Proceedings of the seventh
OCEANIAFOODS Conference

Innovations in Nutrient Information

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Wellington, New Zealand
April 12 - 15 2005
PROCEEDINGS OF THE 7TH OCEANIAFOODS CONFERENCE:
“INNOVATIONS IN NUTRIENT INFORMATION”

Duxton Hotel, Wellington, New Zealand

13 – 15 April 2005
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Report on the recommendations and resolutions from the 6th OCEANIAFOODS Conference

List of participants
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Last but not least, a big thanks to all the presenters for giving high-standard presentations and enabling much discussion on topical food composition issues.
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The 7th OCEANIAFOODS conference here in Wellington provides the food composition community an exciting opportunity to get together to review the progress since the 6th OCEANIAFOODS conference held in Brisbane in February 2002. The theme of this conference, “Innovations in nutrient information and in food composition databases”, now sets the stage to plan for future advancements in the food composition area in this region. It is very encouraging to see the conference being opened by the Hon. Annette King, Minister of Health, and to see the commitment extended by the New Zealand Ministry of Health for the conference.

Some of the key recommendations from this 7th OCEANIAFOODS conference are to investigate the possibility of a joint database publication focusing on indigenous foods of the Oceania region, to encourage representation from IT professionals and analysts at the OCEANIAFOODS Conference, to promote students to present their work by offering student grants, and to explore the possibility of collaborative work in folate analyses and glycaemic response area. Last but not least, to investigate the possibility of organizing a training course on food composition as part of the next OCEANIAFOODS conference.

These proceedings of the 7th OCEANIAFOODS Conference provide an excellent record of the progress towards recommendations made at the 6th Conference, as well as key research that has important implications for nutrition researchers in our region. Some recommendations have been amply fulfilled. Particularly noteworthy is the publication of the revised edition of the South Pacific Food Composition Tables, now freely available at: www.fao.org/documents/show_cdr.asp?url_file=/docrep/007/y5432e/y5432e03.htm

A related achievement described in Fiji’s Country Report was the full accreditation of the Analytical Laboratory of the University of the South Pacific Institute of Applied Science at its Laucala Campus, Suva, Fiji. The accreditation was from the world-renowned accreditation body, International Accreditation New Zealand (IANZ). The United Nations Food and Agriculture Organization (FAO) funded the accreditation process as part of a technical cooperation project to strengthen analytical capabilities in the Pacific. Much credit is due to the efforts of all Pacific Island workers involved in this task, and to the FAO for funding this excellent programme.

Given the recommendation in 2002 for closer collaboration with Hawaii, it is pleasing to note the keynote presentation given by Suzanne Murphy on “Expanding the Cancer Research Center of Hawaii’s food composition table for use in other Pacific Islands”. There is no doubt that these food composition activities in Hawaii will be of great benefit to other areas in Oceania where similar island foods are consumed. It is encouraging that the recommendations from this conference state that the Hawaii Cancer Centre will continue to explore possibilities for collaboration with OCEANIAFOODS.

Another recommendation made in 2002, to stimulate research on indigenous Pacific Island food crops, has also been fulfilled. Lois Englberger and her collaborators have identified unique micronutrient-rich locally grown foods in the Federated States of Micronesia, Marshall
Islands and Kiribati. Their findings are described in their paper entitled “Identification of micronutrient-rich locally grown foods in Federated States of Micronesia, Marshall Island of Kiribati”. Another important aspect of this work has been a project to develop appropriate promotional materials and messages in order to communicate the new food composition data on these foods effectively (see paper “A novel approach for presenting food composition data in the Federated States of Micronesia, Marshall Islands, and Kiribati”).

Many other recommendations from the 6th OCEANIAFOODS Conference are echoed in the recommendations arising from this meeting. Of particular importance is the involvement of more Pacific Islands in the next meeting and in the work of OCEANIAFOODS generally. The widely scattered island nations of the Pacific are often small, generally poorly equipped and sometimes their communications technologies are unreliable, even in this electronic era. This means that we have to make even greater efforts to find funding for their projects and to equip their analytical laboratories, and at the very least support ways for their scientists to attend OCEANIAFOODS meetings.

