toe every morning. Their skin is exposed to the hot tropical sun all day long and yet they have beautiful, healthy skin. Doctors tell us not to get too much UV radiation from the sun because it will cause skin cancer. These islanders have been doing this for thousands of years and they have never been troubled with skin cancer. As long as they eat coconuts and use the oil on their skin they don't get skin cancer.

If coconut oil can stop and reverse the progression of melanoma, it can certainly prevent cancer from developing in the first place. Using coconut oil as a daily body lotion is a simple way to protect yourself from skin cancer.

Studies have shown that coconut oil protects animals against cancer-causing chemicals added to their foods and applied on their skin. This suggests that coconut oil can be helpful in protecting us from the cancer-causing substances in our food and environment. Case histories show that for those who already have cancer, using coconut oil in conjunction with other cancer treatments may significantly enhance the effectiveness of these treatments.

Conclusion

I've explained how coconut oil helps protect against heart disease, diabetes and cancer. Research also shows that it has the potential to protect against a large number of other health problems including liver disease, kidney disease, Crohn's disease, gall bladder disease, chronic fatigue, malnutrition and a host of infectious diseases.

One of the most remarkable characteristics of MCFA is their ability to destroy disease-causing bacteria, fungi and viruses. Research has shown that MCFA from coconut oil kill bacteria that cause gastric ulcers, sinus infections, urinary tract infections, dental cavities, pneumonia, gonorrhea and other infections. They destroy fungus and yeasts that cause ringworm, athlete's foot and candida infections. They kill viruses that cause influenza, measles, herpes, mononucleosis, hepatitis C and AIDS.

Although the MCFA in coconut oil are powerful enough to kill disease-causing microorganisms, they are harmless to us. Our cells actually use them as food. So they protect us from infectious disease as well as nourish our cells. Coconut oil in amounts up to 60% of daily calories has been shown to have no adverse side effects (Prior et al. 1981).

Coconut oil is emerging as both a nutritious health food and a promising new natural treatment for many common health problems. Past research has provided the groundwork, and the few clinical studies that have been done on human subjects have shown promise in a variety of areas. An initial study conducted in the Philippines using coconut oil to treat HIV/AIDS patients demonstrated a 60% success rate (Dayrit 2000). The study, however, was limited to only 14 subjects because of the lack of HIV-infected people in the country. A much larger study is now being organised in Africa where more HIV-infected subjects are available.

A lack of funding has limited the number of clinical studies to date. More clinical studies are needed to verify laboratory, theoretical and anecdotal evidence.

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From: Adkins, S.W., Foale, M. and Samosir, Y.M.S. (eds) 2006. Coconut revival—new possibilities for the 'tree of life'. Proceedings of the International Coconut Forum held in Cairns, Australia, 22–24 November 2005. ACIAR Proceedings No. 125.

Bringing hope to remote island communities with virgin coconut oil production

D. Etherington[1]

Abstract

There is new hope for the coconut industry of the South Pacific region with the advent of modern small-scale processing technologies. Such technologies allow for the commercial production of virgin coconut oil (VCO) at the farm level. The implications are manifold because VCO is arguably the most useful vegetable oil in the world. With microprocessing into final products, the coconut can reclaim its titles of 'king of palms' and 'the tree of life'. VCO has immediate medicinal, cooking, massage, cosmetic and fuel uses both for the local economy and for export. These commercial uses of coconut oil were denied to coconut farmers for decades as they were urged to produce copra for the export market. Although coconut is the most abundant and sustainable rural resource of the islands, it became increasingly viewed as just a subsistence crop since farmers were less and less willing to engage in the hard and dirty work of producing copra for export. There have been major failures by export marketing authorities, and by research institutes, who have only focused on embodied crop technologies. These failures occurred amid volatile and falling prices of coconut oil on world markets and had catastrophic consequences for farmers and their families. Product diversification and attention to processing technologies, drawing on local knowledge and directed towards local demand, were largely ignored. These are the keys to sustained benefit. This paper looks at the potential contribution of small-scale processing to income, health and environmental sustainability by drawing on the experience of working with the Direct Micro Expelling (DME) technology for over a decade.

Introduction

The history of coconut (*Cocos nucifera*) oil production in the South Pacific is interesting. For western colonial interests, the dried flesh of the coconut fruit, transportable to distant markets and known as copra, was their primary attraction as a source of vegetable oil for industrial extraction. The initial strategy was to encourage expatriate companies and individuals to set up large plantations using the abundant land resource and local or imported indentured labour. Processing was confined to weight reduction of the bulky coconut fruit by extraction and drying of an exportable commodity. Coconut palms constituted an abundant renewable resource on the groups of small islands and atolls which make up the land area of the South Pacific nations, and were valued and accorded special status in the local life, culture and rituals. However, it was only after World War II that local populations began to participate seriously in copra production. Post-colonial history has been woven around copra as a primary export, with rural households producing the copra for cash income. Coconut products continue to play a central role in the livelihood of the subsistence societies of the South Pacific.

For the governments of the South Pacific nations, the value of a living coconut palm has been dependent only on the price copra-based coconut oil fetched in international markets. The copra produced in the South Pacific is only a tiny proportion of the world production. Furthermore, world production of coconut oil is barely 4% of the total production of the nine major vegetable oils. Its price in international markets is not only on a significant long-term decline but also, more importantly, is highly volatile. In an analysis of the price instability of 42 primary commodities in the period 1950 to the late 1980s, the World Bank found coconut oil to be the most

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unstable (World Bank 1990). Halving or doubling of the price of coconut oil quoted in Rotterdam within the space of a single year was not uncommon.

The policies of the governments and international research priorities sought to increase the yield potential of coconut in order to restore the value of the palm to the communities. This paper argues that the supply of coconuts is not the problem, but it is the use to which the existing supply is put that is critical.

The aim of this paper is to show that the long-term coconut policy needed to reap the real value of the coconut palm should rely heavily on alternatives to copra, and introduce appropriate coconut-processing technologies that match the factor proportions as well as engage local knowledge. A key to success is wider participation of local people, and dovetailing of products to niche markets and domestic demand. This argument has been presented in detail elsewhere (Etherington and Mahendrarajah 2001). Here we revisit the fact that coconut oil can become a significant energy resource for remote island communities. This illustrates the scope for increasing domestic demand and shows how import substitution can moderate the volatile copra price in South Pacific communities. There is new hope for the coconut industry of the region following the advent of modern small-scale processing technologies. Such technologies allow for the commercial production of virgin coconut oil (VCO) at a farm level and thus contribute significantly to farmer income, improved health and enhanced environmental sustainability. The paper draws on the experience of working with the Direct Micro Expelling (DME) technology for over a decade.

Coconuts and the Pacific

Coconut palms are ideally suited to the humid tropical coastal climate. They thrive even in poor sandy soils and tolerate short-term exposure to saline water. The coconut palm may live beyond 70 years, needing hardly any nurturing, and propagates by seed (nut) only throughout its life. The nuts are produced year round at regular intervals on bunches of 5 to 20 nuts. The coconut palm is often referred to as 'the tree of life' in the South Pacific nations (Ohler 1984) because of the regularity of production, its multiple uses, its resilience to cyclonic wind and its longevity.

With a myopic focus on copra for export, governments have failed to recognise and capitalise on the multiple alternative uses of coconut. The extraction of the kernel from mature fruit for copra production was arduous, dirty work. Rather than being regarded as a desirable means of earning cash, it was viewed as a necessary evil. In many instances it was the only means of earning cash for school fees and medical care, and for obtaining modern conveniences. It was an inefficient use of forest resources in cutting firewood for drying the copra. Copra itself was a polluted raw material which locked out producers from final products as they lacked the means to extract the oil from it. As world prices declined, so farmers abandoned many of their coconut groves and simply collected enough nuts for their own household needs and for feeding their livestock, principally pigs.

It is only an increase in demand for the nuts derived from other marketing opportunities that will raise farm incomes. When such derived demands are stable the incomes will be sustained. The benefits of an increase in demand will be widespread, benefiting all existing producers in the short run without any gestation period, quite unlike the supply side policies of the perennial crop research institutes. The focus need not be on fruit alone. The coconut palm produces many different raw materials which can be processed into an extraordinarily wide range of products. The most advantageous feature of the coconut palm is that it produces fruit and fronds continuously year round with little seasonal variation. This feature is ideal for on-site small-scale processing enterprises as it avoids any raw material storage issues.

The relatively rich rural resources of the islands and the lack of acute human population pressure prompted the economist Fred Fisk to coin the phrase 'subsistence affluence' to describe this situation in the South Pacific. A traditional island economy emerging from subsistence with the sale of copra is portrayed in Figure 1. In addition to an increasing reliance on the flow of aid from official and non-government organisation sources, rapid population growth of over 3% could quickly lead away from self-reliance to the subsistence poverty of many areas in Africa and parts of South Asia.

Coconut products

The coconut provides some of the healthiest food products known to mankind. By following the copra route, downstream processing virtually destroys its nutritional values. Kiln or sun drying of copra, with unhygienic handling and storage, changes a highly edible product into something potentially toxic. The high temperatures used to make copra and copra oil

From: Adkins, S.W., Foale, M. and Samosir, Y.M.S. (eds) 2006. Coconut revival—new possibilities for the 'tree of life'. Proceedings of the International Coconut Forum held in Cairns, Australia, 22–24 November 2005. ACIAR Proceedings No. 125.

destroy essential amino acids and tocopherols (vitamin E) (Banzon and Velasco 1982). The nutritional qualities of copra cake are degraded and the coconut oil expelled from copra is inedible. Refining the oil is essential. Processing via copra severely limits the alternative market potential for downstream coconut products. Finally, oil extraction from copra is a centralised and large-scale operation carried out in metropolitan centres. Hence, it does not match the abundance of available labour in these economies, and offers no scope for participation and development of skills within rural areas.

The key to enhancing demand, and for widespread diffusion of benefits, is coconut product diversification in rural areas, and new markets for existing products as well as new products. There is growing interest at the community level in alternative processes and product diversification. New markets should include the domestic market, including import substitution. Farm-level production of VCO provides the greatest potential to enhance local demand, as it suits product diversification and import substitution. VCO offers immediate access to edible oil, massage oil, medicinal products, liquid fuel, soap and edible meal. These commercial possibilities for coconut oil were denied to coconut farmers for decades, as they were urged and given support only to produce copra for export.

Farm-level production of high-grade VCO provides increased rural employment. It effectively uses an existing, sustainable, renewable rural resource that is available year round. New technologies for VCO are culturally sensitive, income generating, health promoting and greenhouse gas friendly. The VCO industry could kick-start the rural economies of failing South Pacific states and become the means by which the coconut industry can reclaim a significant national role.

Much has been written about the fossil fuel dependency of the Pacific island nations, with the value of fuel imports alone often exceeding the total value of export earnings. Liquid fuel is used extensively for land transport, inter-island shipping, diesel generators of electricity, fishing vessels, motorised canoes, lamps and lighting, refrigeration and some cooking stoves.

As an example, fuel imports are already expensive on arrival in Honiara, Vila or Suva. To this must be added import duty and, when the fuel is distributed beyond the capital cities, the cost of repackaging into 200 L drums. There are also shipment costs to outer islands plus the sales margin at each step in the mar-

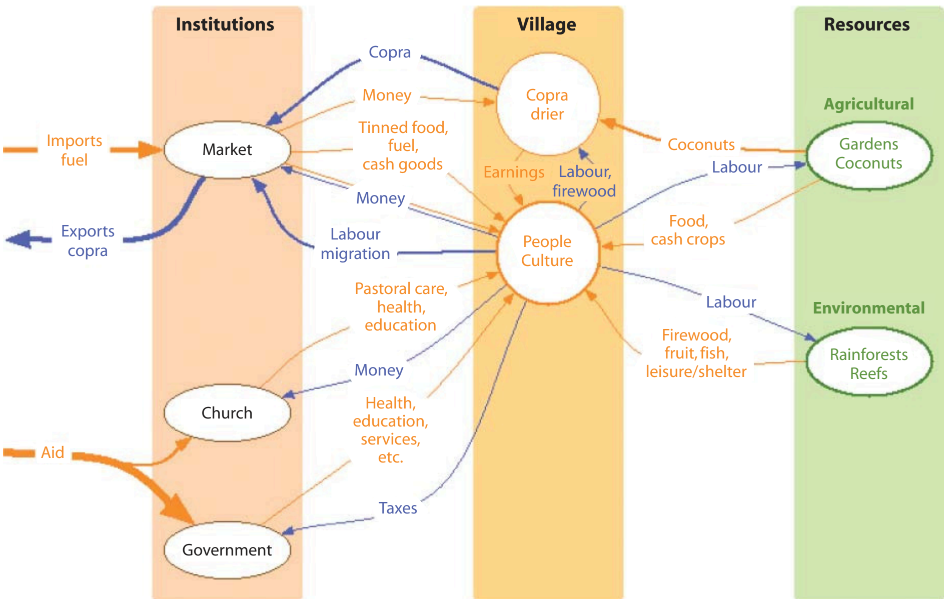

Figure 1. Flow diagram of a current or traditional island scenario of economic activity

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keting chain. The result is a dramatic increase in fuel prices in rural areas.

The impact on price as imports move from the central port to the remote areas is illustrated in Figure 2. Each ring in the diagram represents some change in the mode or form of transportation. For example, the goods may move from ocean-going ferry to wharf to truck to canoe to tractor and trailer. It also shows the increase in the value of export products as they move from the remote points of production towards the port.

The definition of what is 'remote' will depend on the product that one is concerned with and the ease or otherwise of moving it between the centre and the periphery. The price differentials are notional but (in AUS$) they approximated reality a decade ago.

Closer to the current situation is shown in Figure 3. Effectively, whole island nations are becoming 'remote' in the fossil fuel economy as world fuel prices rise.

In addition to the rise in world petroleum prices, many national currencies have devalued significantly in recent years so that in local currency terms the cost of imported fossil fuels has skyrocketed. Now is the time to actively pursue the means by which locally produced coconut oil (CNO) can be substituted for imported fuels.

We have written extensively about the practicality of using CNO as a direct biofuel substitute for diesel and as a blended substitute for kerosene. Coconut oil when pure is a natural biofuel since no chemical alterations have to be made to the oil in warm climates. Also, no modifications need to be made to the diesel engines themselves. The further bonus is that the fuel is non-polluting, with zero net greenhouse gas emissions.

It is an irony that the Clean Development Mechanism (CDM) of the Kyoto Protocol currently excludes tree-crop plantations like coconut, oil palm and rubber from carbon sequestration credits. This is surprising since these long-lived perennial plantations are very similar to forest plantations in the carbon benefits they offer.

While the only major commercial product of forests is timber, plantation crops also give regular harvests of fruit or latex in addition to timber. Thus they provide renewable energies (oil as a substitute for petroleum fuel, biomass and biogas) and substitution products (natural latex as a substitute for synthetic rubber) which make them readily compliant with other CDM projects. Also, in the case of

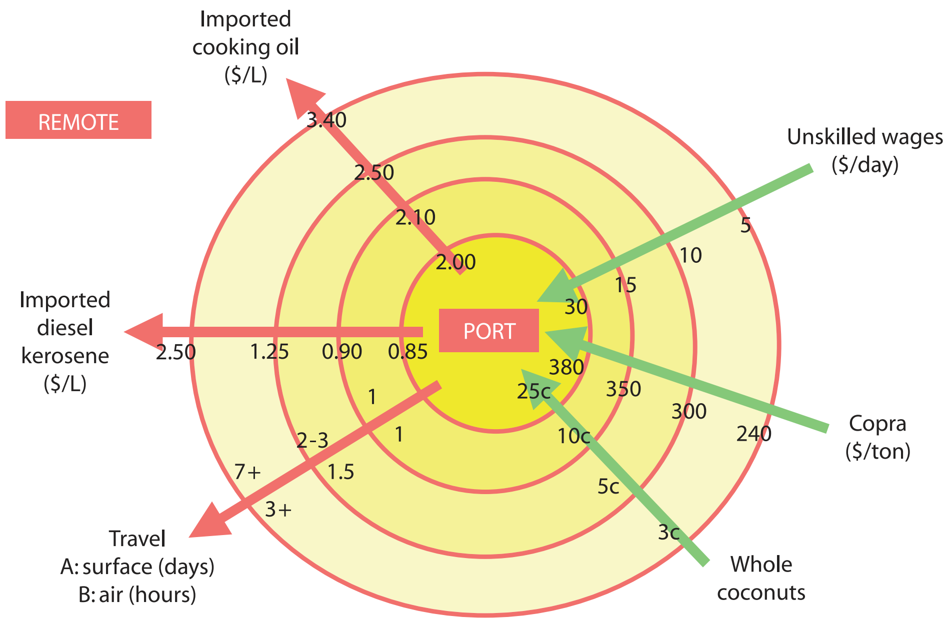

Figure 2. Coconut product trade: price (US$) vs distance from site of production to port, and port to consumer

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coconut, most of the palms are owned by smallholders who comply with other main CDM goals like poverty alleviation and sustainability.

