**Promoting nutritious leafy vegetables in the Pacific and Northern Australia**

G.H. Lyons R.G. Goebel

University of Adelaide, Waite Campus Etty Bay Exotics

Glen Osmond Mourilyan

Australia Australia

P. Tikai K-J. Stanley

World Vegetable Center (AVRDC) Women in Business Devt. Inc.

Honiara Apia

Solomon Islands Western Samoa

M. Taylor

University of the Sunshine Coast

Maroochydore

Australia

**Keywords:** minerals, nutrients, carotenoids, polyphenols, genotype-environment interaction

**Abstract**

**A more traditional lifestyle, especially with respect to diet and exercise, is needed to address the alarming rates of obesity, heart disease and diabetes in Pacific Island countries and indigenous communities in northern Australia. Leafy vegetables should play an important role but are often regarded as “low status” foods and have received little research attention. This study found that, although certain leafy vegetables are popular in some countries, particularly Solomon Islands and Tonga, there is little knowledge of their health benefits. Leaf samples were collected in Solomon Islands, Samoa, Tonga, Kiribati, North Queensland and the Torres Strait Islands and minerals, carotenoids and polyphenols were analysed. To study genotype-environment interaction, different species growing at the same location (same soil) and common species growing at multiple locations (different soils) were included in the survey. The data, together with flavour and popularity, were used to make a “Top 12” nutritious leafy vegetable factsheet series, which was distributed in participating countries and published online (**[**www.aciar.gov.au/News2013July**](http://www.aciar.gov.au/News2013July)**). Outstanding species included *Abelmoschus manihot* (aibika, bele), *Polyscias spp.* (ete), *Sauropus androgynus* (sweetleaf), *Moringa oleifera* (drumstick tree) and *Basella alba* (creeping spinach). Aibika was high in iron, zinc, magnesium, manganese, protein and lutein; sweetleaf was high in iron, zinc, calcium, magnesium, manganese, sulphur, lutein, b-carotene and protein; ete was high in zinc and calcium and grows well on alkaline coral soils; drumstick was high in b-carotene, sulphur and selenium, and creeping spinach was high in magnesium and polyphenols. Reliable provision of quality germplasm, more nutrition education, including school food gardens which feature the most nutritious vegetables, and value chain research to improve shelf-life and delivery of nutrients to consumers are recommended.**

**INTRODUCTION**

Since the 1940s the consumption of high-energy, low-nutrient foods, including white flour, sugar, polished rice and turkey tails by Pacific Islanders and indigenous Australians, combined with reduced exercise, has resulted in an epidemic of obesity, diabetes and heart disease, so-called non-communicable diseases (NCDs). These are the leading cause of death for 12 Pacific countries with data available, often accounting for around 70% of all deaths (SPC, 2010). These diseases were absent when traditional diets and lifestyles predominated (WHO, 2004).

Many different types of leafy vegetables are grown and eaten in the Pacific region. When available, local vegetables are usually inexpensive; despite this, they can be overlooked and are often regarded as foods of low status. However, research has shown that most leafy vegetables are valuable foods, being nutritious and rich in protein, vitamins, minerals, phyto (plant) chemicals and fibre (Dignan et al., 2004; French, 2010; Keatinge et al., 2011; SPC, 2012).

In addition to the health benefits of traditional diets, local food crop (including “wild food”) biodiversity strengthens the resilience of food systems through increasing the crop species richness and therefore enhances food security (Taylor et al., 2014). Moreover, it is also economically advantageous: growing foods such as leafy greens, sweet potato, taro and cassava to improve nutrition helps to reduce trade deficits associated with high consumption of imported foods in the Pacific.

This study surveyed attitudes to leafy vegetables in several Pacific countries and northern Australia. The nutritional composition of a range of leafy vegetables and other edible leaves was also surveyed, in order to recommend an effective strategy to promote production and consumption of local nutritious leafy vegetables.

**MATERIALS AND METHODS**

The people surveys were conducted in Solomon Islands, Samoa, Tonga, Torres Strait Islands and Arnhem Land using a combination of questionnaire, semi-structured interviews, focus groups and information from key informants. Flexibility was necessary in obtaining relevant, valid data. In Solomon Islands workshops were held at the villages/sites where leaf samples were collected (Burns Creek, Marau Sound and Aruliho); in Tonga interviews and a market survey were conducted; in Samoa interviews were conducted with farmers and agriculture and health officers, and focus groups were included in a workshop conducted by Women in Business Development Incorporated (WIBDI). In Arnhem Land (Northern Territory) and the southern Torres Strait Islands (Queensland) findings were based on information from key informants, colleague interviews and third party sources.