All of this means searching for funding. It was a particular pleasure to note the sponsorship by Crop & Food Research and Unimonde for Joanne Holden’s participation, and also the assistance of International Life Science Institute, South East Asia Region (ILSI) in the participation of Bill Aalbersberg and Lois Englberger. The New Zealand Ministry of Health is sincerely thanked for sponsoring the student competition and the attendance of the two prize winners, Jimaima Lako and Shyamala Vishnumohan.

Looking beyond the recommendations from these OCEANIAFOODS meetings, it is important to note other regional developments that provide examples worth following or adapting. New Zealand conducted its second evaluation of its Food Composition Database service in 2003 (see paper entitled “Audit of the New Zealand Food Composition Database Service 2003”). In Australia the web-based Nutrition Panel Calculator is now in routine use and being adapted for use in New Zealand (see paper entitled “Country report, Australia”) and several conference papers cover topics of increasing importance, such as data for antioxidants and other bioactive compounds; quality control of analytical data; and nutrients with important public health implications, such as selenium, iodine and folate.

These meetings are an invaluable way of exchanging information and advice. They provide an opportunity to make new contacts and renew acquaintances. We all look forward to meeting again in Fiji in 2008 when we are certain to see many interesting developments and the involvement of more Pacific Island scientists.
Conference photographs

OCEANIAFOODS conference delegates, presenters and the organising team from Crop & Food Research gather for a group photo at the conclusion of a very successful 7th OCEANIAFOODS Conference.

OCEANIAFOODS conference student grant recipients Shyamala Vishnumohan (left) of the University of New South Wales, and Jimaima Lako of Monash University (second from right), with Graham Smellie, Crop & Food Research Business Manager (second left), the Minister of Health, Annette King, Maria Turley, Senior Advisor Public Health Intelligence Ministry of Health (third from right), and Dr Barry Borman, Manager Public Health Intelligence Ministry of Health (right).
SUMMARY OF RECOMMENDATIONS AND RESOLUTIONS FROM THE 7TH OCEANIAFOODS CONFERENCE

1. Encourage all Pacific Island countries to be more involved in food composition database activities (a letter is to be sent to the health and agriculture departments of all Pacific countries asking them to become active corresponding members of OCEANIAFOODS).
   
   **Action:** Bill Aalbersberg and SPC

2. In organising OCEANIAFOODS conferences, pay special attention to raising the funds required for participation by Pacific Island countries, especially funds for the attendance of people from these countries.
   
   **Action:** All members

3. Investigate the possibility of a joint database publication focusing on indigenous foods of the Oceania region.
   
   **Action:** All members

4. Encourage information technology (IT) professionals to participate in the OCEANIAFOODS conferences.
   
   **Action:** All members

5. Encourage representatives from analytical laboratories to participate in the OCEANIAFOODS conferences.
   
   **Action:** All members

6. Prepare a list of email addresses of conference attendees to facilitate information sharing about the food composition activities and related activities relevant to the Oceania region.
   
   **Action:** Nelofar Athar, Jo Dellow

7. Investigate the possibility of developing an OCEANIAFOODS website.
   
   **Action:** Judy Cunningham

8. Continue to encourage students to present their work at OCEANIAFOODS conferences by offering student grants.
   
   **Action:** All members

9. Share in-house reference material within the Oceania region with the objective of assuring quality performance in analytical methodologies for food testing by regional laboratories.
   
   **Action:** All members

10. Explore the possibility of collaborative work for expressions of folate analysis, glycaemic response, and other properties of foods in the Oceania region.
   
   **Action:** All members

11. Investigate the possibility of running a training course in food composition data production, management and use in conjunction with the next OCEANIAFOODS conference. Fiji and the SPC to investigate ways to implement and coordinate the course.
   
   **Action:** Bill Aalbersberg and SPC
12. Support efforts to encourage growers within the Pacific region to consider nutrient composition when selecting which cultivars and crops of indigenous or local origin to grow. Use cost effective methods to promote consumption of nutrient rich cultivars.