Direct Micro Expelling Technology

The comparative advantage of remote locations is that, in contrast to high and rising prices of imported liquid fuels and oil products, they have low prices of raw materials. The relatively low cost of nuts and labour could make production of CNO for fuel an economic proposition. The key requirement is an appropriate method of oil extraction that can take advantage of this price–cost differential. The Direct Micro Expelling (DME) technology that we have developed offers such a method. DME gets its name from the fact that it is direct in the sense that it 'strikes oil' within an hour of cracking open a nut; and it is micro since it is a small-scale (family farm) operation requiring 4 to 6 adults engaged in expelling the oil. Such units have been producing 30–50 L/day of oil on a regular basis.

The DME process is very easy to learn. It simply involves grating the flesh out of fresh mature coconuts, weighing out a batch and drying it on a purpose-built shell- and husk-fuelled drier, and pressing out the oil in a manual press. DME VCO is a pure, natural and stable final product with a long shelf life. Its free fatty acid level is as low as 0.1%. Given the freight difficulties in remote areas, localised production of final value-adding products should be commercially viable in many situations.

We have helped set up DME units across the South Pacific, including Marshall Islands, Kiribati, Papua New Guinea, Solomon Islands, Vanuatu, Fiji, Samoa and Tonga. Many of the units are isolated and cater for local demand. For example, some are directly linked with boarding schools where the oil is used for cooking, making soap and as a fuel for diesel generators. It is indeed a most versatile oil.

The challenges of DME have included such issues as the equitable sharing of the benefits of paid employment; jealousy of those in leadership at a site and also between families; absenteeism of trained personnel; and discipline in quality control. Such problems are typical teething problems with any new technology. We have found that the constructive sharing of the problems can lead to a village designed

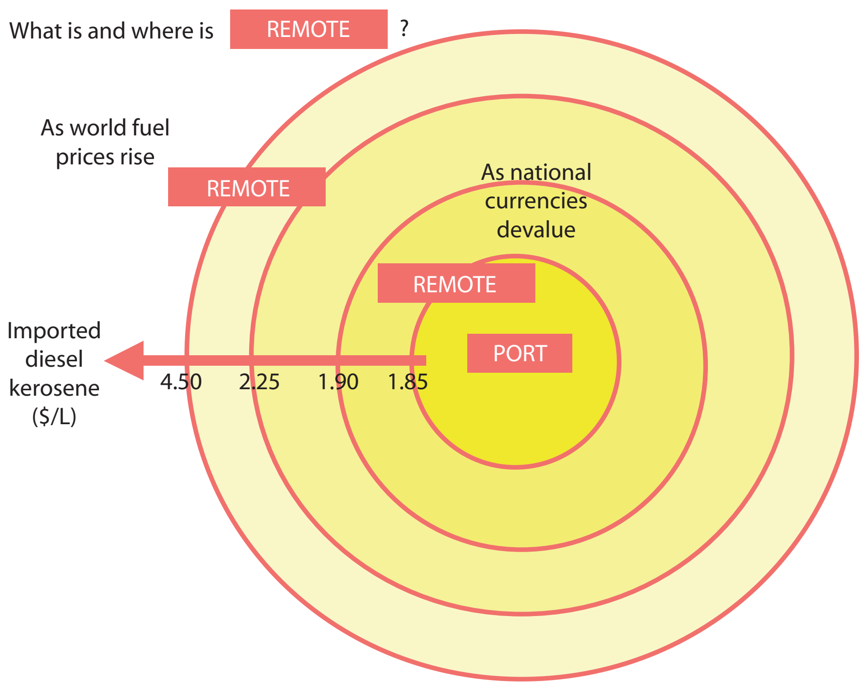

Figure 3. Relative remoteness as mineral fuel prices increase and local currencies devalue

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solution. For example, in terms of the authority of the team leader in the DME operation, a parallel was drawn with the role of a canoe captain who has authority at sea but whose authority ceases once they come back into the village.

Our experience suggests that a successful future for such micro-enterprises requires a focused organisational structure with regular oil collection schedules, payment to producers, quality control, and credit and marketing structures. All of these are critical but it is not clear how they can be provided in many situations. For example, political instability (in Fiji, Solomon Islands, Indonesia, East Timor and Papua New Guinea), poor governance with corrupt and bankrupt commodity marketing boards and development banks, the lack of credit structures for rural income-generating projects, and the environmental impacts of logging and cyclones all militate against the successful implementation of DME. Solomon Islands has provided a worst-case scenario, where, with institutional bankruptcy, came lawlessness, an inability to market cash crops, a collapse of transport systems, plummeting rural incomes, a lack of social services, and an inability to pay school and medical fees. It involved a virtual return to subsistence and barter trade.

In the case of Solomon Islands, we have partnered with a local company to set up a vertically integrated commercial 'DME System' that provides full support services (Figure 4).

The vertically integrated system provides equipment, credit, training, extension, oil collection, quality control, marketing and administrative services. The introduction of the system on three islands in Solomon Islands has had a profound impact on remote communities by providing employment and raising rural incomes, resulting in improvements in health and education. Rural communities are producing extremely good oil in larger volumes than can be absorbed by the local domestic market. Over a period of 18 months, ten DME units have produced about 100,000 L of export grade VCO. About 80% has been exported, earning the country considerably more than AUS$ 250,000. Gaining 'certified organic' status has been crucial in obtaining access to the niche international markets for VCO.

However, marketing of VCO is greatly hindered by the consistent message of The Heart Foundation of Australia that coconut oil is the one vegetable oil that should be avoided at all costs because it is a saturated fat. CNO is condemned as a danger to our health, and yet it is used as the fat in feeding formula for premature babies and for adult patients with compromised digestive systems. The medium-chain fatty acids of CNO are also highly valued by elite athletes. An increasing number of scientists and nutritionists now tell us that VCO actually raises HDL (the good cholesterol), minimises free radicals and has significant anti-viral and anti-bacterial properties (Enig 2000; Fife 2003).

Local and in-country markets for the oil are developing slowly. Sales are being made through rural shops with a 'fill-your-own-bottle' service from the tap on a 60 L barrel. Soap production has started. The oil is being blended with kerosene for hurricane lamps, and it was a major breakthrough when a rural tractor owner began to use VCO because diesel supplies failed to arrive. He has been so satisfied with the result that he says he has permanently switched fuels. Progress is slow because of the limited resources devoted to promotional activities.

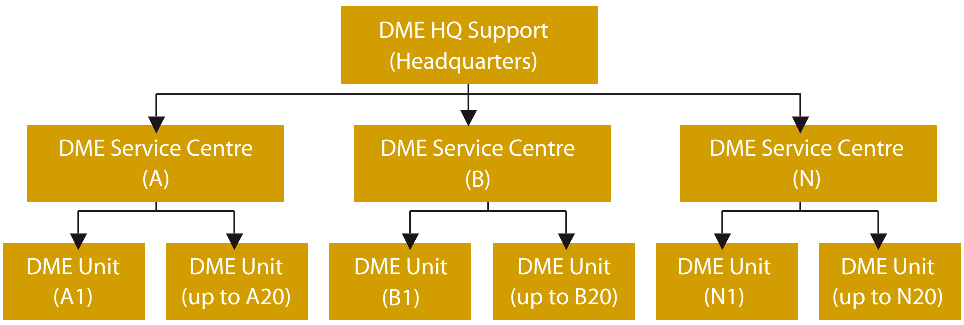

Figure 4. The 'DME System' is a vertically integrated commercial organisation

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Rural electrification becomes a real possibility with locally produced fuel powering relatively inexpensive Chinese diesel engines. Innovative schemes have been suggested using such gen-sets to charge batteries that are hired out and used to power economic LED lights. We have spoken to two companies actively working on a new generation of local diesel-powered, water-jet, mini-cargo vessels for transporting people and goods within protected waters (mainly the lagoons) and for reef fishing.

People have written about the need to 'replant the tree of life' (Persley 1992); others have urged the need to 'rehabilitate the tree of life' (World Bank 1991). I have suggested that we 'reclaim the tree of life' because the resource already exists in abundance (Etherington and Mahendrarajah 2001)! It has the potential to become a veritable sustainable gold mine! A perpetual oil well! The potential future of the islands is portrayed in Figure 5—when their existing, renewable and sustainable coconut resource provides them not only with food and shelter but also with a safe liquid fuel that will bring hope to remote rural communities.

Summary/conclusion

The advent of modern small-scale processing technologies allow for the commercial production of VCO at the farm level. The implications are manifold because VCO is arguably the most useful vegetable oil in the world. VCO has immediate medicinal, cooking, massage, cosmetic and fuel uses both for the local economy and for export. These commercial uses of coconut oil were denied to coconut farmers for decades as they were urged to produce copra for the export market. As the price of copra declined, farmers were less and less willing to engage in the hard and dirty work of producing the commodity. The commercial failures of copra marketing boards were critical. At the same time research institutes focused on long-term crop breeding technologies that had little relevance to farmers faced with volatile and falling prices on world markets. Product diversification and attention to processing technologies drawing on local knowledge and directed towards local demand were largely ignored. Local production of final products is the key to significant improvements in income, health and environmental sustainability for South Pacific nations. This potential is being demonstrated by the DME technology.

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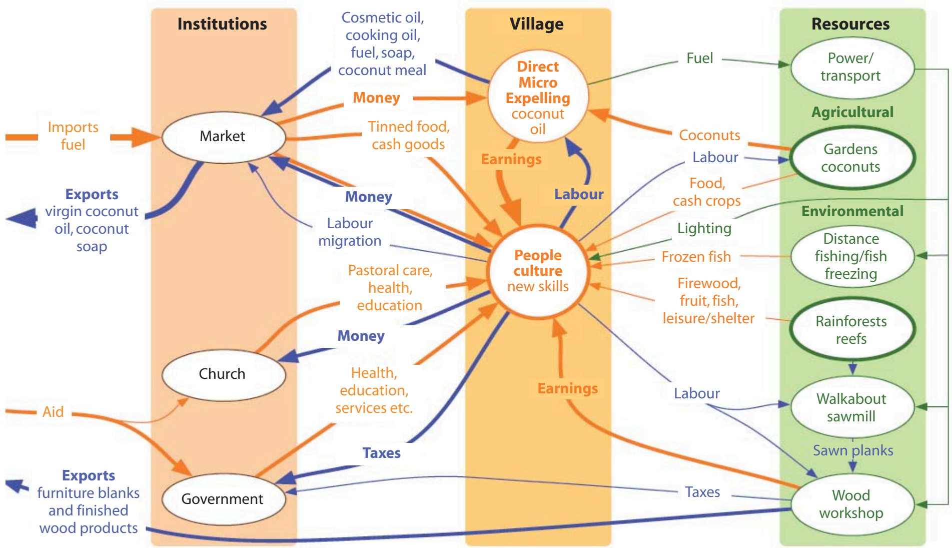

Figure 5. The renewable coconut resource allows for a sustainable development scenario

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Value-added coconut co-products

T.J. Kempton[1]

Abstract

While a great array of useful products are derived from the coconut palm, coconut oil is the dominant commercial commodity. The recent diversion of some interest from industrial end products derived from the oil to interest in the health benefits to humans and domestic animals has opened up limited new markets. Organic Products Pty Ltd has developed a range of stockfeed products based on the residual meal from the process of oil extraction from copra. Sound science and clear technical communication have gained us significant markets in the equine and ruminant feed industries in Australian and international markets. Horses benefit particularly from the low starch content, high fibre and energy from the oil in our product, while for cattle the intake of significant bypass protein is important.

Introduction

The coconut tree (*Cocos nucifera*) is known as the 'tree of life' because of its range of environmentally sustainable uses (Foale 2003). This forum addresses the many and varied uses of coconut, from the smallholder village level through to industrial applications in the modern world.

The coconut industry is founded on producing coconut oil, mainly for industrial purposes. Recent focus has been on the key nutritional benefits of coconut oil on human health (Fife 2003). Although the benefits are known, the world demand for virgin coconut oil is still limited. Apart from coconut oil, the coconut tree produces a range of valuable co-products. Approximately 5,500 coconuts produces 1.9 t pith, 0.8 t coir, 1 t shell and 1 t copra. In turn, 1 t dried copra produces 600 kg coconut oil and 400 kg copra meal, depending on the variety and expelling process used.

Copra meal

Research and development

Organic Products Pty Ltd began researching the nutritional benefits of copra meal in 1984. Feeding trials conducted with cattle and horses identified the unique nutritional benefits of copra meal. All our products are supported by good science. Coconut oil is rich in medium-chain fatty acids, which have major nutritional effects in both humans and animals (Table 1). Horses exhibit a raised energy level and a more attractive shiny coat.

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Table 1. Chemical composition of copra meal (dry matter basis)

Copra meal composition	Proportion/amount
Moisture	<8%
Crude protein	>21%
Oil	<9%
Starch	<3%
Metabolisable energy	12 MJ
Digestible energy	15 MJ
Aflatoxin	<20 ppb

Our company has successfully developed products and large-scale markets for copra meal in the equine and grazing ruminant industries in Australia, New Zealand and America. This success is attributed to having undertaken research and development to produce sound technical information that clearly identifies the benefits of the products. Technical publications have been prepared to provide the research data in a format that can be directly translated to specific markets. For further information see <www.stancegolbal.com>.

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Table 2. Comparison of vegetable oil fatty acid components

Oil type		Carbon no. per molecule	Coconut	Canola	Soybean	Corn	Cotton seed	Rice bran
Saturated	Caprylic	8	8					
Saturated	Capric	10	7					
Saturated	Lauric	12	49					
Saturated	Myristic	14	18				1	
Saturated	Palmitic	16	8	4	11	12	26	16
Saturated	Stearic	18	2	2	4	2	2	2
Mono-unsat.	Oleic	18.1	6	64	23	28	18	42
Polyunsat.	Linoleic	18.2	2	26	53	57	53	37

Key benefits

For horses copra meal has specific benefits because it contains very little starch, digestible fibre and energy from the coconut oil. For cattle copra meal contains a high level of bypass protein and a balanced supply of metabolisable nutrients that supports growth and milk production. The copra meal oil profile is different to that of other oils from other plants (Table 2). Coconut oils are unique because they contain over 60% medium-chain fatty acids consisting of small molecule fatty acids with only 8, 10 and 12 carbon atoms (C8 to C12).

Quality control and packaging and branding

In order to access modern world markets with third world products, it is essential that products are packaged to sell in those markets, and meet the appropriate requirements of the customers.

It is also necessary to develop a brand that is clearly identified in the marketplace. A number of brands were developed including CoolStance for the equine market and CopraStance for the ruminant industries.

Logistics

There are over 1,000,000 t of copra meal produced annually worldwide, with approximately 30,000 t produced in the South Pacific. The product must be milled to a standard quality, packaged to meet modern world market requirements, then shipped to the destination port. The copra meal must be processed, packaged and fumigated to meet the import requirements of the regulatory authorities in the importing country (e.g. Australian Quarantine Inspection Service or New Zealand Ministry of Agriculture Food and Fisheries). The product must then be shipped and available on a 'just-in-time' basis for the animal feed industries. Animals eat every day and the challenge is to coordinate the supply of copra meal to meet the daily demand.

Coir peat

The Australian horticultural industry has been using coir peat as a replacement for natural peat moss for the past 10 years. This product is supplied mainly from Sri Lanka, India and Malaysia. The same issues of product quality, biosecurity and logistics apply to the manufacture of coir products to meet the Australian markets.

Conclusion

The coconut palm provides a wide range of potentially valuable products. To achieve large-scale commercial use, the products must be produced, packaged and delivered to market in a form that meets the market requirements. Copra meal has unique nutritional benefits for animal production, provided that the products meet quality assurance requirements and are backed by sound scientific principles.