Representative samples of a range of leafy vegetables and wild edible leaves were collected from sites in Solomon Islands (mostly from Guadalcanal), Samoa (Upolu), Tonga, Torres Strait Islands (Thursday and Horn Islands) and Mourilyan, south of Cairns, Queensland. An effort was made to sample different species growing at the same site/on the same soil and common species from multiple sites/different soils in order to assess genotype-environment interaction. Leaves of different taro cultivars growing at several sites in Samoa were also analysed, along with breadfruit leaves and fruit from Kiribati.

To limit degradation of the carotenoids analysed, samples were dried rapidly in a microwave oven as soon as practicable after collection, usually the same night. The samples were brought to Australia under permit and irradiated. Samples were analysed for a range of mineral nutrients (iron, manganese, boron, copper, molybdenum, nickel, zinc, calcium, magnesium, sodium, potassium, phosphorus and sulphur) and also aluminium, titanium and chromium (for quality control purposes to detect soil contamination) using inductively coupled plasma (ICP) optical emission spectrometry, and a sub-sample was analysed for selenium using ICP mass spectrometry. Nitrogen was analysed using the combustion method and protein % estimated by multiplying nitrogen % by 4.4. The carotenoids beta-carotene (the major pro-vitamin A carotenoid), lutein (usually the most abundant carotenoid in leaves) and alpha-carotene were analysed by high pressure liquid chromatography (HPLC). A sub-sample of leaves was analysed for total phenolic content (as gallic acid equivalent) and antioxidant activity (using 1,1-diphenyl-2-picrylhydrazyl (DPPH) as a stable radical, reporting half-maximal inhibitory concentration, IC50).

**RESULTS AND DISCUSSION**

**People survey**

In all of the countries/regions involved, there was considerable enthusiasm for the study. There were large differences in the number of leafy vegetable species grown and eaten, from many in Solomon Islands to relatively few in northern Australia. Leafy vegetables, including *Abelmoschus manihot* (aibika, sliperi kabis), *Cyathea spp.* (sweet fern), *Sauropus androgynus* (sweetleaf) and *Ipomoea aquatica* (kangkong) form an important part of the diet of many Solomon Islanders, whether they live in remote or peri-urban settings, and in rural areas wild-collected leaves also are commonly eaten. In addition to food, many leaves were used for medicinal purposes, and several of the commonly eaten leafy vegetables were also used to increase lactation, e.g. sliperi kabis, sweetleaf and *Polyscias spp.* (ete, hedge panax). It was evident that the people had greater medicinal knowledge than nutritional knowledge of leafy vegetables. However, the Ministry of Health and Medical Services is striving to increase nutrition education (headed by Ms Rosemary Kafa), through *inter alia* a village level program which uses posters and postcards featuring the most suitable local foods. Moreover, the Kastom Gaden Association and the Ministry of Agriculture and Livestock are enthusiastic promoters of local food crops.

Leafy vegetables are not as popular in Polynesia as in Melanesia and this was evident in the surveys and sample collection in Samoa. Taro leaf and pele (aibika) are the most common leafy vegetables, with *Cucurbita spp.* (pumpkin) tips and *Capsicum spp.* (chilli) leaf also consumed widely. The survey revealed that more nutritional information and awareness were needed to increase consumption, and also improved availability of planting material of known and currently unknown vegetables. Information about recipes was also important. Cost was also mentioned in the survey as one of the main factors when buying food, especially for a family.

To achieve impact, promotional campaigns need to be conducted by all sectors, community groups and churches. The WIBDI group works with organic farmers, and was keen to establish nurseries and information centres to help promote leafy vegetables and to encourage their use in tourist outlets. Our findings agree with an FAO study in Samoa which found that the main external factors which influenced people’s decisions about food were availability, accessibility, cultural obligations and family income. For example, fruits and vegetables were expensive compared to other foods, and traditionally leafy vegetables are not considered as a Samoan food, or are given only to children or the sick, to make them strong. Internal factors included taste, with a preference for meat, salt and sugar, and lack of knowledge about cooking methods and health benefits (FAO, 2004).

In Tonga leafy green vegetables are relatively abundant. Chinese cabbage and rocket (*Brassica spp.*) are becoming increasingly common in markets. Ms Luseane Taufa (Ministry of Agriculture, Food, Forests and Fisheries) is an enthusiastic promoter of nutritious local food crops and the factsheets (see below) are now used in her education program. The *African Leafy Vegetable* program (FAO, 2011) and the *Go Local* program in the Federated States of Micronesia (FSM) (Englberger et al., 2010) show what can be achieved with commitment, effort and funding to promote nutritious local crops.