    *Action*: All members

13. Work with the New Zealand Ministry of Health and Food Standards Australia New Zealand (FSANZ) to respond to expectations once the final document on new Australasian NRVs (Nutrient Reference Values) is released. (New NRVs are expected to be adopted in New Zealand and Australia later this year and are likely to have significant implications for food composition work.)

    *Action*: Nelofar Athar and Judy Cunningham

14. The Pacific Islands is to become the new convener of OCEANIAFOODS and will host the next conference in Fiji in 2008.

    *Action*: Bill Aalbersberg

15. The Hawaii Cancer Centre will continue to explore possibilities for collaboration with OCEANIAFOODS.

    *Action*: Suzanne Murphy
WELCOME TO DELEGATES

Dr. Nelofar Athar

Crop & Food Research, Private Bag 4704, Christchurch 8140, New Zealand

Opening remarks

Honourable Minister of Health, Annette King, distinguished guests, ladies and gentlemen.

New Zealand’s Ministry of Health and Crop & Food Research are privileged to co-sponsor the 7th OCEANIAFOODS Conference - ‘Innovations in Nutrient Information’. We are delighted to be hosting this conference here in Wellington. Shortly I will call on the Honourable Minister of Health to open the conference. But first I will introduce myself.

My name is Dr Nelofar Athar and I am the convenor of OCEANIAFOODS. I work at Crop & Food Research as a Nutrition Scientist and am responsible for managing and developing the New Zealand Food Composition Database.

Today, the demand for information about food extends beyond the traditionally studied nutrients to bioactive compounds, such as lycopenes and anthocyanins. We need to make this information available. Also, of equal importance is the quality of nutrient and non-nutrient data. Like the data itself, information about it must be available to users.

Indeed, availability, ease of access and ease of comprehension are vital to food composition data users. Users such as dietitians, nutritionists, health professionals, educators and policy-makers have key roles in developing healthy nations. Hence, the role of our OCEANIAFOODS representatives is even more important today. This is particularly so with rapid advances in technology. I believe we must work together to find innovative ways to deliver food information that is relevant, of a high quality, and easy to use.

I do extend to you my best wishes for an informative and innovative OCEANIAFOODS conference.
OPENING OF THE 7TH OCEANIAFOODS CONFERENCE

Hon. Annette King, Minister of Health

Parliament Buildings, Wellington, New Zealand

New Zealand is proud to be the current co-ordinator for OCEANIAFOODS and to be hosting the 7th OCEANIAFOODS Conference.

Thank you firstly to the conference organisers, Crop and Food Research, and the Ministry of Health (Public Health Intelligence), and thank you to Dr Nelofar Athar for your introductory comments.

I also want to warmly welcome all invited speakers and delegates. Many of you have travelled from overseas, and I specially welcome the keynote speakers:

Ms Joanne Holden, Research Leader at the US Nutrient Data Laboratory at the US Department of Agriculture.

Professor Bill Aalbersberg, Director of the Institute of Applied Science at the University of the South Pacific.

Professor Heather Greenfield, University of New South Wales.

I am also pleased today to be able to congratulate the two recipients of the Ministry of Health Student Grant Fellowships – Jimaima Lako and Shyamala Vishnumohan. I am sure this conference will be of great benefit to you, and I wish you both well in your careers.

OCEANIAFOODS is, of course, a regional data centre of INFOODS, or the International Network of Food Data Systems. INFOODS coordinates a global network of regional data centres directed at generating, compiling and reporting food composition data. New Zealand’s membership reflects its commitment to developing the New Zealand Food Composition Database, and we strongly support the international collaboration demonstrated by INFOODS.

The conference organisers, the Ministry, and Crop and Food Research, jointly own the New Zealand Food Composition Database. I understand that Dr Barry Borman, from the Ministry, and Dr Chris Downs, from Crop & Food Research, will talk more about this partnership later, as well as plans for developing this important resource.

The database has many uses, but perhaps the best-known is converting food intake data collected in national nutrition surveys and nutrition research studies into nutrient intake information. As a funder of the national nutrition surveys, the Ministry clearly has a particular interest in maintaining and developing the database, because high quality food composition data are vital to determine nutrient intake and the adequacy of diet. Such data are used in developing and evaluating evidence-based strategies, policies, guidelines and programmes.