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Potential for profitable coconut production in northern Queensland

M. Foale[1] and P. Roebeling[2]

Abstract

Although there is no tradition of coconut (*Cocos nucifera*) production in tropical Australia, there are subcoastal environments where it could be highly productive. On good quality, well-watered sugarcane lands the coconut is potentially quite productive and also could add some environmental amenity to the land. A lucrative market for home-grown fresh fruit could be developed. Technology for processing to high-value virgin oil on an appropriate scale has been refined already for small-island situations, and virgin oil technology might find an Australian niche in some situations. The presence of an Australian-based coconut industry, even on the most modest scale, might help in persuading Australians that coconut is a valuable health-promoting food. Turning the attention of Australian food researchers to coconut would provide an opportunity to redeem coconut oil from its bad reputation, which was constructed solely by competing oil marketers.

Introduction

The coconut (*Cocos nucifera*) palm, which is prominent in the food and trade economies of all peoples located in humid tropical coastlands and islands throughout the world, has a curiously low profile in Australia. Except for the Melanesian peoples of the Torres Strait Islands close to Papua New Guinea, there were no significant numbers of palms growing, and no coconut tradition, among the indigenous inhabitants of tropical northern Australia. While coconut seeds undoubtedly washed ashore in great numbers on the north-east coast of Australia, in particular, those that were not opened by the voracious native white-tailed rat were consumed as fortunate gifts from the sea by the human hunter-gatherers of the region. Any young palms that did become established on less-frequented strands provided a delicious meal of 'cabbage' when eventually discovered. With very few exceptions the coconut palm was absent from tropical Australia before European settlement began in the early 19th century.

During the early settlement period mariners operating in the vicinity of the tropical Australian coast were encouraged to plant coconut palms as a potential source of emergency food in case of shipwreck. Later, missionaries on Cape York planted coconuts for food, to help support settlements of Aboriginal people. Early in the 20th century the Australian Government encouraged some northern Queensland investment in coconut plantings in response to a very high price for coconut oil. These did not succeed as labour for processing was poorly skilled and too expensive, whereas contemporary plantations throughout the South Pacific were highly profitable (Foale 2003).

The dominance of coconut oil in the world market for edible and industrial vegetable oil has long gone, but virgin coconut oil (VCO) derived from cold pressing or biological separation is perhaps fetching a high enough price for local production from the coconut to find a niche in the Australian economy. The perceived need for diversification of products to supplement income from traditional sugarcane lands (ABC TV *Landline*, 3 April 2005) offers a possible opening for coconut to become a component of the production systems of suitable environments in tropical Australia.

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The coconut palm as a crop

The coconut palm is best known in tropical Australia as an ornamental plant that contributes to the atmosphere of tourist resorts and urban streetscapes. There is considerable farming experience that could be drawn upon for the management of coconut as a productive crop, yielding fresh fruit of mid, late and full maturity for various direct-to-consumer markets, but especially for the mature fruit to be processed for oil production.

The Tall form of coconut is best suited to oil production, having more oil in the kernel and larger fruit than the Dwarf form, which produces high-quality drinking nuts. A Tall palm would probably 'deliver' its first mature fruit at 5–6 years of age and reach maximum productivity at 15–20 years, by which time the trunk would be 6–8 m tall. The Dwarf variety bears fruit 1–2 years earlier but gains height at less than half the rate of the Tall. Where temperature fluctuation between seasons is moderate, both Dwarf and Tall forms of the coconut produce fruit regularly, usually achieving 12 or more bunches/year.

The potential productivity of a coconut monoculture depends on the environment, but under ideal conditions, comprising a non-seasonal mean temperature around 28 °C and rainfall around 3,000 mm per year, Tall palms could produce more than 3 t/ha/year of oil and 1 ha of Dwarf palms could produce 25,000 fruit/year. It may be possible to use a simulation tool to calculate the likely yield performance for several different locations in northern Australia, where seasonal water deficit and lower-than-ideal temperature would constrain productivity.

Possible field arrangements for a coconut crop

A Dwarf coconut plantation to produce drink products might well be suited to a monoculture arrangement on land close to an urban market or a concentration of tourist venues. The Tall varieties, on the other hand, could be planted as a companion crop on sugarcane farms, to provide another source of income that could be earned at regular short intervals.

Where the land is to be shared between sugarcane and coconut, strips of palms comprising two or three rows could be planted across the paddock, oriented to provide some protection against the most likely direction of cane-damaging wind. The proportion of land that is to be occupied by the coconut palms would need to be worked out in advance against the predicted value of the two products and the anticipated benefit to the business of having a diverse product base. Coconut rows that occupy one-tenth of the land might be a good starting point. In this case triple rows of palms that occupy a band 24 m wide would be separated by a strip of sugarcane 216 m wide. Closer spacing of the strips might be wise where the risk of wind damage is greater.

Coconut fruit could be harvested simply by mechanical raking and collection from the ground, every 2 months, from a particular section. This time interval carries only a low risk of spoilage of the fruit due to sprouting or pest attack. The palm rows would be 7–8 m apart, allowing for movement of an adapted rake that could direct the fruit into a holding bin. The fruit could be processed on an appropriate scale to yield VCO of high value. As production grew in a given region, the fruit would be delivered to the site of the cane mill, where an industrial-scale coconut processor would operate.

Local establishment and management costs

Establishment

A number of steps would have to be followed if coconut were to be established and brought into production in northern Australia, as follows:

- A specialised nursery is needed to raise seedlings in large poly-bags to reach about 12 months of age. Initially, seeds would need to be imported, possibly as embryos that are transplanted into surrogate nuts. A possible source of high-value embryos could be the coconut research centre on Santo Island in Vanuatu. The cost of raising such planting material to the field-ready stage is not known (at least AUS$25/palm), but the technology for embryo transplanting has been developed by University of Queensland (Samosir and Adkins 2005).
- Early management of the field planting could involve continuing to grow cane between the rows of young palms for 2 years, with a row spacing of 7–8 m. In the absence of an intercrop the ground cover would require regular mowing combined with chemical ring-weeding close to each palm. Cultivation for weed control between the palms is advised against as feeder roots are active close to the soil surface.

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- Young palms are fairly susceptible to attack from the *Brontispa* leaf beetle but simple protection can be provided by applying pesticide to the emerging 'spear' (the youngest frond not yet opened). There is the possibility of other insects such as locusts damaging the coconut leaf and, if needed, there should be robust protection against grazing animals that find the leaf of the coconut particularly attractive. The feral rat and some species of native rat (e.g. the large white-tailed rat) could damage immature fruit on the palm. The best protection against rats is a metal sheet wrapped around the trunk to deny the pest any grip when attempting to climb the palm.
- Depending on the fertility status of the soil, there will be a requirement for addition of fertiliser to achieve the potential growth of the young palm. At the very least some nitrogen, phosphorus and potash will be needed. The amount can be determined by foliar diagnosis, which works very well for coconut. The coconut has a particularly high need for potash; however, this nutrient is vulnerable to leaching, particularly from light-textured soils where rainfall is high. Close to the coast there may be a significant amount of salt delivered in the rainfall, which will increase the leaching of potassium. Fertiliser application is therefore best done two or three times/year, placing it close to the young palm but enlarging the area of application as the palm grows (Foale 2003).
- Tall palms are generally cross-pollinating as the active stages of the separate male and female flowers do not coincide. Both wind- and insect-borne pollen usually abound, so there is little risk of poor pollination where there are many palms together. Fruit set falls in response to the stress of water deficit. Persistent rain for several days can also prevent pollination and cause failure of fruit setting. There is a tendency for the coconut palm to experience alternating periods of high and low yield, as a large maturing crop evidently suppresses fruit set in younger bunches and vice versa.

Harvesting and processing

Appropriate harvesting and processing technology would have to be developed if coconut was to become productive in northern Australia:

- Mechanical collection of fallen fruit is indicated for an oil production enterprise in the Australian context of high labour cost. An interval of 2 months between collection events would be suitable. Climbing or the use of a cherry picker may be economical where there is a market for fresh fruit for drinking.
- The whole mature coconut fruit comprises a layer of shock-absorbing husk surrounding the shell and kernel. The fruit can be transported and handled in bulk, and stored in an exposed heap for 1 or 2 weeks before processing, without loss of yield or quality of the oil. Fruit that has a visible shoot should be separated, as enzyme action of the seedling on the kernel has already affected the chemistry and flavour of the oil. Such fruit could provide excellent pig or cattle feed.
- The most practical processing option for a large turnover involves a feed-race that pushes the fruit lengthways through a band saw. A water jet directed at the centre of the kernel in the half nut lifts the kernel out in one piece. The kernel pieces are then shredded finely and this material is passed through a fluidised-bed drier to a press which extracts the VCO. This is a continuous flow process involving an interval of only a few minutes from fruit opening to oil pressing. Up to 25,000 fruit/shift (7–8 hours), producing about 2,000 L of oil, could be processed with an installation costing AUS$5–6 million.
- There are small-scale options for VCO production, but as these are quite labour intensive they are more suited to a 'cottage-scale' operation. For example, the DME system of Kokonut Pacific Pty Ltd has a potential throughput of 400 fruit in an 8-hour shift operated by three skilled workers. The output would be around 40 L of cold-pressed VCO for an investment in equipment of AUS$1,200 plus the cost of labour to construct the drier.
- In several Asian countries the traditional method of separating the VCO from the kernel is to employ fermentation of extracted coconut milk. The activity of yeasts in the milk at ambient temperature (around 28 ^{o}C usually) breaks down the natural stabiliser that keeps the oil suspended in fresh coconut milk, such that the oil rises to the surface. This appears to be particularly a cottage-based process although large volumes can be accumulated by entrepreneurs to build marketing strength. Quality control, particularly of free fatty acid, would be a challenge where many suppliers are contributing.
- The principal by-products of VCO production are the residue of the kernel following separation of

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80% of the oil during processing, and the husk and shell. In the water-jet process, machinery is provided to hammer the husk and shell and then separate the three components (fibres, coir pith and shell fragments) over a sieve. An air draft allows the shell fragments to fall through the sieve, while the fibre and pith are blown and shaken into separate bins. The shell can be directed to charcoal and activated carbon production while the husk components have horticultural and industrial uses. The pith or cortex goes into potting mixes and the fibre may be used for matting to protect steep landscape surfaces and the edges of road cuttings, besides the traditional domestic matting uses.

- The residual kernel has potential value as human or livestock food. Where VCO has been produced by pressing dried shreds, the residue contains more than 20% oil. If the water content is reduced below 8% this has an extended shelf life. Fine grinding of the residue to a flour-like particle size provides an attractive additive to combine with wheat flour for breadmaking, as well as being successful in many other baked products. The potential for other cooking uses are many for both this fine material and the coarser material direct from the expeller, as has been explored most thoroughly in the Philippines. The high residual oil is a valuable component for supplements in the diet of small children in the tropics, containing high energy as well as a valuable protein content at 10% or more concentration.
- The best-known product from coconut plantations for over a century up to the present is copra, the dried kernel that can be stored and transported for a period of months without significant loss of its oil content. The oil quality may suffer, however, if the period is prolonged, because a small fraction of coconut oil is unsaturated and vulnerable to release of free fatty acids. In addition, the risk of invasion by insects and microorganisms increases over time and these can cause significant loss of oil quality.

Copra can be pressed at high temperature to produce a lower grade oil that needs refining, bleaching and deodorising before it is suitable for conversion to soap, detergent, shampoo or skin lotion. The price of copra at the farm gate is currently equivalent to about AUS$0.25/L of oil. Some farmers selling to a VCO factory are paid the equivalent of AUS$0.40 for the fruit needed to produce 1 L oil, while the VCO from those fruit may be worth AUS$3–4 at the factory door. It is too early to estimate production costs for a large-scale VCO production unit operating in tropical Australia. A notional calculation of the gross return to the farmer, based on production of 10,000 fruit/ha and a price of AUS$0.10/fruit at the factory door provides a figure of AUS$1,000/ha equivalent of coconut palms. This is based on a spacing in field strips that gives 160 palms/ha of land actually occupied by the strip. The factory operator in this case has an outlay of AUS$1.00/L for raw fruit.

Potential benefits of a significant coconut enterprise in tropical Australia

A coconut industry in northern Australia could have the following impacts in this region:

- Sugarcane farmers, whose product is harvested over a few months each year, would have the benefit of a regular monthly flow of income over the whole year from another product. The deep-rooted coconut palm would be expected to extract deeper water from the profile than sugarcane during periods of low rainfall. Replenishment, after a dry period, of the deep soil layers beneath the coconut strips across the paddock would provide increased buffering against early run-off following heavy rainfall. There will be some reduction of sugarcane growth adjacent to the coconut rows but protection of the cane against destructive wind will be a compensating effect of the palms. Even cyclone Larry (northern Australia, 2006) caused only limited damage to the coconut palms in its path, whereas practically every other crop or forest was devastated.
- If coconut products, particularly VCO for the food and high-value cosmetic markets, become a viable component of the Australian economy, the existing misguided aversion of the consumer and health professional to coconut would more readily be broken down. When coconut is a home-grown commodity, the consumer might become more sceptical towards the negative message about the effect of coconut on health that has been promulgated by marketers of rival food oils. Production within Australia is unlikely to expand to anywhere near the potential demand for coconut once its reputation has been restored, such that demand for imports of high-quality coconut

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products from our neighbours is also likely to increase substantially.

- Australian food-science research would become more open to investigating the benefits of coconut in the diet, and less likely to accept at face value the existing bad reputation. A home-grown industry would also be in a position to contribute to basic study of the benefits of coconut oil that are currently buried in scientific journals published in other countries.

Conclusion

Ecologically, the coconut palm would be quite productive on good-quality sugarcane land in the coastal wet tropics of Queensland. Diversification of their production base might appeal more to hard-pressed farmers than leaving the industry to adopt another production system (e.g. bananas) that is more risky.

The lack of a coconut tradition in Australia makes it more difficult for farmers to consider the prospects for this crop, indicating that concerted research is needed to develop low labour technology and to demonstrate the financial viability of coconut as a new crop.

Adoption of coconut as a commercial crop would assist in liberating coconut oil from the false negative image that has been forced upon it by rival vegetable food oils, particularly soy, thereby enabling the market for coconut foods to grow in the community.

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Urban coconut management by Townsville City Council

J. Roach[1]

Abstract

Coconut (*Cocos nucifera*) palms are synonymous with the tropics and are seen as a valuable asset for tourism and its associated revenue by the Townsville City Council. However, falling nuts and fronds pose a safety risk that requires management. Townsville City Council has over 1,000 coconut palms to manage. The location of all palms is currently being mapped during compilation of an inventory of street trees. Routine management is focused on achieving 6-monthly denutting and frond reduction programs. Unsafe trimming practices and options for mitigating damage from pests, disease and injury associated with palms are presented. No traditional spikes are allowed to be used when climbing coconut palms in order to minimise later decay. Some replacement planting is done using Dwarf coconut varieties that are expected to pose a reduced risk to the public.

Introduction

Coconuts (*Cocos nucifera*) say 'the tropics' to tourists and surveys show that people come to northern Queensland to see the Great Barrier Reef or 'to lie under a coconut palm'. The largest concentration of coconuts in northern Queensland is around Townsville, Cairns and Port Douglas although nut-bearing palms are also found as far south as Hervey Bay. Palms and coconut palms are a particular feature in tourist-based promotions for these tropical locations (Tucker 1988). Thus, coconut palms are seen as a valuable asset for tourism and its associated revenue by the Townsville City Council (TCC).

Coconuts and the City Council

Coconuts are the first line of defence, in a civil engineering sense, as they retain the foreshore and are more attractive than rocks. However, there are issues to do with public safety as coconut fruit can fall from the palms, often at random and silently. If they hit, they can kill or seriously injure a person or severely damage property. Globally, approximately 150 people are killed annually by falling coconuts, and many more are seriously injured. In comparison, sharks attack approximately 50 people/year globally and kill on average 10 each year.

Coconuts are key features of both tourist precincts and major public open spaces where the public and asset exposure is often high. Coconut palm maintenance issues include:

- minimising the potential litigation that may be caused by falling nuts and fronds
- keeping sites tidy
- ensuring that palms are kept healthy
- ensuring that palms are kept aesthetically pleasing.

The challenges for the TCC include keeping accurate records of where all the coconut palms are on Council-controlled land, which is achieved by computer mapping and undertaking regular safe and adequate denutting and frond removal programs. The main issues are that clearly defined standards are not available, there are few skilled tradesmen available to help mind the palms, and a number of unsafe practices are also possible. These include:

- failing to remove sufficient lower frond growth
- leaving long frond and fruit stalk stubs on the palms damaging young growing fronds
- failing to remove all stages of nut growth
- failing to provide a support structure for the lower fronds
- the continued use of standard tree climbing spikes.

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These common shortcomings can result in sizable projectiles becoming dislodged and falling between maintenance visits.