In the southern Torres Strait Islands and Arnhem Land the long dry season, inhospitable soils and less need for subsistence food gardens (as a range of foods can be bought in stores) result in few leafy vegetables grown and eaten in these regions. Indigenous vegetation here usually has tough, unpalatable leaves, hence people traditionally obtained nutrients from other food sources. Moreover, people are usually not able to collect bush tucker or hunt on other people’s land; therefore if they live in towns they will have limited access to traditional foods. On Thursday Island, George Ernst of the Torres Shire Council has established a community horticulture program, similar to one in Todmorden, England (Bioversity, 2014) which features over 60 prominently located plots of fruit trees, *Moringa oleifera* (drumstick tree) and other nutritious food crops. This complements the *Quality Lifestyle* program based on exercise and diet, conducted by Natalie Orero, Queensland Health community nutritionist, aimed at reducing the high rates of diabetes and heart disease in the area.

**Plant survey**

The 250 leaf samples collected were analysed for mineral nutrients, with a subset analysed for three carotenoids (a-carotene, b-carotene, lutein), nitrogen and selenium. Accounting for genotype-environment interaction (Fig. 1 and Table 1) enabled determination of those species which were highest in particular minerals and protein (Table 2) and carotenoids (Table 3) as well as those with outstanding all-round nutritive value. Of particular interest is the finding that the drumstick tree accumulates around 12 times the concentration of selenium and around four times the concentration of sulphur compared to most other plants grown on the same soil. This trait would be especially valuable in Sub-Saharan Africa, where these minerals are deficient in many soils. Their deficiency is considered by some researchers to increase risk of HIV/AIDS (Lyons et al., 2014).

This study provided some evidence of intraspecific genotypic variation in addition to clear evidence of interspecific variation in mineral concentration in leaves. The survey of leafy vegetables grown in Samoa included five taro cultivars grown at four sites. The concentrations of most minerals in leaves varied by between 1.6-fold (sulphur: 2500-3900 mg/kg DW) and 4-fold (manganese: 47-186 mg/kg DW) and a significant proportion of this variation appeared to be due to genotype, to the extent that a provisional ranking of the cultivars could be made (in decreasing order of overall mineral levels): cultivars 4, 2, 5, 1, 3.

The literature describes a range of phytocompounds derived from leaves, including those of sweet potato (Islam et al., 2002), with activity against cancer, heart disease, diabetes and infectious diseases. Of the subset of samples analysed for total phenolics and antioxidant activity, *Basella alba* (creeping spinach) and *Alternanthera sp.* excelled (Table 4). Creeping spinach has long been used in traditional medicine as a remedy for dysentery, anaemia and cancer (Adhikari et al., 2012), and *Alternanthera* is used as a medicinal plant in Solomon Islands. Five major phenolics (kaempferol, ferulic acid, salicylic acid, syringic acid and chlorogenic acid) are found in its leaves (Bhattacherjee et al., 2014).

**Factsheets**

The nutrient data, together with consideration of acceptable flavour and popularity, were used to formulate a “Top 12” list of leafy green vegetables for the Pacific and Northern Australia. A factsheet series was developed, featuring the 12 species: *Colocasia esculenta* (taro), aibika, ete (and included in the same factsheet because of its similar appearance was *Pseuderanthemum whartonianum* (ofenga), sweetleaf, kangkong, *Cucurbita spp.* (pumpkin) (included with *Sechium edule* (choko)), drumstick, creeping spinach, *Capsicum spp.* (chilli) and *Amaranthus spp.* (amaranth). These species have also been recognised for their nutritional value in other studies (Bailey, 1992; French, 2010; SPC, 2012).

For each species, photographs, characteristics, uses, availability, propagation and growing methods, disease and pest threats, harvest/post-harvest/storage recommendations were included. Finally, leaf mineral and carotenoid data were presented in a table which included the featured leafy vegetable sampled at a representative site, compared with another leafy vegetable growing at the same site, and also compared with English cabbage (see Table 3). An introductory factsheet describing the project and another describing the Thursday Island community horticulture program were also included. The factsheets (500 sets) were printed and laminated in Fiji for durability, distributed in the participating countries/regions (where they were enthusiastically received) and published online at [**www.aciar.gov.au/News2013July**](http://www.aciar.gov.au/News2013July)**.** Although not featured in the factsheets, other nutritious leafy vegetables included *Ipomoea batatas* (sweet potato), *Manihot esculenta* (cassava), sweet fern, *Brassica spp.* (watercress) and *Ficus spp.* (sandpaper cabbage).