In fact, such data were fundamental in developing New Zealand’s Healthy Eating-Healthy Action or HEHA strategy and implementation plan, and will also be important in monitoring and evaluating HEHA. Data from the database and the 1997 National Nutrition Survey have also been used in developing the Food and Nutrition Guidelines for Healthy Adults, including calculating sample diets.

There are many other important uses for such data as well, of course. As Minister of Food Safety, I know how important high-quality food composition data are to the New Zealand Food...
Safety Authority in implementing the Australia New Zealand Food Standards Code. The code requires most packaged foods to include a Nutrition Information Panel, and this information is either based on laboratory analysis or can be calculated using data from the database. Many food producers use this option, so high-quality data are critical if labels are to be accurate and useful to consumers.

Data from the New Zealand database are also shared with other countries in the Oceania region on a reciprocal basis. Such sharing benefits the whole region, particularly as globalisation is affecting all our food intakes.

It is also good to know that our database continues to evolve to meet user needs and to respond to changes in food and nutrition policy and guidelines. An upcoming challenge for the database will be to respond to the new Nutrient Reference Values, or NRVs, once these are adopted by New Zealand and Australia.

This ongoing development of our database, and of similar databases from other Oceania countries, clearly supports the conference theme – Innovations in Nutrient Information. The conference provides an excellent opportunity for the international food composition community, as well as nutritionists, researchers, analysts and food company representatives from Australia, New Zealand and the Pacific Islands, to share latest developments in food and nutrient information.

In the two years since the last OCEANIAFOODS conference was held in Brisbane, the continuing development and enhancement of food analysis data has gone from strength to strength, and this conference gives you the opportunity to catch up on what is now an increasingly fast-changing and dynamic world of food composition data.

I note that the workshops are covering topics such as data quality, analytical methods, data quality tools and the food composition database from a users’ perspective. All these workshops will provide you with valuable knowledge for future research and application.

As I mentioned earlier, high quality data are being used in many ways around the globe, in food industries, and by dietitians, analysts, food scientists and technologists, researchers and regulators.

It is increasingly important, therefore, that governments support the collection of comprehensive and scientifically robust data if we are to successfully monitor the health of our nations and continue to deliver a safe food supply. The more collaboration and sharing of information we can have among Oceania countries, the better it is. The data you gather help shape and nurture public health policy.

Since its inception, the member countries of OCEANIAFOODS have made much progress in generating new and relevant food composition data, and the Oceania region has been active in the new wave of food composition work since the 1970s.

As I am sure you all know, New Zealand has had a steering committee for its food composition programme since 1984, and it is now a lead player in food composition, with a reputation on the international scene for producing high quality data. As far as the government is concerned, it is crucial that this position is maintained.

Up-to-date and accurate data are also invaluable in areas such as fortification, the development of functional and novel foods, the increasing importance of ethnic foods and changes in lifestyle.
New Zealand has an increasing range of fortified foods on the market, and work is taking place around food standards for fortification, particularly with regard to folic acid and iodine. This could impact on the requirements of food composition data in the future.

Iodine deficiency disorders, such as goitre, common in New Zealand early last century, are beginning to cause concern again among food safety, nutrition and medical experts. Statistics show that the iodine status of New Zealanders and Australians is dropping, and fortification of the food supply is one option being considered by Food Standards Australia New Zealand.

Both countries are also considering the mandatory fortification of folic acid and are looking at the most effective mechanism for increasing the total folate intake in peri-conceptional women as a possible means of reducing the incidence of neural tube defects. I hope that your discussions at this meeting will help expand food composition databases to include robust data on folic acid and iodine.

Functional and novel foods, such as pre- and pro-biotic yoghurt-type products, will also play a role in altering the make up of our food supply as they become more mainstream. Such functional foods aim to provide health benefits above and beyond those of the normal diet and so there will be a need for more research around ingredients.

Our increasing love of ethnic foods also provides ample scope for research, as does a decline in traditional home cooking and the increasing preference of many people for convenience foods.