Management

To maximise safety and longevity of the TCC coconut palms a number of potential problems have to be dealt with (Tucker 1988). The damage to trunks, by the use of traditional gafs or climbing spikes for nut harvesting activities, has to be kept to a minimum as it affects the structural integrity of the palm. The physical damage caused can lead to water collection and then to fungal and bacterial invasion. In addition, the excess removal of fronds increases the chances of pest infestation in the crown.

The TCC has to be aware of the signs and symptoms of decay and then rapidly respond to prevent the introduction of new pests or diseases (Uhl and Dransfield 1987). Quarantine and vigilance is part of this prevention strategy. Such maintenance allows the TCC to provide healthy coconut fruit for certain cultural events and festivities.

One option for minimising coconut fruit and frond drop includes the total removal of palms when they can no longer be safely maintained. However, it is more common for a regular denutting activity to take place. This procedure can remove the 80–90 nuts that are formed on each flowering branch. The nuts can start falling from palms when they are only 6 months old, at which time they are already as large as a fist. The rapid expansion in fruit size occurs 5–6 weeks after the 6-month-old mark. Because the public's safety from falling nuts can only be guaranteed for a period of 6 months after the previous denutting activity, this maintenance has to take place twice a year.

There are several means for capturing nuts. These include the Coconet® (<http://www.coconet.net.au>), a net-like object that is clipped to the tree, under the fronds, and is able to entrap the falling coconut fruit. The trapped nut or nuts are then guided into a basket which can be lowered at the discretion of the owner. However, this option has not been adopted due to the look of the product and some maintenance concerns.

The use of Dwarf coconut types to lessen the risk of falling nuts has been adopted in some locations. As these varieties do not grow as tall as regular coconuts and many produce smaller fruit, they are easier to maintain and thus the risk is reduced (Foale 2003).

Summary

In summary, the TCC takes care of a maintenance program which removes nuts and fronds from its palms. The yearly coconut contract to denut and clean old fronds from palms on the foreshore is awarded to a local competent operator. In these foreshore areas no climbing of palms using traditional climbing irons or gafs is allowed. On The Strand coconut denutting takes place three times each year due to the high site usage by tourists. Annual denutting occurs in suburbs, where their retention is generally discouraged.

In other non-tourist areas active removal of coconut palms is undertaken to reduce the cost of maintenance to the TCC. Coconut palms under powerlines are also removed and, in some locations, tall palms are replaced with Dwarf varieties to aid maintenance. TCC is also actively researching new techniques and technologies for maintaining and determining safety indicators for planted coconuts.

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A regional outlook on the potential of the coconut market with special reference to sustainable socioeconomic empowerment of island communities in the South Pacific

A.B. Lombardozzi[1]

Abstract

This paper relates lessons learnt in the implementation of a business model focused on economically empowering island communities by creating an alternative route to the international niche markets of organic and fair trade commodities. It identifies entry principles and assumptions, development outcomes, and caveats and lessons for niche products sold in what is still principally a commodity market. A base model for the integration of coconuts into the fair trade market is proposed.

Seven years of hindsight, defining the perspective

I hope that a brief outline of the history of African Pacific (AP) Pty Ltd over the past 7 years will provide some insight into what defines our company's perspective. Our mutual aim, in general terms, is to bring the potential of the coconut (*Cocos nucifera*) to the world stage and, more specifically, to highlight its potential as a vehicle to alleviate rural poverty in island communities of the South Pacific (SP) (Batugal and Oliver 2004).

The rationale behind setting up AP was to create an independent development agency, passionate about and dedicated to the social and economic empowerment of island communities in the SP. The initiative was set up as a practical application of academic work in development and resource economics. Having identified the particular trading history of the SP, the region was seen as an ideal testing ground for the model. The challenge was, in the first 7 years, to focus predominantly on the gifts of coconut, the 'tree of life' (Foale 2003).

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From the outset, the intention was to model the initiative as a vertically integrated social ecosystem. That is, a business model or economic system similar to its biological counterpart that gains its strength and resilience from its complexity and biodiversity rather than from simplistic linear systems that predominate in our present economic world; a system in which fair trade principles are accepted as the basic processing software in creating an organic economy; a society of ethical exchange based on social and distributive justice.

African Pacific was primarily seen as a service provider for communities in the SP. We wished to engage in trading relationships that focus on bringing products, specifically coconut and other related tropical commodities, to the market and allow participants to use the structure as a ladder for self-empowerment in the market. The principle was to create an organic structure that would allow and encourage communities to participate at any and every level, from selling whole nuts to production and processing of value-added products, distribution, marketing and branding.

African Pacific was registered as a Pty Ltd company primarily to show the difference that a corporation can make in alleviating poverty at the bottom of the pyramid through building bridges from the communities to the consumer. To underline and

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entrench this ideal, an ethical trading charter was incorporated into the company's articles of association. Our 'fair trade for a fair go' charter acts both as an indication of our intention and a guide for our engagement with partner producers, as well as a yardstick for our public accountability.

The pinnacle of the structure would be represented by a pan-Pacific certified organic, fair trade food and skincare brand. The aims of the brand were the following:

- We aimed to showcase to the world the possibilities of the 'tree of life' and virgin coconut oil (VCO) as well as the stories of our partner producers in the different regions. Our assumption was that if we could engage directly with the customers and tell them the 'Pacific coconut story', then, however small, we would at least be seeding its potential in the market.
- The second assumption was that, on a retail level, businesses have an innate need to adopt new products for their own corporate survival. Presenting quality retail products to the market would 'inevitably' lead to deeper and wider market integration, both through the pan-Pacific brand and potential partner brands.
- Through sales at both wholesale and retail levels, we would create an important 'in-house' demand for coconut products that would give our partner producer at least some form of volume and price stability over time and, in the long term, create capital value through brand equity.
- By creating a brand-story (Pacific, coconut, organic, fair trade) instead of a brand image/name, we hoped we would be able to transcend the orthodox marketing philosophy of 'one brand one market' and present the Nui range as a brand in both the functional food market as well as the lucrative skincare industry.
- Traditional saponification with coconut oil to create an organic surfactant was particularly focused on within the skincare market. The advantages were seen as twofold: expand the possible demand base for VCO, but also accept and productively integrate lesser qualities of VCO and allow production partners to 'learn as they go', without the consequences of financial loss if quality indicators were not initially achieved.
- The brand would have further important roles to play in the model's structure, communicating to participating communities better market–price information, and allowing them to bargain from a position of knowledge and hopefully strength.
- It was hoped that most partner producers, over time, would move through the structure and become economically independent, thus allowing the brand, at least in the long term, to protect vulnerable partner producers in the SP. This is because they, given size, capacity, location, etc., are locked into a difficult and marginal trading scenario.

Additional assumptions in achieving development outcomes

There are a number of additional assumptions that have to be made if development outcomes are to be reached:

- The economic rationality of our 'homo economicus' in the model must be judged in accordance with all possible opportunity costs, of which traditional cultural values are not only valid criteria, but most likely are also the most important and costly ones.
- A rise in price of the whole coconut at the farm gate will be the greatest catalyst for the rehabilitation of the 'tree of life', and would have a strong impact in alleviating rural poverty.
- The usefulness of innovation is only found in its application.
- The inverse of Say's Law is the valid catalyst for production in relation to development goals: demand creates its own supply.
- Organic growth remains a virtue of sustainability.
- Nothing breeds success like success and, more dangerously, its inverse.

2005: Status quo: African Pacific estimates

Production in the South Pacific

In 1998 hardly any VCO was being produced in the SP. Until 2002 there was limited production, mainly using the Direct Micro Expelling technique (see Etherington 2006 in these proceedings), of around 20–30 t. In 2003 there was stop–start production in the region, with Wainiyaku Estate in Fiji delivering its first certified organic coconut oil, with total production for the region being no more than 100 t. Production of around 250 t was achieved in 2004, of which 150 t

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were organic, and in 2005 annual production is assumed to be just over 350 t for the region, with possibly 250 t being organic. In 2006 there should be a strong increase in production of VCO, especially if the new mechanised production process in Vanuatu is successful. The planned outcome for this operation alone is around 600 t of non-organic VCO annually, with many more producers planning to come on board.

Virgin coconut oil as a functional food

The specific marketing of organic VCO from the SP under the Nui brand has made Australia our largest market for food oil, followed by the United Kingdom (UK; albeit with a partner brand) and smaller markets including New Zealand, Malaysia and South Africa. VCO comprises around 40% of our sales turnover. At present we assume to be holding a dominant position in branded product both in Australia and UK, but this will change rapidly with the influx of new product from overseas and the SP region. We are awaiting with interest the impact of the new trend of flavoured VCO from the Philippines.

The entry of new brands into the Australian market, both from the region and outside, is starting to create downward price pressure on retail prices for VCO. However, we assume that the market still has more room for growth, especially if the new entrants focus on marketing and educating the retail customer. The relatively small size of this market has, so far, been a natural entry barrier for large volumes of bulk product to the food industry.

The European market has potential, in its northern and eastern countries, both for bulk and branded product. We are hopeful to make some inroads into this market through launching an expanded Nui food range from the SP in Europe in February 2006.

The United States of America (USA), in our opinion, remains the largest world market for both bulk and retail, but it is extremely price driven given the volumes of production from the Philippines, Indonesia and Sri Lanka. At present around 50% of our production in Fiji is brokered into the USA market. Our entry into the USA retail sector is being planned for 2006 with a certain amount of nervous anticipation.

Organic skincare

African Pacific was determined to research and design an innovative organic process of traditional saponification that would allow us to develop a range of new bodycare products under the Nui brand and for contract manufacture. This, in turn, would create a new demand source for VCO in the annual US$1 trillion international skincare market.

The successful development of an organic surfactant based on VCO has, as it was hoped, presented a new market to us. We are able to market the virtues of VCO in multiple formats, thus moving away from VCO in a bottle to 24 different products, each containing the minimum oil that could be extracted from one coconut.

African Pacific now supplies five partner brands with either VCO, organic surfactant or our services as a contract manufacturer using our base products. These raw materials are also exported to processors in Europe and the USA. After less than 1 year in commercial production, the skincare sector of AP has now, as expected, started to dominate internal sales, with 60% of turnover in the last quarter. Although food sales still retain around 60% of our VCO volumes in general, the return on investment in relation to skincare is much higher and less volatile than in the food sector.

We believe that our primary growth in the next few years will come from the value-added skincare sector, giving AP the margins to expand its development program to other tropical commodities such as cocoa, coffee, high-value essential oils and vanilla, and taking pressure off the production of VCO as a development tool. This is fortunate timing, given the fact that the first signs of a glut in the regional market are starting to appear.

Development outcomes

Judging and defining development achievements is always a difficult task, especially within these early stages of the business model—a young brand and a very fluid market. The outcomes outlined below are drawn from, and based around, the original aims set out earlier in this paper, namely:

- AP is successfully creating, in Fiji, with our present partner producer Wainiyaku Estate and the assistance of Coconut Industry Development Authority (CIDA), a vertically integrated structure that may act as a living model for the potential rehabilitation of the coconut industry in Fiji and the Pacific. We are producing organic VCO from the plantation and wild harvested VCO through purchasing coconuts from surrounding communities using a fair trade pricing model. The

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impact of this on the local economy in Taveuni has not been insignificant. The addition of partner producers in production and packaging in Fiji have benefited urban and peri-urban communities.

- The growth of the Nui brand is achieving our commitment to make Wainiyaku Estate sustainable and give AP the ability to diversify into more markets with more products. This is giving stability to the brand and thus hopefully to our new generation of partner producers, both in VCO and other products. A diversified range of development initiatives should create a stronger, better and more solid platform for social and economic empowerment for island communities.

As a founding member of the Fair Trade Association of Australia and New Zealand (FTAANZ), the National Initiative of the Fair Trade Labelling Organisation (FLO) in the Asia–Pacific region, AP has accepted the mandate to model a fair trade pricing policy for the coconut industry, which is presently in circulation for comment. This pricing model is the de facto policy for all processors who wish to supply AP with VCO. We believe it can have a major impact on economic development at the 'bottom of the pyramid' should it be accepted as the common denominator for coconut oil pricing in the SP. It can also be the foundation for a policy that will allow products from coconuts to be accepted as fair trade input in the emerging market of fair trade products around the world.

Fair trade pricing model in the South Pacific: brief outline

The underlying principles for the creation of a 'fair trade' model in the coconut market are as follows:

- attempts to use the fair trade pricing system as a policy base for a true valuation of the coconut resource, thus seeking to re-establish the coconut industry as a community-based activity
- allows the introduction of a standard that is easily accessible, inclusive to all community resource owners, and allows integration into the system at the primary level while still receiving fair return for the resource
- values the entire coconut (mature whole fruit) as a complex commodity instead of only valuing the dominant traded commodities—copra and crude coconut oil
- accounts for labour and traditional culture as part of the opportunity cost
- is based on established pricing criteria that allow price comparisons with the world market (in US$) as well as local (island/local economy) currency price structures, thus allowing for flexibility in different regions and easier communication with and integration of local producers
- acknowledges that the concept of a fair trade pricing model for coconuts would still require an additional fair trade premium to be paid to a collective/cooperative of growers for social development projects. The calculated premium would be in addition to and independent of the fair trade price.

The consequences of operating the model are as follows:

- Economic rationality as well as economic reality have shown that the prime motivator for the continued cultivation, maintenance and expansion of coconut groves is price. The implementation of the above policy would, in the long term, secure a re-engagement of communities in the coconut industry.
- The establishment of community-based cooperative structures should, in the longer term, be able to create economies of scale, allowing for direct community niche market exports of value-added coconut products, and understanding that demand for such products is still limited.
- However, the possibilities of using a fair trade standard to encourage/influence an improved mechanical production of copra to improve cash returns to the community, while taking advantage of a far greater international market demand in the copra / crude coconut oil market, should not be underestimated for a region such as the SP.
- Where possible, fair trade operations should encourage additional value-adding through certified organic status to gain additional premiums.

'The tree of life' economic development and poverty reduction model

Fundamentally, it is our opinion that, as in economic theory, the coconut industry has not come up with anything new in the last 200 years. This must of course be seen in relation to more than 4,000 years of documented history for coconut oil.

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The geopolitical and economic area of the SP, including Australia and New Zealand as its main markets, represents in its own right a smaller version of the world market, and thus learnt experiences can be extrapolated for the global market. The only significant difference is that the SP region, given its special characteristics, will seemingly always remain the loser within the global market, based on competitive and comparative disadvantage.

All coconut products continue to suffer from classical price/value impediments of market undervaluation. The 'market' continues to hold a bias in discounting a potentially abundant crop, originating from tropical/developing economies with large volumes of relatively cheap labour and infrastructure, complemented with a competitive supply side.

The stagnation of the coconut industry over the last 60 years has probably had a significant impact in creating rural poverty in real terms or at least maintaining it. The development objective of alleviating poverty and creating social and economic empowerment has yet to be realised. Given the volatility of price and demand in the past, the question needs to be asked: 'Does the expansion of the coconut industry on a commercial commodity level structurally impede or even exclude the goals of poverty reduction globally and specifically in the SP?'

All present-day production technologies for VCO have the potential to produce a similar quality product and can be available to most producers, eliminating much of the comparative or competitive advantage through technology in production. The greatest market advantages for producers thus remain economies of scale and lower cost of accessing logistical infrastructure.

The production of VCO over the past 7 years has stimulated the mechanisation of production in some form or another to achieve consistency of the required quality indicators. Thus, in an attempt to boost production at the bottom of the pyramid, there would have to be reasonably large requirement for capital investment in the production system as well as expenditure in infrastructure. This, together with maintenance costs, could act as a strong barrier to entry into production and an impediment to its long-term sustainability for smaller community producers.

Virgin coconut oil, with its relatively high value to volume ratio, can act as a catalyst or bridge for community development, but does bring with it certain logistical complexities on larger volumes that can create negative economies of scale in remoter communities. The problem is that although you may be moving product, economic growth is largely based on a return on labour and not on capital growth. Given the dedication that is required for the production of VCO, especially certified organic, an abundance of potential labour is required to maintain income revenue from the project. Given the fact that communities historically operate larger garden economies, of which coconut is only one crop and not necessarily the dominant one, these factors have to be taken into consideration when looking at the possibility of remote community production.

It also has to be remembered that, assuming a change in demand, in relation to poverty reduction, volatility in larger volumes, albeit at higher prices, can still be more destructive to economic empowerment than lower but consistent prices in smaller volumes. An increase in demand alone may not have the desired impact on poverty alleviation.