**CONCLUSIONS**

The impact of poor nutrition needs to be more clearly defined to support the claims that leafy vegetables actually help to prevent diabetes and heart disease. People need to become more aware of what happens when they get these diseases.

Increasing awareness and generating interest, however, must be met with availability of supply, whether planting material for home gardens or on a larger scale for farmers to produce for markets and tourism outlets (Taylor et al., 2014). Value chain research is essential: the producer needs to be convinced that production of green leafy vegetables is worth the effort. What arrangements are needed to deliver health benefits to consumers and economic benefits to local horticultural producers and other value chain participants?

Children need to be involved; in many countries their importance in influencing lifestyle factors, especially diet, is becoming recognised. For example, schools can include food gardens featuring the most nutritious local plants, and students can transfer knowledge back to their villages.

Improving nutrition is usually seen as the task of health agencies, but it is apparent that a cross-sectoral and multi-agency approach is needed. The NCD pandemic may be at least as important a challenge to humanity as climate change. Both can be addressed by increasing diversity on the farm and extending this diversity (of which nutritious leafy vegetables form an important part) to the diet.

**ACKNOWLEDGEMENTS**

To the Australian Centre for International Agricultural Research (ACIAR) for funding and the World Vegetable Center (AVRDC), our main collaborator in Solomon Islands, for conference support. To Waite Analytical Services and the Mares Laboratory (University of Adelaide) and Dr Shahidul Islam and colleagues (University of KwaZulu Natal) for technical assistance.

**Literature Cited**

Adhikari, R., Naveen Kumar, H.N. and Shruthi, S.D. 2012. A review on medical importance of *Basella alba* L. Intl. J. Pharm. Sci. Drug Res. 4:110-114.

Bailey, J.M. 1992. The Leaves We Eat. SPC Handbook No. 31. South Pacific Commission, Noumea, New Caledonia.

Bhattacherjee, A., Ghosh, T., Sil, R. and Datta A. 2014. Isolation and characterisation of methanol-soluble fraction of *Alternanthera philoxeroides* (Mart.) – evaluation of their antioxidant, a-glucosidase inhibitory and antimicrobial activity in in vitro systems. Nat. Prod. Res. June 23:1-4 (epub).

Bioversity 2014. Case Study 10: the Incredible Edible Todmordenprogram. In: J. Fanzo, D. Hunter, T. Borelli and F. Mattei (eds.), Using Agricultural Biodiversity to Improve Nutrition and Health. Routledge-Earthscan, London and New York.

Dignan, C., Burlingame, B., Kumar, S. and Aalbersberg, W. 2004. The Pacific Islands food composition tables. 2nd edition. Food and Agriculture Organisation of the United Nations (FAO), Rome.

Englberger, L., Kuhnlein, H.V., Lorens, A., Pedrus, P., Albert, K., Currie, J., Pretrick, M., Jim, R. and Kaufer, L. 2010. Pohnpei, FSM case study in a global health project documents its local food resources and successfully promotes local food for health. Pac. Health Dial. 16:25-36.

FAO 2004. Research report: Knowledge, attitudes, beliefs and practices related to the consumption of fruits and vegetables in Samoa. FAO, Samoa, November 2004.

([www.fao.org/docrep/015/an432e/an432e00.pdf](http://www.fao.org/docrep/015/an432e/an432e00.pdf))

FAO 2011. African Leafy vegetables in Kenya: local biodiversity in production, market and consumption. FAO, Rome.

([www.fao.org/fileadmin/user\_upload/wa\_workshop/Factsheet/FSNL\_Fact\_sheet\_AfricanLeafyVegetables-12oct2011.pdf](http://www.fao.org/fileadmin/user_upload/wa_workshop/Factsheet/FSNL_Fact_sheet_AfricanLeafyVegetables-12oct2011.pdf))

French, B.R. 2010. Leafy greens and vegetables in Solomon Islands. Food Plants International ([www.learngrow.org](http://www.learngrow.org)), Devonport, Tasmania.

Islam, M.S., Yoshimoto, M., Yahara, S., Okuno, S., Ishiguro, K. and Yamakawa, O. 2002. Identification and characterization of foliar polyphenolic composition in sweetpotato (*Ipomoea batatas* L.) genotypes. J. Agric. Food Chem. 50: 3718-3722.