The diversity of New Zealand’s food supply is widely recognised. We are interested in expanding data to include the composition of wild and indigenous food – from wild game, through fish and shellfish, to plants and berries collected in the wild. It is important that this part of our database is maintained and enhanced.

But what does all this mean to the consumer? How can your work be made more accessible to people as they go about their daily lives?

We cannot afford to overlook the potential for making food composition data more consumer-friendly and accessible to the public. One option perhaps worth considering is developing an Internet programme that allows consumers to calculate their daily intake of nutrients, such as fat, sugars and sodium. This would help consumers make informed choices about what they eat, and could benefit all of us. I am sure such issues will help occupy you productively over the next few days.

The partnership of OCEANIAFOODS has a reputation for providing robust, comprehensive and world-renowned data. Its success reflects the ongoing commitment of many of you here today. Your efforts are reflected in the continuing improvement of the health of our nations, and in the ability of governments to provide a safe food supply.

On that note, I am very pleased to declare the 7th OCEANIAFOODS Conference open. Thank you very much for inviting me to join you, and I look forward to hearing about future innovations in the New Zealand Food Composition Database.
Dr Barry Borman

Manager, Public Health Intelligence, Ministry of Health

Dr Borman welcomed delegates and VIPs, then outlined the Ministry’s commitment to the New Zealand Food Composition Database (NZFCD) as follows:

- The Ministry (formerly the Department of Health) has been funding the ongoing development of the NZFCD since the early 1980s. The current contract has been recently extended for 3 years with the aim of developing a joint research program.

- In 2003 the Ministry of Health commissioned a review of the NZFCD to ensure that it was a high quality database that met the needs of stakeholders. Professor Heather Greenfield from the University of New South Wales undertook the review – see page 45 for Professor Greenfield’s detailed presentation on the review.

Dr Borman acknowledged the partnership between the Ministry of Health and Crop & Food Research through the following key points:

- NZFCD is jointly owned and funded by the Ministry and Crop & Food Research.

- Crop & Food Research and the Ministry of Health are jointly responsible for the maintenance and development of the NZFCD, with input from a Food and Nutrition Advisory Group (FNAG).

- The FNAG has representatives from all major stakeholders – government (Health and Food Safety Authority), health professionals, NGOs, academics and the food industry.

Dr Borman then focused on the importance of the NZFCD to the Ministry of Health by indicating:

- The Ministry’s responsibility for food and nutrition monitoring and national nutrition surveys are a core component of this. Hence, high quality food composition data are essential for converting food consumption data collected in national nutrition surveys into nutrient intake data.

- Together, these data are used to inform the development and evaluation of evidence-based policies, guidelines and programmes.

- A joint research programme will include investigating other ways the NZFCD can be used for food and nutrition monitoring.

Dr Borman’s concluding remarks included underlining the Ministry’s commitment to making the data more useful and accessible to stakeholders and making more data freely available.
Minister, colleagues and distinguished guests – good morning and welcome to the OCEANIAFOODS Conference. Crop & Food Research (C&FR) is also very pleased to be sponsoring and contributing to the organisation of this event.

I would especially like to acknowledge the work that Nelofar Athar and her organising team have put into running this conference. Their work is providing an important opportunity where representatives of the local, regional and international food composition database and INFOODs communities can meet to share the latest thinking around the development and use of food composition information.

As we open this conference, I’d like to spend some time:

- Introducing C&FR;
- Speaking about the NZ Food Composition Database and its users;
- and then, focusing in on the theme of this conference “Innovations in Nutrient Information”.

C&FR is an independent, government-owned research institute. It is one of New Zealand’s eight Crown Research Institutes which fall under the responsibility of the Minister for Research, Science and Technology – Steve Maharey.

We employ about 370 staff who work at eight locations throughout New Zealand. The team who work on the NZ Food Composition Database are located at C&FR’s second largest centre in Palmerston North.

Our Mission Statement – “Knowledge and Value from Scientific Discovery” – demonstrates our commitment to the development of new scientific knowledge and then applying that knowledge in ways that are valuable and useful to New Zealand.