Organic certification and fair trade are both niche market structures that can be advantageous for those producers that have the size, location and, most importantly, administrative capacity to carry either or both certifications.

Australia, in relation to the world coconut industry, has played and continues to play a significant role, not only in supporting research. Thanks to the Australian lamington, the nation is the largest per capita importer of desiccated coconut. Copha also plays its part, with the processing industry importing both refined and crude coconut oil in volume. A large amount of husk derivatives are also imported from Sri Lanka by the horticultural industry. In relation to VCO, the market has been a relatively early adopter of organic VCO as a functional food, as well as for organic skincare. However, it is safe to say that less that 1% of this total volume is imported from the SP.

In relation to these facts, the creation of a coconut industry in Australia (see Foale and Roebeling 2006 in these proceedings) cannot at this stage be seen as a valid economic initiative. The following question needs to be asked. 'Where do Australia's comparative and competitive strengths lie in relation to the coconut industry?' In our opinion its strength continues to be as an extension service to the SP—in research and development, especially in relation to plant disease technology; in its potential for creating awareness and partnerships with SP producers; and most importantly in creating demand. However, the idea of a 'Coconut World' theme park, based in the beautiful heartland of tropical Queensland and acting

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as an educational showcase for the 'tree of life' and the SP, would have our unreserved support.

Conclusion

Coconut should not be seen in isolation when seeking to reduce poverty in relation to small community production in general, or in any specific form of production, in the SP. The potential of the cash crop needs to be seen as part of a portfolio of micro-agribusinesses that communities may hold. These may include cross-cultivation of high-value crops in garden economies, a potential source of timber, a companion crop for vanilla and beef, and a source of raw materials for handicrafts.

The question on everybody's mind is, and has been for the past 60 years: 'Will demand increase and bring with it a structural shift in price?' In some tacit form, a hopeful and positive YES to this question is hidden in the title of the forum: The coconut revival: new possibilities for the 'tree of life'.

However, our assessment is that although we may see an increase in demand for coconut oil and VCO, and invariably some price increases due to changes in the fats and oil industry, this is far from identifying an underlying and permanent structural shift in the demand curve. Even if such a shift was identified as permanent, it could be moderated or even negated in relation to price given the competitive supply side of the industry and the possibility of substitutes and similar products.

Any present revival, whether based on demand, product or price, must be assumed to be cyclical, at least in real terms, given the nature and history of the industry. The consequences in terms of development and poverty reduction are clear—make hay while the sun shines—especially in the SP.

Making 'hay' means, from our point of view, creating sustainable demand at fair prices that will filter through to the growers, and using the opportunity of engagement for building capacity through long-term business relationships and diversifying products to buffer overall growth. Our experience has been that island communities are more than capable of successfully bringing product to the market given the opportunity and the right information. Our primary responsibility must be to build the bridge to the international market, especially from the SP.

It has been an inspiration to see the market and the potential grow over the years, and although the way forward will continue to present many issues for the SP region in particular, we remain confident for the future. We will be able to play a part in bringing the virtues of the 'tree of life' to the market, while balancing this with our primary objective of sustainable social and economic empowerment of our partner producers. For this we remain extremely grateful.

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Coconut World: an opportunity for northern Queensland

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Abstract

The coconut, as an ornamental palm, is inseparable from the image of the tropical beach and an idealised lifestyle in the eyes of the modern tourist. In addition to the atmosphere of languid relaxation and self-indulgence evoked by the palm, there are possibilities for more engaging experiences connected with the many foods and drinks prepared from its fruit, as well as the activities associated with the harvesting and processing of its fruit, and the production of curios and other items derived from the 'tree of life'. The creation of 'Coconut World: an agriculture-based theme park' is a feasible project for northern Queensland because this location has a well-watered hinterland and many tropical beaches that are good for both attracting tourists and for the growth of the palm. In northern Queensland there is already a strong connection of coconut with people and tourism. While the coconut was never cultivated by the early inhabitants (Aborigines) of the mainland, there are relics (ancient palms 30 m tall) of plantations set up 100 years ago, plantations that never retained their profitability in copra production as the price of coconut oil fell and the price of labour rose. A venue such as Coconut World could not only showcase the palm, but also demonstrate the procedures for preparing coconut cream, virgin coconut oil and the many forms of food and drink that come from its fruit. This would have strong tourist appeal. In a more expansive concept Coconut World could become a major tourist attraction for entertainment and education. The park would comprise an extensive collection of coconut varieties of global significance, an attractive landscaped plantation and beach, and various products and services. There would also be activities and shows related to coconut for tourists to enjoy and participate in. The visitor could see the wide variety of palm types and fruit in the field; the tools and techniques required for harvesting, dehusking and extraction of the raw materials; and then a range of techniques and processes that are used in the creation of value-added alternatives to traditional coconut foods and drinks. Coconut World would be created so that any profits generated could be used to support coconut research and development and education. Such work would provide indicators to possible investors within Australia or overseas as to the future commodities that could be produced from coconut. The park would also be part of promotional and education activity to improve public awareness of the benefit of coconut to the environment as compared to other replacement crops.

Introduction

Coconut (*Cocos nucifera*) is one of the most important crops in the tropics. It is grown by more than 11 million smallholders on approximately 12 million ha in more than 90 countries. More than 80% of the global production comes from Asian and Pacific countries which are in the 'Australian region'. Coconuts also grow well in moist tropical regions of Australia, particularly in northern Queensland. In fact some plantations were established in the past but later abandoned for economic rather than ecological reasons.

Because coconut provides many useful and diverse products for the local people, the palm is widely known as the 'tree of life'. The many uses of the palm include the production of drinks, foods, stock feed and craft items from the shell and fibre, and other ritual or religious items. Most of the products are for sale on the local market but some are for made for export, and income generated in this way is signifi-

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cant for some countries such as the Philippines. In addition, coconut has the potential to contribute to a profitable tourism business for local economies.

The tropical symbolism of coconut has been extensively used to promote tourism in northern Queensland and to some extent in the Northern Territory. In these regions palms are maintained as ornamental trees in parks, on street margins and in tourist resorts. Several distinct dwarf coconut varieties were introduced to the Townsville Palmetum in the 1990s from Solomon Islands to meet the growing interest in planting coconut in regions of northern Queensland frequented by tourists. Regular denutting and cleaning of these palms are necessary to prevent injury from falling fruit and fronds. This practice causes distortion of the palm's crown, making the trees less visibly attractive.

Despite the strong association of coconut with tropical tourism in northern Queensland, its potential in this sector has not been fully exploited. The idea of 'Coconut World – an agricultural theme park' (Samosir et al. 2004a, b) aims to build on this concept, particularly near Cairns, where the tourism industry is likely to continue to grow rapidly. This paper highlights the concept of Coconut World and how such an approach could be applied in northern Queensland.

Coconut—the palm and the farmer

There is no doubt as to the value of coconut to the various communities where it is grown. It has many uses, from food to non-food, from industrial to household products. The items produced, to mention but a few, include oil, copra meal and coconut water; ingredients for confectionery, chocolates, desserts and authentic Asian dishes; and charcoal, wood and handicraft items. About 70% of these coconut products are consumed or used in the producing countries, while one-third are exported and include copra, coconut oil, desiccated coconut, copra meal, coco chemicals (from the fractionation of coconut oil), activated charcoal and coir (Rethinam 2004).

Coconut has a very long and close history with human society, which has promoted its planting and ensured its prosperity in many tropical islands and coastal regions. The ability of the wild-type coconut fruit to survive for approximately 100 days floating on the ocean (Anonymous 1955) led to its wide natural dispersal several million years prior to human colonisation. Subsequent human voyages completed its dispersal to virtually every suitable habitat on the planet, most notably to the tropical coasts lapped by the Atlantic Ocean.

Coconut has become an important component in many kinds of farming systems, transformed from its most common niche in the fragile coastal environment. In such farming systems it can play a crucial role in providing ecologically sound and sustainable production through longevity and the protection of soil from erosion. The negative impacts in annual crop production caused by soil tillage and chemical use are reduced or absent in coconut cultivation. In addition, not many other perennial crops can grow well on semi-exposed coastal areas with high salinity as can coconut.

The coconut palm is also well suited to mixed farming systems and has been used this way for millennia. Intercropping, underplanting and grazing are some of the methods that can be applied to coconut production to make the farming system more profitable. Some of the more popular intercropping species are cocoa, ginger, black pepper, vanilla and pasture grasses.

The coconut palm, in association with the tropical beaches where it grows, attracts many tourists from around the world for extensive periods of holiday. The palm has become a symbol of relaxation and is used extensively to promote the idea of romantic, indulgent holidays in the sun, which are particularly attractive for people living in the temperate regions of the world.

Apart from its universal image in the tourism landscape, exhibiting the great variety of products derived from all parts of the palm will further enrich the tourist's experience. Such products could include fresh fruit drinks, cocktails, ice cream (all possessing the distinctive coconut flavour); health and beauty related oils and lotions; and handicraft souvenirs.

The tragedy for the coconut farmers is that the potential value of coconut does not reach them and they remain trapped on a low income. The problems they face are very complex and cannot be solved unless an integrated approach to improving their farming lifestyle is taken. Present day coconut fruit productivity is declining, caused by the ageing of palms planted 50 years or more ago, the use of unimproved varieties of coconut, attack from pests and diseases, and decimation from droughts and typhoons. In many parts of the tropical world palms are being neglected by farmers because of the low income potential, and the ageing trees are being

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replaced by other cash crops. Thus, coconut is declining in popularity in the environment where ecologically it does best.

Coconut farmers have very little access to the recently developed processing technologies that could open up markets for new, high-value coconut products. Instead, they are locked into exporting the lowest value product, copra. Since most of the production of coconut is on smallholdings of approximately 0.5–4.0 ha of land, the establishment of any new processing technology will need to be done under a cooperative scheme, which is difficult to set up. One issue here is maintaining quality control, which cannot be easily imposed without external support and good organisational skills among the farmers.

The lack of adequate marketing and promotion of coconut and its products in the industrialised marketplaces is another constraint on the development of new coconut industries. Resource-poor farmers are precluded from undertaking such tasks. In addition, the relevant marketing boards and corporations seem unable to play significant roles on behalf of the subsistence farmer in this process of marketing and processing.

Coconut in Australia

Is coconut native to Australia? This question is debatable. Aided by a thick husk and a rugby-ball shape, the fruit of the wild coconut can retain viability up to 4 months while floating on the sea (Edmondson 1941), during which time it can travel up to 5,000 km (Anonymous 1955). This means that coconut has been carried by the sea to many far-off shores, certainly including Australia, long before human intervention to disperse it further. However, since the arrival of the first European settlers and for 60 years later, there were no reports of coconut palms being found on the thousands of kilometres of Australia's tropical mainland shores (Foale 2003). The reason for this absence is still not clear. Nevertheless, there was a Dutch report on large numbers of coconut palms in nearby Torres Strait Islands.

Since the mid 19th century there have been some reports of coconut palms growing on the mainland coast, particularly in northern Queensland. This presence of coconut might relate to the displacement of Aborigines who hitherto had hunted and gathered food, including coconut on the beaches. They were not aware of the potential of coconut cultivation but enjoyed consuming the kernel found in the fruit.

Since the late 19th to early 20th century several coconut plantations were established on the northern Queensland coast for ornamental and food security purposes, and briefly in the hope of profitable copra production. The demand for glycerine, derived from coconut oil for the armament industry to make nitroglycerine, raised the price of copra to great heights for a few years. Unfortunately, the high cost of labour after World War I and the great economic depression in 1929–35 made the plantations uneconomical. Some remnants of these plantations remain even to this day.

Coconut continues to play an important role as an ornamental plant to beautify parks, streetscapes and tourist resorts in northern Queensland. In the late 1990s some attractive Dwarf types were introduced from the Pacific islands to meet the demand for more ornamental palms (Townsville City Council, pers. comm.). Coconut has become a significant symbol of tropical tourism, second only to the Great Barrier Reef, in northern Queensland. The image of waving coconut fronds with bunches of fruit stimulates in the would-be tourist thoughts of a warm environment, relaxation, good beaches, friendly people, romance and generous banquets. It is not surprising to see that coconut palms have been planted as ornamentals from Geraldton in the west coast all the way around the north coast to Byron Bay in the east.

Coconut grows well and bears fruit in many parts of northern Queensland, although rarely is it as productive as in traditional coconut-producing countries such as Indonesia, the Philippines and the Pacific islands. The annual daily mean temperature of below 21 ^{o}C for lengthy periods of time (about 6 months) makes some areas like Brisbane and Gold Coast marginal for its growth. Coconut still grows in these marginal areas but the fruit fails to mature. The suitability of coconut for commercial production in Australia is reviewed by Foale (2003).

Coconut plantations were operated on Cocos (Keeling) Islands for more than one century but have been abandoned and now become overcrowded coconut woodlands (Foale 2003). Coconut has also been grown for millennia and has become part of the culture in Torres Strait Islands in northern Australia.

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Tourism in northern Queensland

There is no doubt that tourists go to northern Queensland to experience a tropical holiday. This destination offers unique attractions to both domestic and overseas visitors. Queensland leads the nation in ecotourism and has been the preferred destination for a majority of local and international tourists for many years. In 2004 more than 40% of the international visitors to Australia came to Queensland, mainly for holiday purposes, and this was an increase of 8.2% over the previous year (Queensland Tourism). Occupancy rates for accommodation were also the highest in the country, exceeding their southern counterparts.

The main regions of residence of visitors coming to Queensland are Japan, New Zealand, United Kingdom, Europe, United States of America and China. These locations account for about 65% of all international visitors that come each year (Queensland Tourism). The temperate origin of residence of these people implies that there is a potential to further enhance the tropical image of Queensland, which will maintain and even increase the numbers of visitors. With growing international concern about safety, tourists are likely to prefer Australia as it is considered to be a safe destination to gain a tropical experience. This trend may also be true for domestic visitors, who may in the future prefer to visit northern Queensland instead of taking overseas vacations with a higher security risk.

The main tourist attraction in northern Queensland is undoubtedly the Great Barrier Reef, but other attractions are also highly popular, including the rainforest, the tablelands and Sky Rail. The popularity of these kinds of attractions point to the general view that tourism in this part of the world is related to the experience of natural wonders and open space. A new initiative like Coconut World would be compatible with this theme and could be expected to strengthen the resource base of tourism in the area.

General concept of Coconut World

The coconut is universally one of the most popular images used to promote tropical tourism around the globe. The word coconut is used extensively in glossy booklets, and photos of the palms are used widely in promotion campaigns. However, there is little effort to provide coconut products and services for the tourist once at their destination.

As mentioned above, coconut has a great potential in providing a diversity of products to generate the ingredients for a unique and profitable agricultural theme park. This potential to catch the public's attention and its amenability to a theme park has been identified and developed into a new idea called Coconut World, an agricultural park for research, education, promotion and tourism (Samosir et al. 2004a). The concept is in line with that of agritourism, a type of tourism that is growing in popularity and one that encourages participation in a rural farm experience (Jolly 1999).

The idea of Coconut World was first conceived in 1997 after visiting some agricultural and modern theme parks in Queensland. The concept, in summary, could evolve as a prominent agricultural theme park which meets educative, recreational and relational needs for all ages while strongly supporting the promotion of coconut research and development. Coconut would be the major crop in the park, but other tropical species and animals could be included as well as other tourist needs such as restaurants, rides and shows.

Depending on the location of the park in relation to other tourism destinations, Coconut World would be developed in an ecotourism context, having a strong emphasis on nature and the ecological relationship the palm has with other plant species. Educational activities would be used to target tourists to help raise their awareness of coconut and its benefits in a healthy diet. In addition, the park would host promotional activities of coconut products. A permanent exhibition and trading house would be built in the park where coconut products and associated technologies could be on display at all times.

The entertainment part of Coconut World would suit the whole family. The park would house an extensive collection of coconut germplasm from around the globe in an attractive landscaped plantation setting. Other entertainments, both traditional and contemporary, would include rides and interactive activities.

Efforts would be made to make the park environmentally friendly, sustainable and safe, providing a high standard of product and service. The park would be expected to be an independent commercial entity capable of generating a profit while maintaining a strong commitment to coconut education, research and development.

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Coconut World in northern Queensland

In the tourist-rich region of northern Queensland, the Coconut World theme park could be another attraction alongside the Great Barrier Reef, the tablelands and Sky Rail. The reputation of northern Queensland as a tropical wonderland could be easily tapped to develop the Coconut World concept. In fact, many establishments in the northern Queensland area already use 'coconut' in their names and logos. Unfortunately, there are no traditional experiences with coconut production in the region. Fear of injury, amounting almost to paranoia, caused by falling fruits and fronds has forced the town councils and resort owners to adopt a draconian denutting and trimming plan that spoils the appearance of the palms. Not surprisingly, coconut palms loaded with bunches of nuts at different stages of development are rarely seen in Cairns for public appreciation. People would be interested to be able to view the 'real' coconut palms in their natural shape at a dedicated location.