Keatinge, J.D.H., Yang, R-Y., Hughes, J.d’A., Easdown, W.J.and Holmer, R. 2011. The importance of vegetables in ensuring both food and nutritional security in attainment of the Millennium Development Goals. Food Security 3:491-501.

Lyons, G., Gondwe, C., Banuelos, G.S., Zambrano, M.C., Haug, A. and Christophersen, O.A. 2014. Drumming up Selenium and Sulphur in Africa. In: G. Banuelos, Z-Q. Lin and Z. Yin (eds.), Selenium in the Environment and Human Health. London: Taylor and Francis Group, London, pp 91-92.

SPC 2010. NCD statistics for the Pacific Islands Countries and Territories. Secretariat of the Pacific Community, Noumea, New Caledonia.

SPC 2012. Green leaves leaflet No. 8. Secretariat of the Pacific Community, Noumea, New Caledonia.

Taylor, M., Kambuou, R., Lyons, G., Hunter, D., Morgan, E., Quartermain, A., Lorens, A., Hadosaia, C. and Robert, N. 2014. Realizing the potential of indigenous vegetables through improved germplasm information and seed systems. Acta Hort. (in press).

WHO 2004. Pacific Islanders pay heavy price for abandoning traditional diet. WHO Bulletin 88:484-485.

**Tables**

Table 1. Effect of species on concentration of a micronutrient (zinc) and a macronutrient (magnesium) in leaves of leafy vegetables grown together at Burns Creek, Guadalcanal, Solomon Islands in 2012.

|  |  |  |  |
| --- | --- | --- | --- |
| Species | Mineral nutrient (mg/kg DW) | |  |
|  | Zinc | Magnesium | |
| *Lactuca sp.* (lettuce) | 20 | 3300 | |
| Sweet potato | 29 | 2400 | |
| Aibika | 32 | 4700 | |
| Cassava | 40 | 2300 | |
| Ofenga | 46 | 16000 | |
| Sweetleaf | 61 | 6500 | |
|  |  |  | |
| Variation | 3-fold | 7-fold | |

Table 2. Selected mineral nutrients and the leafy vegetable species found (using opportunistic GxE analysis) in this study to be the most efficient accumulators of these minerals in leaves. Selenium is a micronutrient for humans, animals and algae but not for higher plants. Samples collected from various locations in Solomon Islands, Samoa, Tonga, North Queensland and Torres Strait Islands in 2012.

|  |  |
| --- | --- |
| Nutrient | Most efficient accumulators |
| Iron | Sweetleaf, kangkong, taro, aibika |
| Zinc | Ete, sweetleaf, cassava |
| Magnesium | Ofenga, aibika |
| Calcium | *Coccinia grandis* (ivy gourd), ofenga |
| Selenium | Drumstick |
| Sulphur | Drumstick, watercress, cabbage |
| Nitrogen/protein | Sweetleaf, drumstick, cassava |
| Multiple nutrients | Sweetleaf, aibika, ete, drumstick |

Table 3. Concentrations of selected carotenoids in leaves. The three highest species (mean levels of samples collected at various sites on Guadalcanal) compared with the lowest (mean levels of English cabbage samples obtained from Honiara markets).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Species | Carotenoid (mg/kg DW) | |  |  |
|  | beta-carotene | alpha-carotene | | lutein |
| Drumstick | 427 | 0 | | 773 |
| Aibika | 356 | 38 | | 1024 |
| Sweetleaf | 289 | 32 | | 773 |
| English cabbage | 0 | 2 | | 5 |

Table 4. Total phenolics and antioxidant activity in leaf samples collected at various sites on Guadalcanal, Solomon Islands in June 2012. The two “best” species (creeping spinachand *Alternanthera sp.*) compared with selected other species.

|  |  |  |
| --- | --- | --- |
| Species | Total phenolics | Antioxidant activity |
|  | mg/g gallic acid equiv. | DPPH IC50 |
| Creeping spinach | 76 | 42 |
| *Alternanthera sp.* | 25 | 12 |
| Ofenga | 26 | 688 |
| Sweet fern | 2 | 227 |
| *Melicope elleryana* (butterfly tree) | 2 | 820 |

Note: Phenolics: ethanol extract used. In general, the higher the level, the better.

Antioxidant activity: ethanol extract used. Units: DPPH radical scavenging activity, using half-maximal inhibitory concentration, IC50: the lower the value, the more effective.

**Figures**

Fig. 1. Variation in manganese and zinc concentrations in leaves of aibika growing at eight locations on Guadalcanal, Solomon Islands in 2012. This study illustrates variation due mostly to differences in plant-available levels of these nutrients in the soil.