C&FR’s capabilities are utilised by both government and industry partners, and in the food and nutrition area, for example, this includes work with government agencies such as the Ministry of Health, the NZ Food Safety Authority, FSANZ, and with many New Zealand food companies and related organisations.

C&FR’s science capabilities are best described by our five Centres of Innovation and our activities are integrated across the food value chain:

- In Sustainable Land and Water Use, we conduct research which aims to understand and optimise the primary agriculture production environment.
- In High Performance Plants, we aim to develop new arable and vegetable cultivars for use in food production.
- In Personalised Foods, we integrate our capabilities in food science and technology with our work in the nutrition and health sciences. These combined capabilities help us to understand the New Zealand food supply and then work with organisations wanting
to promote health. Our work on the Food Composition Database and other aspects of nutrition information are central here.

- C&FR has a unique position in being the only New Zealand research institute to focus on postharvest seafood research. In High Value Marine Products, we aim to support the development of both food and industrial products from New Zealand’s unique marine resources.

- In Biomolecules and Biomaterials we are researching raw materials that are being used in the development of a range of non-food products such as new pharmaceuticals and new packaging materials.

As we move into a discussion about the NZ Food Composition Database, I would especially like to acknowledge C&FR’s partnership with the Ministry of Health in the development of this important information asset for New Zealand. Many people, over many years, have contributed to the database project.

Barry Borman has already outlined the many ways in which this work is jointly managed and the database is being jointly developed. Our work together is far more than a contractual relationship, it is a partnership of which we are proud. And now we are entering an exciting new phase where we are jointly developing a research program which will further add value to the database and make the information even more widely available.

Over recent years, C&FR has been making a significant investment in the development of a new database management system – the system upon which the food composition data sits and is managed. Our work with Infinity Solutions Ltd on this project is now nearing completion.

Staff are available during this conference to discuss the highly complex requirements of this new database management system and the many ways in which it will support new approaches in food composition science.

The new system has features which include:

- web enablement which allows far greater and easier access to packages and subsets of data than previously possible;
- far greater flexibility and usability – enabling far more diverse uses;
- a customised reporting system which can be used to support activities such as food labelling, publications, recipe calculations and research reporting;
- overall we believe that the new system will be far easier to use for both researchers and other organisations.

The NZ Food Composition Database, like the databases in many other countries, has many uses. As has been outlined previously, the database has an important role for government in supporting the development of policies, strategies and guidelines aiming to promote a healthy food supply and ultimately a healthier population.

Many researchers in our universities use the nutrient information from the database, for example in programs to develop experimental diets in their clinical research studies. Others use the database to support food, nutrition and dietetics education in our universities, polytechs and schools.

There is a growing health management sector in New Zealand which includes gyms, trainers, dietitians and nutritionists. Food composition information along with dietary management software packages are routinely used to assist people in managing their food intakes.
With the implementation of the Food Standards Code in 2002, the use of Food Composition Datasets by the food industry has increased substantially. Packaged foods are now required to include a Nutrient Information Panel as part of product labels. There is also growing use of food composition data by food companies that are developing new food products which are aiming to deliver particular nutrient profiles and compositions.

One of the dominant “drivers” in the international food market is a focus on health. In this market, sectors of the population are increasingly aware of product nutritional quality and potential health benefits of certain food products. Food companies, motivated by the prospect of greater product sales, are expanding their ranges with these so-called functional foods.

The theme of this conference is “Innovations in Nutrient Information”. If we consider the many facets of Food Composition Databases there are many opportunities for innovation including:

- Data quality – there will be presentations during this conference which will outline new ways in which food composition data can be collected and presented, based upon the quality status of the data;
- Data management and access – as can be found in new database management systems and resulting data products and services.

There are growing opportunities for innovation around new types and sources of data – such as new foods including native or indigenous foods, larger ranges of nutrients and components, more information on the effects of processing, and information on physiological effects and bioavailability of components – are of growing interest.

Future innovation may also come where there is integration of food composition datasets with other datasets relating to things such as food effects, health or disease status, or physiological status. C&FR is involved in research programs where opportunities such as these are beginning to be investigated.