The location

The coconut palm is able to grow very happily in just about any area in northern Queensland. However, Coconut World would need to be strategically placed in relation to the centre of existing tourism. Like most theme park concepts, it would need to suit daytrippers. Therefore, for the convenience of visitors, the location of Coconut World should be less than 2 hours' drive (or about 120 km) away from one of the main transport hubs and accommodation centres, for example Cairns or Townsville. Location along a tourist-drive route would be ideal as it would suit the package tour operators involved in the business of marketing to tourists with limited time. Access to a good sandy beach would be essential to illustrate the potential independence of dispersal of coconut seeds on the ocean 'carrier'.

The microclimate of the site chosen should be moist as palms grow less well in dry locations. Coconut is best suited to areas with an annual rainfall of not less than 2,000 mm/year with approximate equal distribution by month. Irrigation could substitute for insufficient rainfall, as is done in some parts of Tamil Nadu, India, where annual rainfall can be as little as 800–1,000 mm/year (Venkitaswamy and Khan 2005).

Time is another important factor that needs to be considered. Wherever Coconut World is established, benefits will not be returned immediately because planted palms may take a further 4–7 years before they start producing fruit. In addition, it may take another 10 years before the palms can fully develop the structure that is most attractive to visitors. The Coconut World concept therefore may need at least 15 years before the park can provide the full value of the mature palm. This timeframe is unlikely to be of interest to many entrepreneurs unless they could integrate other attractions into the concept at an earlier stage to generate income while waiting for the palms to mature.

Alternatively, Coconut World could be established in one of the existing coconut plantations present in northern Queensland. Although some features of these old plantations may not fit well with the requirements of the idealised concept, transforming such a plantation into a theme park would be much easier, quicker and cheaper than starting from scratch. Another advantage of developing an established coconut plantation could be its history. The extremely old palms may add some value to the park because visitors are generally interested to see such tall trees and to learn the history of their establishment. As mentioned above, the history of coconut in Australia is unique, and this could be added to the many stories of coconut from around the world and packaged in such a way as to entertain the visitors.

Finally, the Coconut World concept could be further developed or diversified by using other crops but the location would need to suit their growth. Cocoa and vanilla growing under coconut would be a popular combination of plants to show to tourists. Other tropical crops like rubber and various ornamental palms could also enrich the park.

Facilities, products and services

Coconut World would provide the visitor with a good insight into the growing, harvesting, processing and production of a diverse range of end products from coconut. It could also be used as a showcase for coconut-related technologies from around the world, including some Australian inventions such as the Direct Micro Expelling apparatus, the Coconet, the Cocotap, the Kernel Extraction Knife. Many other products and services could also be made available in the park if necessary.

The list below, which has been presented elsewhere (Samosir et al. 2004a, b), gives some idea as to possible requirements of the Coconut World concept:

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- a coconut garden with beautiful landscaping consisting of selected palms with public appeal
- a coconut plantation showcasing various intercropping, monoculture and mixed farming systems
- a germplasm collection which may be part of the International Coconut Genebank (ICG). The collection may serve as a backup to the five ICGs, particularly to conserve rare and endangered germplasm from around the world including the wild coconut types from Cocos (Keeling) Islands
- an ability to grow other tropical crops such as rubber, cocoa, oil palm and tropical fruits (rambutan, durian, jack fruit etc)
- a coconut house constructed largely with coconut wood for housing exhibitions and a museum
- promotional activities on the value of coconut products and technologies
- training of hobbyists in the art of growing coconut and the technologies that are used in producing coconut products
- coconut games and skill competitions such as 'U pick' a coconut, coconut survival, dehusking, splitting and kernel cutting
- coconut shows and talks—history, nursery, copra making, oil extraction, sap tapping, soap making, brown sugar making, cooking, craft making, health etc.
- other shows and talks on tropical plantations (rubber, cocoa and fruits) and culture
- guided tour to plantations (coconut, rubber, oil palm, coffee, cocoa and fruits) and factories
- coconut tower (coconut fruit-like tower as the icon and to provide a scenic view)
- accommodation in the form of a hotel-resort or cottage
- restaurant serving various foods and drinks including coconut-based ones
- rides and thrills
- shops selling various products, souvenirs, seedlings, artworks and books
- venue and facilities for functions and conferences
- walking track and adventure playground
- picnic ground
- retreat program for professionals
- kids playground and creativity centre
- car park
- management office
- Coconut World website.

Support systems available in northern Australia

Coconut is not new to Australia and has been part of the history in some parts of the country, particularly northern Queensland, Torres Strait Islands, the north-west coast of Western Australia, the Northern Territory and Cocos (Keeling) Islands for many years. The Torres Strait Islanders, for example, have had a strong connection with the palm for many hundreds of years and this history and culture would contribute to the uniqueness of Coconut World.

Australian institutions have provided good support to help South-East Asian countries for more than two decades. This makes some, like the Universities of Queensland and Adelaide, leading agencies in coconut research and development. Other institutions in northern Queensland, such as the South Johnston Research Station of the Queensland Department of Primary Industries, could also become supporting partners in this project. In addition, there are other coconut specialists and consultants available in Australia who could contribute.

More than 80% of the world's coconut palms are grown in the Asia–Pacific region, which is relatively close to Australia. It is anticipated that the countries in this zone would provide support and planting materials as well as examples of coconut products that are not available in Australia.

Benefits and impacts

Coconut World would benefit both the local and national economies by providing a new, or expanding an established, tourist destination. The concept would provide an opportunity for trading and promotion of certain kinds of coconut products and associated production technologies, and for stimulation of investment in the crop. In addition, like most tourism industries, Coconut World would create more opportunities for local related businesses. This multiplier effect would significantly benefit the local economy.

Locating Coconut World in northern Queensland would have a positive impact on coconut industries worldwide, including those of the Pacific countries. Public education with firsthand experience of the importance of coconut in human society would be expected to improve the appreciation of, and demand for, coconut products in international markets.

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Acknowledgments

The idea of Coconut World has been widely discussed with various specialists. The authors gratefully thank Dr Pons Batugal (COGENT, Kuala Lumpur), Dr David Allorerung (ICERD, Bogor), Dr Hengky Novarianto (ICOPRI, Manado), Dr Poniah Rethinam (APCC, Jakarta), Dr Gabrielle Persley (Coconut Support Group), Ms Myra Gunawan (former Deputy to the Minister for Culture and Tourism, Indonesia), Mr Ian Kean (APEC International Centre for Sustainable Tourism) and Mr Ian Siagian for their valuable suggestions. ACIAR has supported a research project that has been undertaken at the University of Queensland since 2002, during which time Dr Yohannes Samosir, with the help of others, has been able to develop this concept.

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FAO activities on coconut conducted by FAO Regional Office for Asia and the Pacific, Bangkok, Thailand

K.R. Chapman[1], W.J.M.M. Liebregts[2] and Tran Tan Viet[3]

Abstract

During the past 3–4 years the Food and Agriculture Organization Regional Office for Asia and the Pacific (FAO-RAP) in Bangkok has been active in funding and implementing research and development (R&D) projects on virgin coconut oil (VCO) production technologies as well as development of VCO products. With funding from FAO core and Technical Cooperation Program (TCP) facilities, six interventions for the biocontrol of the coconut hispine beetle *Brontispa longissima* were implemented in Vietnam, Maldives, Nauru, People's Republic of China, Thailand, Lao People's Democratic Republic and Cambodia. Furthermore, seminars and presentations to raise awareness of the threat of this pest were conducted in Sri Lanka and Vanuatu. Specialist meetings on Brontispa were organised in Bangkok (2004) and Ho Chi Minh City (2005) to focus attention on this devastating pest and the urgent need for containment and control, and to discuss approaches for a regional initiative. Separately at this meeting you will hear of the Asian and Pacific Coconut Community's (APCC) strong support in promoting awareness of this very serious coconut pest.

Virgin coconut oil

Virgin coconut oil (VCO) is a relatively new value-added product which has become available in the international commercial market for only the past 6–7 years (Bawalan and Chapman 2006). VCO offers greatly increased returns to coconut farmers over production of traditional copra or the simple selling of whole fresh nuts for coconut cream, desiccated coconut, coconut water etc. and other downstream products. Sale of VCO at the farm gate is likely to bring at least a five- to sixfold increase over the sale price of copra. The return can be much greater depending on location and the novelty of the product. Also, value-adding can be done on farm or in small farmer groups via production of soaps, lotions, medicinal oil, massage oils etc. Much greater profitability is achieved through this vertically integrated approach provided that careful attention is given to marketing.

As the Industrial Crops Officer for FAO in Bangkok, I took a keen interest in this VCO product because it offered another way to greatly improve returns to farmers from their coconut trees. I especially became more interested after buying, in 2002–03, five different brands of VCO in retail shops in Australia, derived from Pacific-based producers, at greatly inflated prices. On taking these oils home I was very disappointed to find that all these products were either discoloured yellow or in some cases were rancid in the container. None would meet the Philippine standards set for VCO, but also none were from the Philippines. It was not hard to conclude that there were processing problems that needed to be resolved. Even in the past 12 months inferior VCO is still to be found in the retail market.

I contacted Mrs Divina Bawalan, a very experienced food engineer (especially on VCO and its products, which she has researched for some 17 years) who was working at that time with the Phil-

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ippine Coconut Authority. I also had discussions with Dr Peesamai of the Thailand Institute of Scientific and Technological Research (TISTR), who is a pioneer of cocodiesel and biodiesel in Thailand. We, together with a TISTR team, set about conducting targeted research and development (R&D) on VCO to resolve some of these problems. In addition, new VCO products were developed by TISTR, with the FAO Regional Office for Asia and the Pacific (FAO-RAP) providing the funding.

At a later time the TISTR team, with Divina Bawalan's assistance and FAO funding, transferred the appropriate VCO technologies to Horticulture Research Institute, Department of Agriculture (DOA), personnel at the Chumphon Horticulture Research Centre in southern Thailand. At the same time, in conjunction with the Department of Agricultural Extension (DOAE) and the village administration and farmers, an outreach village production unit was set up in southern Thailand using TISTR, DOA and DOAE trained personnel.

The many lessons learned and the outcomes of the R&D have now been compiled by Divina Bawalan and myself into a user-friendly, practical manual on VCO. The FAO manual entitled 'Virgin coconut oil–production manual for micro- and village-scale processing' is now available from FAO-RAP in Bangkok.

Further, transfer of the technology has begun in an FAO-TCP project in Maldives, and more is planned for a regional project involving Thailand, Vietnam and Myanmar with FAO assistance in 2006. We know this has been a long time coming but funding is always difficult. Delays have meant, however, that we are now able to promote the right technologies. Many of these technologies will be further developed and field tested in Maldives and Thailand.

The major concern is that in the rush to make quick money from VCO there are many substandard and in some cases shabby practices being put into place in various countries. We hope that the guidance on acceptable practices and advice on machinery and techniques presented in the new manual will greatly assist the production of high quality VCO and associated products.

Coconut hispine beetle

The coconut hispine beetle *Brontispa longissima* can be considered as the scourge of coconut palms—it is one of the most damaging pests of both coconut and a range of ornamental palm species. Both larvae and adults of the beetle feed on the tissues of developing, unopened leaves of the trees. The beetle can cause significant production losses, and a high population density of the pest may result in tree death (Anonymous 2004).

Brontispa is known to have a long history in Papua New Guinea and Solomon Islands, and there is a related but less active beetle named *Plesispa* found in Indonesia. In the 20th century the beetle was accidentally introduced into several countries in the Pacific region, such as Samoa and French Polynesia, but has not reached Fiji. There is significant resistance to *Brontispa* in the indigenous Tall populations of Papua New Guinea and Solomon Islands. The pest, however, was not recorded from continental South-East Asian countries until the late 1990s when it was first detected in the Mekong Delta region in Vietnam, probably due to an accidental introduction with ornamental palms. The pest had a highly significant impact on the country's coconut industry and on the livelihoods of small-scale farmers and their households.

With assistance from FAO-RAP, Bangkok, the larval parasitoid *Asecodes hispinarum* was collected in 2003 in Samoa, where it had been imported in the 1980s for classical biological control of *Brontispa*, and successfully introduced into recently affected countries in South-East Asia and the Pacific region (Liebregts et al. 2006). The parasitoid has become established, and results from southern Vietnam, Maldives and Thailand indicate that pest populations and damage have declined significantly to levels whereby economic damage is insignificant. Socioeconomic analysis has confirmed that the cost–benefit ratio of FAO's intervention in Vietnam alone is in the range of 1:3,000 to 1:4,000 for a 30 year period. It is likely that the parasitoid has saved the coconut industry of Ben Tre province, the largest producer of coconuts in the country. Recent and ongoing assistance to South-East Asian countries is expected to yield similar returns, particularly in Cambodia, Laos and Nauru, where FAO has assisted with control using the *Asecodes* parasite. Advice has also been given by this FAO team to Sri Lanka, Myanmar and China (Hainan Island) on control strategies, and recently to the Philippines to deal with an outbreak near Manila airport.

The parasitoid's impact on *Brontispa* has been dramatic in the humid tropical zones in the region, and pest populations have been maintained at a low level. However, its impact in areas with a cooler and drier

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climate appears to vary, despite an initially similar reduction in *Brontispa* populations within the first year following the release of the parasitoid. In these zones the *Brontispa* population density continues to fluctuate and appears to increase, in particular during the dry and cooler season. The reasons for this are not fully understood and require further study. However, this phenomenon underpins assumptions made at the commencement of FAO's assistance in 2003 which clearly identified the need to study and identify other species of natural enemies which could be introduced to complement the control exerted by *A. hispinarum*. Despite endorsement from regional high-level meetings of the need for surveys in Indonesia and Papua New Guinea to seek other parasites, financial support has not been forthcoming. Clearly, the need to identify additional species of natural enemies has now become even more urgent.

Brontispa has continued its invasion of new areas and countries on the South-East Asian continent. In Laos the pest incursion is rapidly advancing westwards along the major highways that link the country with Vietnam. Authorities in the Philippines are attempting to control an incursion of *Brontispa* and prevent its spread to other islands. In Myanmar symptoms of *Brontispa* have been observed and the Government has requested assistance from FAO to help reduce the rate of spread and impact of the pest. It is certain that *Brontispa* will continue to spread westwards into Bangladesh and India, and possibly even to Africa.

We are of the view that the *Brontispa* incursion should be considered a regional emergency, and therefore requires priority action. The processes to request funding support from FAO and other donors, however, are slow and success is not assured. This means that until now we have only been able to apply reactive approaches, by acting only after an incursion into a new country has occurred. Although our responses are becoming faster, significant damage to coconuts and direct impact on the incomes and livelihoods of the rural producers will continue to occur if we proceed in this way. But we believe that there is another, more proactive approach that is based on a strategy to release the natural enemies in the incursion 'frontline' of the pest. This strategy would allow the parasitoids in their own capacity to closely follow the outward migration of *Brontispa*, and prevent the build-up of large damaging populations of the pest in new incursion areas. Such a strategy may be best addressed through a regional approach, to include not only countries where *Brontispa* is present now but also those that are under direct threat of incursion. The FAO, possibly with assistance from the APCC or other regional organisations, is keen to assist with such an initiative, which will help maintain the livelihoods of rural farmers and their families in the region. The coconut hispine beetle is now classified as an invasive species and a regional assistance effort is urgently needed to prevent its spread to other parts of the Indian Ocean and Africa.

Recently, a manual entitled 'Mass rearing of the coconut hispine beetle (*Brontispa longissima*) and its natural enemy (*Asecodes hispinarum*)' has been produced by FAO-RAP and is available from the Bangkok office. Also a video on the same methodologies is nearing completion and will be available from FAO-RAP in June–July 2006.

Conclusion

Over the past 5 years the FAO-RAP has had a very defined commitment to the production of high quality VCO via improvement in technologies for processing and product development. This commitment continues in a number of countries in the Asia–Pacific region with FAO assistance (Bawalan and Chapman 2006). An FAO manual entitled 'Virgin coconut oil – production manual for micro- and village-scale processing' is now available from FAO-RAP in Bangkok.

Another key activity of FAO-RAP has been focused on biocontrol of the coconut hispine beetle *Brontispa longissima* with the parasitoid *Asecodes hispinarum,* and strategic measures aimed at quarantine and prevention of the transport of palms and cycads which are hosts of the beetle (Liebregts et al. 2006). FAO has assisted Vietnam, Laos, Thailand, Nauru, Maldives and Cambodia with direct action projects and has provided advice to the Philippines, Myanmar and People's Republic of China on strategies for control. The coconut hispine beetle is now classified as an invasive species and a regional assistance effort is urgently needed to prevent its spread to other parts of the Indian Ocean and Africa.

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Coconut oil as a biofuel in Pacific islands—challenges and opportunities

J. Cloin[1]

Abstract

In the Pacific there are opportunities to use coconut oil and other vegetable oils as fuel for transport and the generation of electrical power. Technologies already exist that can combust crude coconut oil in adapted compression engines, or by means of an esterification process into biodiesel using a standard compression engine. The initiatives undertaken in the Pacific to use coconut oil in cars and generators have had different degrees of success. The technological challenges can be solved and economic applications can be found if the supply of oil is secured. Economically attractive niches are available for the use of raw coconut oil in adapted engines in remote communities with an abundant supply of coconuts and milling capacity. The production of biodiesel from coconut oil in combination with other vegetable oils can be set up commercially in larger communities for provision of cleaner fuels in cars and electricity generators.

Introduction

The use of biofuels is nearly as old as the diesel engine itself, as Mr Diesel designed his original engine to run on peanut oil. During periods in history when regular diesel supply was seriously hampered, such as during World War II, vegetable oil alternatives from different sources and in different forms have been used throughout the world.

In the Pacific, only recently has there been renewed interest in the use of coconut oil as a biofuel. The need to substitute for diesel imports, safeguard the local agricultural industry and reduce the impact of diesel exhaust on the environment has led to consideration of a range of initiatives using coconut oil as a biofuel in the past 10 years.

In this report an overview of worldwide research and experience using vegetable oils, including coconut oil, will be given. This will lead to recommendations on the best technical application of coconut oil in compression (diesel) engines. Economic issues including the price and supply of oil will be highlighted, and specific challenges and opportunities for the Pacific islands will be discussed.

The objective of this paper is to identify economic opportunities in the Pacific for the use of environmentally friendly coconut oil to replace diesel in compression engines. This will be done through collecting experience throughout the region and analysing results in a Pacific context.

Coconut oil fuel technology

Research on the use of coconut oil within the context of use of pure vegetable oils as fuel is described below. Possible adaptations that need to be made to diesel engines to enable coconut oil to be used are listed, and the use of biodiesel in unmodified engines is discussed (Figure 1).

Use of pure coconut oil in unmodified engines

Many studies involving the use of unmodified vegetable oils (including copra oil) were conducted in the early 1980s. Short-term engine testing indicates that vegetable oils can readily be used alone as a fuel or in a range of blends with diesel fuel. Long-term engine research, however, shows that engine dura-

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bility is questionable when fuel blends containing more than 20% vegetable oil are used (Allen 2002; Jones and Peterson 2002; Knothe et al. 1997).

The lower iodine content of coconut oil, compared to other vegetable oils, should work favourably to reduce carbon deposits; however, this is not always the case (Calais and Clark 2004). Deposits on the pistons, valves, combustion chambers and injectors can cause severe loss of output power, engine lubricant deterioration or even catastrophic failure of engines (Jones and Peterson 2004).

Under specific circumstances unmodified engines can be run on 100% copra oil. Key variables for successful operation on raw copra oil include:

- a stable and controlled copra drying/milling process
- the removal of water, free fatty acids (FFA) and solids
- filtration up to 1 μm
- preheating of copra oil up to 70 ^{0}C
- blending with regular diesel or kerosene for better viscosity
- application of engine in upper load curve (>70%)
- use in an indirect injection (IDI) system.

The long-term use of raw coconut oil in unmodified diesel engines is currently such a specialised circumstance that it is not recommended without special technical supervision. Further research needs to be done to describe and define the key variables in order to minimise modification costs to engines. Current experiences in Vanuatu in the transport sector are promising and deserve follow-up activities in other Pacific island countries.

Use of pure coconut oil in modified engines

There have been a number of successful modified diesel engines that have run on both mixtures of vegetable oil and diesel as well as 100% vegetable oil. There are mainly two types of modifications that have been done to engines—adding an extra fuel supply system to the existing diesel supply and adapting the fuel supply system and injectors.

As coconut oil has up to 30 times higher viscosity than regular diesel at the same temperature, most engine modifications include a fuel heater. This device heats the fuel up to 70–80 °C before injection, using the engine coolant cross-flow with the fuel in a heat exchanger. By heating up the coconut oil, the resulting oil viscosity can approximate the viscosity of diesel (Kopial et al. 2004).

Dual-fuel systems

Dual-fuel systems start and stop on regular diesel. As soon as the engine is at rated operating temperature, the fuel supply is switched to vegetable oil; and just before shutting down, the supply is switched back to diesel to ensure that the fuel system has diesel ready for a cold start and to avoid residues in the fuel system.

In some areas there is also an electrical heater incorporated in the fuel tank to ensure that the fuel remains liquid, even at ambient temperatures below 25 °C. A technical challenge is to ensure that the return line of the alternative fuel does not cause contamination of the regular diesel. This can be done either by using a third 'day' tank that assembles the excess mixture fuel during switching, or by short-

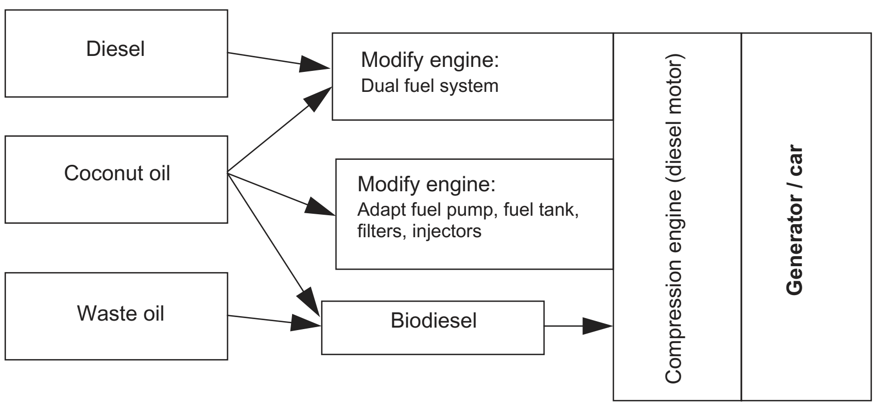

Figure 1. Overview of the biofuel choices for compression (diesel) engines

circuiting the return line and using an extra pump during operation on vegetable oil.

A good example of a dual-fuel system is the village electrification system in Welagi, Taveuni, Fiji Islands, that uses both diesel and copra oil fed into a 55 kW diesel generator. As part of a French-funded project, the village obtained a small copra oil press enabling local small-scale oil production by means of dried copra. Technically, this system has proven to operate with little problem.

This generator has, however, suffered from problems related to spare parts but these problems are not directly attributable to the use of copra oil. The challenge with the system has been to keep it running on copra oil. First a cyclone deprived the community of coconuts for 6 months, and then the acquisition of coconut oil from other mills proved to be more expensive than regular diesel. The local production of coconut oil has also proven to be a very laborious process that can only be maintained with a strong community commitment.

Because the generator has often only been used for a small portion of its design load (as low as 17%), excessive carbon deposits have been found on the exhaust gaskets. This can cause engine failure in the long term, and could be solved by connecting a useful extra load such as water pumping or street lighting when the generator is running at low load.

In Europe and the United States of America (USA), the use of dual-fuel systems, mainly in automotive applications, is slowly developing. Through promotion projects such as the 'Veggie Van' in the USA and the 'VegBurner' in the United Kingdom (UK), these applications have gained wide publicity. Through a combination of very high taxation on fuels (particularly in Europe), low vegetable oil prices (particularly in the USA) and growing environmental concerns, an increasing number of consumers have acquired an alternative fuel system built into their (diesel) vehicles. The emissions reductions measured as a result of the use of these fuels in regular cars have been mixed as compared with the baseline of regular diesel (Lance and Andersson. 2003).

Adapted fuel system

Engines with adapted fuel systems can run on pure coconut oil and use no fossil fuels. Mostly, they feature adapted fuel injectors, special pumps and extra filters. If the coconut oil used in these systems is manufactured locally on a small scale, the quality is not always stable. Therefore, regular quality control and a number of filtering stages are essential to ensuring a long life of this type of system. Often an electrically operated fuel heating system is incorporated for ambient temperatures below 25 °C.

A good example of this is the pilot plant in Ouvea that was implemented by Secretariat of the Pacific Community (SPC) and Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD) in the 1990s, although the generator is currently not in use because of supply problems with locally produced oil. Further feasibility studies have shown a favourable opportunity for the Lory Cooperation on Espirito Santo in Vanuatu. This study also describes the incorporation of the use of raw copra oil in a small number of modified taxi engines (Ribier et al. 2004).

The use of biodiesel in unmodified engines

Biodiesel is a standardised fuel that consists of vegetable oil methyl ester. It is a product of crude vegetable oil that reacts with an alcohol and a catalyst such as sodium hydroxide. This process generates two products: glycerine, which can be used in soap production, and vegetable oil methyl ester, also called biodiesel.

There are two fully developed standards of biodiesel—ASTM-D 6751 in the USA and EN14214 in the European Union (EU). If these standards are followed, the validity of all manufacturer guarantees remains if used up to 5% (EMA 2003). Individual manufacturers have declared that guarantees remain valid in certain vehicle models up to 20% use and some even to 100%. Positive impacts on engines include increased lubricity and a reduction of visible particles in the exhaust. Some engines need replacement of rubber hoses and o-rings, as biodiesel can be slightly abrasive (Chandra 1998; Knothe et al. 1997; Tickell and Tickell 1999).

The use of biodiesel is becoming more mainstream practice in the USA and the EU. Total production in 2003 in the EU grew by 35% to 1.44 million t and in the USA to 83,270 t. It is mostly mixed with regular diesel in low blends. In Germany there are already 800 biodiesel refuelling stations. In Hawaii 1.2 million L of biodiesel is produced annually from used vegetable oil and sold as B1 (1%), B20 (20%) or B100 (100%) biodiesel. In winter blend ratios have to be decreased as biodiesel has a higher cloud point than regular diesel.

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The major disadvantage of biodiesel is that it has to be prepared in a chemical facility. The production cost is estimated to be US$0.2–0.4/L. Because of the return on associated by-products, a Canadian study has indicated that biodiesel cost can be reduced if a market for the main by-product (glycerine) can be found (Chandra 1998). If the biodiesel is produced from waste vegetable oil or beef tallow in large volumes, the resulting price might be lower than for regular diesel. There are also options to produce biodiesel on a very small scale, as has been undertaken in the Philippines (Bulan 2001). It does, however, not appear to be attractive for small island communities because of the use of potentially dangerous chemicals and high working hygiene requirements.

Conclusion

An overview of the advantages and disadvantages of using biodiesel are shown in Table 1. Technically speaking, the production of biodiesel is the best way to use vegetable oils in compression engines. Because of the high production cost of biodiesel, niches for modified engines and dual-fuel systems can be found, depending on the location and availability of good quality coconut oil. The use of straight coconut oil in unmodified engines is not recommended without strict technical supervision.

Coconut oil economics

In every consideration for the use of biomass resources in energy technology, the steady supply of fuel must be safeguarded. Quite a number of initiatives on the use of biofuel have been experiencing difficulties through hampered supply. Mills stop production, coconut trees become senile, rural farmers switch to other forms of income-generating activities. These socioeconomic changes all have their impact on the local availability of coconut oil. First, let us consider the global copra oil market.

Global copra oil market supply

The global production of coconuts, in copra equivalent, has been floating around 10 million t for many years now. Of this production between 1 and 2 million t has been traded on the world market as oil in the last 5 years. The recent volume and associated price/L of the global copra oil market are shown in Figure 2.

As can be seen in Figure 2, the price fluctuation is significant, between US$0.3/L and US$0.7/L. However, the volumes seem to be relatively constant, around 2 million t. The trading volume of copra oil tends to go up when its price goes down, as it replaces the use of other vegetable oils in industrial processes.

Since the Pacific island countries only produce a small percentage of the world supply (Papua New Guinea 2.2%, Solomon Islands 1%, Samoa 0.4%, Fiji 0.3%), it can be safely stated that any increase or decrease in production in the Pacific will not significantly alter the world price. Therefore, the opportunity costs for selling coconut oil as biofuel locally as opposed to exporting oil for the copra mill are determined by the world price minus the cost of transporting and financing the oil.

Local copra oil market supply

Local coconut supply on remote islands can be an interesting source of copra for small- to medium-scale coconut oil production. A niche application can

Table 1. Pros and cons of different coconut oil uses in compression engines

	Advantages	Disadvantages
Straight coconut oil in unmodified engine	Low cost of fuel No modification costs	Works only in certain cases High quality oil required
Coconut oil in modified engine —dual-fuel	Lowest cost fuel can be chosen Flexible	Continued diesel imports Extra components risk extra failure Possible contamination of fuels
Coconut oil in modified engine—pure	100% renewable Low cost of fuel Small island communities can produce own fuel for electricity	Dependence on local oil production Non-standard components Requires heating under ambient temperatures of 25 °C
Biodiesel	Standardised, guarantee remains Opportunity to co-source used oil	Chemical facility required Some rubber parts need replacement

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be identified, especially if the transport costs for both copra export and diesel import are significant. Experience with various projects has shown that safeguarding the supply chain throughout the lifetime of the project is a major challenge.

An overview of the supply chain and the steps required to obtain oil at a generator or fuel pump are given in Figure 3. At each stage a number of important aspects are included. From the plantation the nuts are collected and transported to a dryer. There they are cut and the copra is separated from the husk and the shell. fter drying, the copra is collected in bags and transported to the mill, where it is stored in bulk for milling. The mill processes the copra by means of heat and steam, then grinds and presses the oil. After milling the oil will be filtered from the solids and water. Often, for edible oils and cosmetics, the FFA are reduced through purification stages, deodorising and bleaching.

Copra oil price

The composition of the price of crude exported copra oil throughout distinctive stages in the supply chain is shown in Table 2. As can be seen, the most labour intensive activity of cutting and drying the copra is responsible for 43% of the value of 1 L of oil produced. However, the reward for the labour is very low.

Other emerging alternative sources of rural income have contributed to the deterioration of the copra industry in a number of Pacific islands. In most countries significant replanting is necessary to re-establish pre-1990 production levels by 2010. To revive the industry on the supply side, there are two options that can be considered.

The first option is to increase the payment for dried copra to increase the reward for the cutting/drying of copra. This can be done either by a subsidy or by further rationalising the milling process, thus decreasing its operational margin. This, however, will push up the price of the end product and make it more difficult to compete with both the price level of diesel fuel and the export oil markets. A further disadvantage is that it will require government involvement and possibly further politicise the coconut market.

Secondly, a more mechanised and rationalised process might be looked into, in which the coconuts

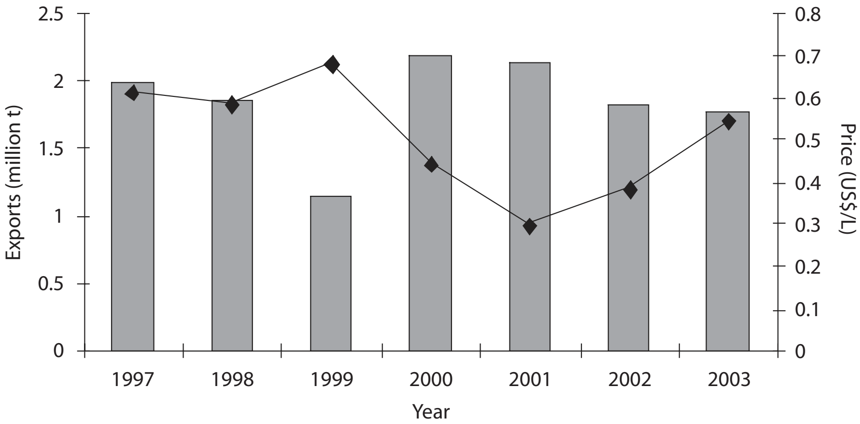

Figure 2. The copra oil world export market (■) and price (◆)

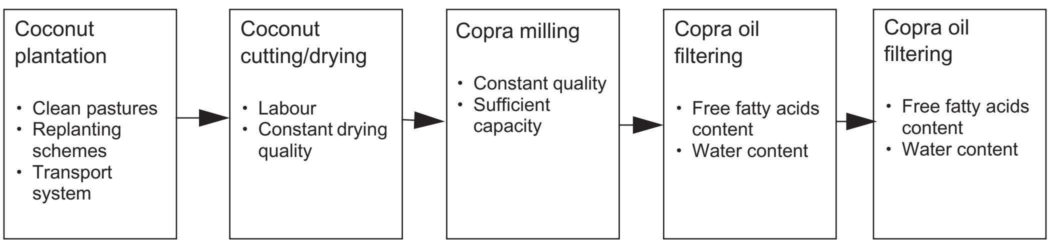

Figure 3. Traditional supply chain copra oil with points that determine quality

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are collected and transported to the mill, where they are cut for copra and dried in a mechanised process. However, such a process requires significant investment in machinery and transport equipment. Another disadvantage is the cost of transporting whole coconuts instead of dried copra, adding to the overall cost of the production process.