Current theory around fostering innovation indicates that greater innovation will come where cross-functional teams are given the time and space to develop new ideas. If you like, these new ideas emerge or appear at the boundaries of disciplines that are brought to work together in new ways.

C&FR is leading a new research program called “Lifestyle Foods” which aims to support the development of new types of arable-based foods which are intended to assist in the management of glycaemia. This program is funded by the New Zealand government’s Foundation for Research, Science and Technology to the tune of $18 M over the next 6 years. Here, research capabilities in food, sensory, nutrition and health sciences are being integrated within a single research program. Alongside the development of these new types of foods, there will be the potential for the development of new ways of presenting the nutritional information designed to assist consumers in their purchase decisions and managing their health status.

In related work, John Monro has developed the concept of virtual food components for inclusion in food composition databases as a way to present information relating to the physiological effects of foods. Currently, work is progressing on virtual foods components associated with both glycaemia management and faecal bulking. What is the future role of Food Composition Databases for information such as virtual food components?

C&FR is also contract manager of a major research program on nutritional genomics or nutrigenomics. This is a $20 M government investment over the next 6 years involving a partnership of three Crown Research Institutes and the University of Auckland. The program aims to understand the interaction of the nutrients in foods with different aspects of the human
genome. This research integrates capabilities in food science, nutrition, bioinformatics (or the science of information management) and human genomics. In this work huge datasets of food components and human genomics information are being produced. Again, what is the future role of Food Composition Databases for new types of information such as that generated in nutritional genomics programs?

And finally, we are in discussion with the Public Health Intelligence group at the Ministry of Health about the ways in which we can add further value to the NZ Food Composition Database in the area of nutritional epidemiology. The PHI group manages huge datasets describing the disease status, including cancer and diabetes for example, of New Zealanders. We would like to explore the ways in which new information can be developed when these datasets are integrated with the information in the Food Composition Database.

In closing, I’m sure that you will agree that we are all motivated to see a healthy New Zealand population. Thankfully, there is growing awareness that a diet based upon healthy foods will assist in the prevention of many diseases.

Good nutrition and healthy foods are essential in disease prevention. And the New Zealand Food Composition Database is an essential tool in helping us to understand and describe the New Zealand food supply. As we have said, it also helps inform our policies, strategies and guidelines for managing population health.

The aim of this conference – innovations in nutrient information and in food composition databases – will therefore help to further advance our efforts in achieving a healthier population.

Minister, thank you for your support of this conference. And to our friends and colleagues at the Ministry of Health, thank you for your ongoing support and contributions to our database partnership.

C&FR is pleased to be supporting this OCEANIAFOODS Conference, and we are very pleased to welcome all participants from both near and far.

Welcome and enjoy the conference!
INFOODS AND OCEANIAFOODS

J.M. Holden

FAO and INFOODS

Dr Burlingame delegated Joanne Holden from USDA to give this presentation on behalf of FAO and INFOODS at the seventh OCEANIAFOODS Conference. A summary of the presentation is given below:

After giving a brief introduction about INFOODS, the presentation focused on ‘publications’ (Books, Series and Journals), ‘standards development’ (Energy and Data Interchange) and ‘projects’ on strengthening analytical capability and cross-cutting initiatives on biodiversity and nutrition in the area of food composition activities.

Under the Publications section, there was information about the books in the UNU INFOODS series, the second edition of Greenfield & Southgate (2003) “Food Composition Data Production, Management and Use”, and about the most recent regional tables “Pacific Island Food Composition Tables, second edition 2004 (C. Dignan, B. Burlingame, S. Kumar, W. Aalbersberg)”. In addition, the presentation highlighted the publication of 40 papers in the Journal of Food Composition and Analysis from New Zealand, Australia & Pacific Islands.

In the Standards section, an update on data interchange (2004), and food energy methods of analysis and conversion factors (2002), was presented.

The presenters were informed about Projects such as the cross-cutting initiative on biodiversity and nutrition sponsored by:

Commission on Genetic Resources for Food And Agriculture (FAO)
International Treaty on Plant Genetic Resources for Food and Agriculture
Convention on Biological Diversity.