Copra oil vs regular diesel

Given the volatility of world market prices for both copra oil and diesel, the best option seems to be a dual-supply system. This could facilitate the use of copra oil in times of high supply and low world prices, and also provide a cushion for times when copra oil ceases to be produced, as has happened in a number of previous projects. Prices of diesel with and without taxes and the local price of copra in the Pacific region are shown in Figure 4.

The difference between the local price of coconut oil and the local price of diesel without taxes indicates the benefits of using copra oil versus exporting it. The benefits will differ from country to country and increase as transport costs to more remote islands increase.

The data depicted in Figure 4 refer to the situation in June–July 2005. However, world market prices have changed, and will continue to do so. During 2005 the South Pacific Applied Geoscience Commis-

Table 2. Traditional copra price composition

	Price in oil equivalent (US$/L)	Value added in oil equivalent (US$/L)	Share of crude export oil (%)
Coconuts collected in field	0.224		39
Copra cutting and drying		0.245	43
Copra dry at mill	0.469		81
Copra milling and filtering		0.107	19
Crude copra oil	0.577		100
Cost, insurance & freight for export		–0.120	–14
Benefit to Pacific island countries	0.497		

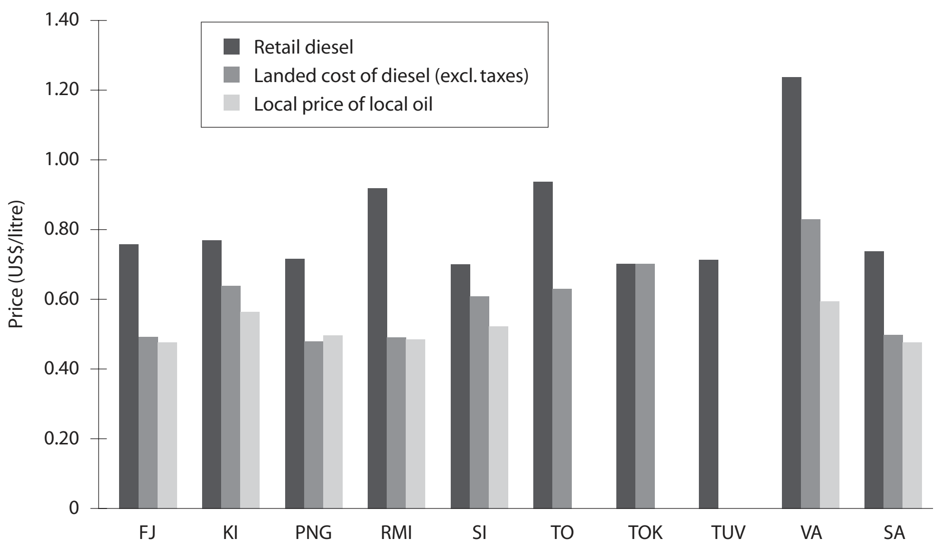

Figure 4. Regional prices of diesel, coconut oil; Fiji (FJ), Kiribati (KI), Papua New Guinea (PNG), Republic of the Marshall Islands (RMI), Solomon Islands (SI), Tonga (TO), Tokelau (TOK), Tuvalu (TUV), Vanuatu (VA), Samoa (SA). Source: SOPAC Regional Workshop on Biofuel, Vanuatu, August 2005

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sion (SOPAC) performed a feasibility study for the power utility of Samoa, EPC. The price movement of both copra oil and diesel, as available in Samoa at constant prices and without taxes, was analysed. The findings of that analysis are indicated in Figure 5.

Conclusion

The prices of copra oil and fossil fuels are highly variable. Depending on one's outlook for the future of the fossil fuel market, geopolitical developments and developments on the vegetable oil markets, prices might become more favourable for biofuels or not. What is clear, however, is that volumes of vegetable oil traded are many times smaller than volumes of fossil fuels. Therefore, it can be expected that exchangeable vegetable oil prices will converge with fossil fuel prices in the coming years.

The reward for the labour involved in the traditional copra process is too low to safeguard the long-term supply in most Pacific islands. Given the low benefits for exporting copra oil in most Pacific islands, there is a strong case for using copra oil locally instead of exporting it. This does not necessarily mean the reward for copra production sold locally is enough to sustain sufficient supply, and therefore has to be looked into on a case-by-case basis. The further rationalisation and mechanisation of the coconut oil supply chain will increase the security of supply; however, this requires significant investment in the coconut oil sector.

Summary—opportunities for coconut oil as a biofuel

For coconut oil as a fuel to be a sustainable alternative to diesel fuel in the Pacific on a large scale, a restructuring of the coconut industry and replanting of palms is required. Alternatives must be sought from traditional copra-based, government-controlled industries towards the more decentralised production of oil, including high-quality control.

The technological challenges can be solved and economic applications can be found if the supply of oil is secured. Economically attractive niches are available for the use of raw coconut oil in adapted engines in remote communities with an abundant supply of coconuts and milling capacity, or in combination with recycled waste vegetable oil to produce biodiesel for low blends in transport and electricity generation.

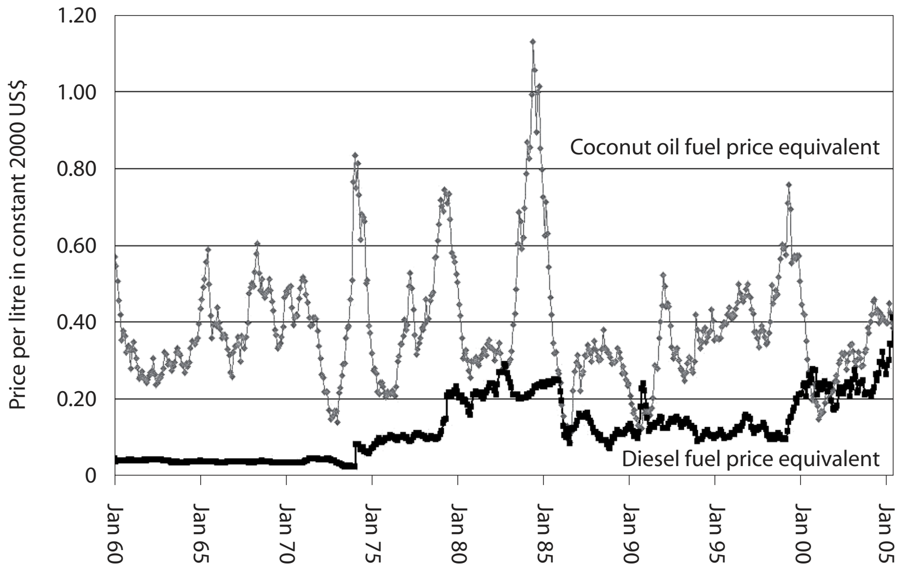

Figure 5. Copra oil and diesel at constant prices in Samoa from 1960 to 2005. Source: UNCTAD, SOPAC CocoGen Feasibility Study

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Acknowledgments

The author is grateful for the essential contributions of Jake Burnyeat, Charlie Blair, Patrice Courty, Tony Deamer, Phillip Hill, Intiyaz Khan, David Parmenter, Ken Roberts, Gilles Vaitilingom and Joseph Walter.

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Assimilate storage in vegetative organs of coconut (*Cocos nucifera*)

I. Miialet-Serra[1], A. Clement, N. Sonderegger, O. Roupsard, A. Flori, C. Jourdan, J.-P. Labouisse and M. Dingkuhn

Abstract

Assimilate storage in vegetative organs is an essential buffer for the source–sink imbalances that inevitably occur in perennial plants. In contrast to temperate trees, little information is available on such storage in tropical perennials, and almost none for coconut (*Cocos nucifera*). This poster describes the chemical nature, quantity, distribution and seasonal dynamics of carbohydrate reserves in 17-year-old adult coconut plants grown in optimum conditions (Republic of Vanuatu, southern Pacific). Plants contained little starch but large quantities of sucrose were found, mainly located in the trunk. Less sucrose was present in roots and little in leaflets. Large glucose and fructose pools were found in leaves near the apex of the trunk, in fruits and in the terminal portions of large roots. Aggregate soluble and non-soluble sugar pools were about equivalent to 6 months of copra production or 51 days of crop growth. Under our optimum conditions, these pools varied little, particularly in the trunk, but they may be mobilisable under stress conditions. The reserves did not seem to play a role in the regulation of production of fruit (in quantity). The number of fruits produced seemed to be controlled precociously during two stages—at the moment of differentiation of the flowers and at the beginning of growth of the fruit. Thereafter, the growth (in terms of dry biomass production) of fruit did not seem to be limited by the availability of sugars.

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From: Adkins, S.W., Foale, M. and Samosir, Y.M.S. (eds) 2006. Coconut revival—new possibilities for the 'tree of life'. Proceedings of the International Coconut Forum held in Cairns, Australia, 22–24 November 2005. ACIAR Proceedings No. 125.

Coconut pests in South Asia – South Pacific and pest risk analysis

L. Ollivier[1]

Abstract

The movement and transfer of coconut (*Cocos nucifera)* and associated plant parts and products from production areas into Australia necessitates assessment of the risks of associated introductions of coconut pests. Insect pests of coconut in South Asia and the South Pacific that may pose a threat to coconut palms in Australia are presented, together with their regional importance. The two rhinoceros beetles *Oryctes rhinoceros* and *Scapanes australis* tunnel through the unopened leaves. If the apical meristem is destroyed the palm dies. Both these pests are not yet present in Australia but occur respectively in South-East Asia and/or the Pacific, and have important economic impacts on coconut production in these locations. The greater coconut spike moth *Tirathaba rufivena* and the coconut scale *Aspidiotus destructor* are widely distributed across the world's coconut plantations and their populations are still spreading into new areas and causing economic damage. The coconut leaf beetle *Brontispa longissima* and the coconut whitefly *Aleurodicus destructor* have been locally recorded in Australia and need to be controlled to avoid further spread. The life stages and life cycle of these species are described along with the potential risks of them invading, establishing, spreading and causing economic impacts. Appropriate management options to reduce these risks are discussed.

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From: Adkins, S.W., Foale, M. and Samosir, Y.M.S. (eds) 2006. Coconut revival—new possibilities for the 'tree of life'. Proceedings of the International Coconut Forum held in Cairns, Australia, 22–24 November 2005. ACIAR Proceedings No. 125.

Rapid diagnosis of coconut fruit quality and sustainable small-scale processing

A. Prades[1], F. Davriux, I.Mialet-Serra, R. R. Assa and A. Rouziere

Abstract

This poster presents an innovative method for determining coconut (*Cocos nucifera*) fruit quality. Several tools were used to assess the coconut fruit quality of two cultivars—PB121 or MYD × WAT from Côte d'Ivoire and VRD × VTT from Vanuatu—at different ripening stages. Chemical analyses were performed using classical and innovative methods. Total soluble sugar and lipid concentrations of the freeze-dried kernel were measured using high performance liquid chromatography (HPLC), accelerated solvent extraction (ASE®) and near infrared spectroscopy (NIRS). These new innovative methods were able to keep the cost of the study down by 70%, while the volume of solvent (petroleum ether) used was reduced by more than 90%. The poster also presents CIRAD's proposals to improve the quality of the traditional aqueous coconut oil extraction process. Part of this proposal was developed in the period 2001–03 (with French Development Agency (AFD) funding) after an analysis of the small-scale coconut processing sector in Ghana. Local traditional processes were characterised within their socioeconomic context, and their environmental impact was assessed. CIRAD experts made several proposals to improve both the productivity and working conditions of processors. The suggested improvements, including graters, presses and furnaces, were all suitable for the small-scale processing procedure and were easy to handle and did not change the characteristics of the final product as assessed by the market. A small effluent treatment unit was also designed to reduce pollution.

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From: Adkins, S.W., Foale, M. and Samosir, Y.M.S. (eds) 2006. Coconut revival—new possibilities for the 'tree of life'. Proceedings of the International Coconut Forum held in Cairns, Australia, 22–24 November 2005. ACIAR Proceedings No. 125.

Cryopreservation of coconut embryos using desiccation procedures

Sisunandar[1], Y.M.S. Samosir and S.W. Adkins

Abstract

Coconut (*Cocos nucifera*) is one of the most important crops in the tropics (93 countries). At present the only way available to conserve coconut germplasm is in field-planted gene banks. This is expensive and the collections are exposed to a number of problems, namely loss of planting land and destruction by pests, diseases and natural disasters such as cyclones, drought, land erosion and tsunami. Cryopreservation of coconut germplasm is an alternative but, as yet, poorly developed conservation approach. Research on coconut cryopreservation has been undertaken in only a few laboratories around the world and, because of this, a reliable method is yet to be developed. As the coconut seed is large and loses viability quickly, most previous attempts at coconut cryopreservation have been undertaken on the excised zygotic embryo alone or have used plumular tissues. The results so far obtained are inconsistent and vary between genotypes. Thus, there is a need to develop a new, more complete coconut cryopreservation protocol. Our work has investigated a number of ways of desiccating coconut embryos without reducing their viability. These methods include different drying techniques: in a laminar airflow, over silica gel, and in a flash desiccation apparatus. The results indicate that embryos can be rapidly dried (in 2 hours) to substantially lower water contents (about 19.5% FW) using the third method only. A longer time (4 hours or more) was necessary to achieve the same low water content (21.3%) when using the other methods. All embryos that had been rapidly dried were shown to retain their ability to germinate (100%) in Eeuwens medium with 60 g/L sucrose and without plant growth regulators. In addition, similarly dried embryos could be immersed into liquid nitrogen for 24 hours, then recovered and germinated. While experiments are still ongoing, these preliminary results indicate that a possible cryopreservation system based on the rapid drying of embryos might be developed for coconut in the near future.

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From: Adkins, S.W., Foale, M. and Samosir, Y.M.S. (eds) 2006. Coconut revival—new possibilities for the 'tree of life'. Proceedings of the International Coconut Forum held in Cairns, Australia, 22–24 November 2005. ACIAR Proceedings No. 125.

Development of a high-fibre white bread using Direct Micro Expeller coconut cake

Yun Yun Xu, B. D'Arcy, N. Caffin[1] and B. Bhandari

Abstract

The aim of this study was to convert Direct Micro Expeller (DME) coconut (*Cocos nucifera*) cake into a commercially viable functional ingredient for food systems. The specific aim was to incorporate DME coconut cake into white bread to provide an increase in dietary fibre content without compromising the basic bread quality attributes and sensory properties of bread. The coconut cake was dried and ground to produce coconut flour in two fractions: a coarse and a fine fraction of either more or less than 500 mm particle size. Prior to grinding, a portion of the coconut cake was defatted, while the other portion retained its original fat content. Thereafter, the coconut cake was used at two percentage levels (5% and 7.5%) as replacement of baker's wheat flour. Automated bread machines were used for baking and a total of eight treatment bread loaves with two replications were evaluated for basic quality parameters such as specific loaf volume, colour and textural properties. Lastly, a taste panel was asked to evaluate the appearance, aroma, texture and overall acceptance of the bread. The results showed that the addition of coconut meal, like other sources of dietary fibre, influenced bread quality characteristics. The most apparent effects were in the reduction of loaf volume, increase in crumb firmness, and change in crust and crumb colour. These effects were more pronounced at higher addition levels of coconut meal (>7.5%) and with the use of fine, defatted coconut meal. Coarse, full-fat coconut meal at the 5% substitution level had less effect on bread quality parameters. Sensory results showed that the majority of panellists liked the bread with 5% added coarse, full-fat coconut meal. Both physical measurements and sensory evaluation for the 5% coarse, full-fat coconut bread were satisfactory, suggesting a possible niche market for this component as a high-fibre functional ingredient for the baking industry.

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