International Rice Commission recommendations for systematic cultivar-specific nutrient analysis and dissemination were also discussed. These recommendations may serve as a model to other commodity commissions.

The presentation also covered the double burden of malnutrition. Further, a summary table of evidence of food/nutrient related chronic diseases (cardiovascular disease, cancer, dental disease and osteoporosis) was presented.

The presentation was concluded as follows:

“Food composition data form the basis by which intakes, and hence diet-disease relationships, are assessed. Food composition data are the fundamental information by which dietary intake goals can be established and achieved. Without sufficient quantity and quality of compositional data—past, present and future—all diet/disease evidence would be insufficient. The body of data used can and should be world-wide.”
COUNTRY REPORT: AUSTRALIA

J. Cunningham

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Abstract

Food composition activities in Australia since the 6th OCEANIAFOODS meeting are summarised. Much of the food composition work is undertaken at Food Standards Australia New Zealand (FSANZ), which maintains a small program of analysis, compilation and publication of data. FSANZ activities over the past 3 years have focused on three key areas. First, the Nutrition Panel Calculator, a free, web-based nutrition labelling tool, has been upgraded to enhance usability and provide improved data. Second, there has been extensive preparation for a new release of Australian nutrient data that will include updated nutrient values for some core foods, data for nutrients not previously reported in Australian tables (e.g. selenium, vitamin D, folates, and improved food names, descriptions and sample information. Finally, a small number of analytical projects have been commissioned, including an Australia-wide survey of iodine levels in common foods and a smaller survey of folates and folic acid in foods such as breakfast cereals. These analytical surveys have focused on addressing issues important for the development of food standards for application in Australia and New Zealand. Activities outside FSANZ include further research on folate analysis at the University of New South Wales, anthocyanins research at Monash University, release of commercial software products to assist with dietary analysis, and product development and analysis of nutrient and non-nutrient food components at commercial laboratories.

Update

Australian food composition activities

Food composition work in Australia is conducted primarily by Food Standards Australia New Zealand (FSANZ), although several other groups are also involved in these activities. This report primarily focuses on FSANZ’s activities but also briefly refers to work being undertaken by other groups.

FSANZ food composition activities

FSANZ maintains a small project team of nutritionists who are involved with the generation, compilation and release of food composition data. Over the past 3 years, staff numbers have varied from the equivalent of two to four full-time officers, assisted as required by a contract programmer.

The project team works to generate and release a wide range of nutrient data, and the work undertaken must also be consistent with the statutory objectives of FSANZ. As a result, the focus of much of the team’s work has been on activities that support the development and implementation of food standards.

FSANZ’s team has been involved in three major areas of food composition activities since OCEANIAFOODS 6, each of which is described in further detail below:

- maintenance and improvement of the web-based Nutrition Panel Calculator and associated database;
- compilation of data for a revised Australian database of nutrient values; and
- a number of small analytical programs focused on specific data needs.
The Nutrition Panel Calculator

The focus on activities that support the setting of food standards is exemplified by the development and enhancement of the web-based Nutrition Panel Calculator (NPC). The NPC was released in late 2001 specifically to assist industry to develop nutrition information panels, which are now mandatory on most packaged foods supplied in Australia and New Zealand. Essentially, the NPC allows users to integrate values from a specially prepared nutrient database with information on the quantities of ingredients in their food, to produce data on the levels of seven nutrients (energy, protein, fat, saturated fat, carbohydrate, sugars and sodium) per 100 g and per serve of their food. The NPC has been described in detail by Cunningham & Trevisan (2002).

Since OCEANIAFOODS 6, FSANZ has undertaken extensive work on the NPC in response to user feedback and areas of identified need. This work has sought to improve programming, enhance user functionality, and improve data quality and descriptive material. This work is summarised below and a detailed discussion of the work undertaken is available in Cunningham et al. (2004).

1. Programming improvements

The NPC was first released in two versions, neither of which satisfied all requirements for user accessibility and compatibility with different computers and web browsers. In addition, a number of minor programming issues were identified during the first year of operation of the NPC. Maintenance of two versions of the NPC and provision of technical assistance to users to overcome programming faults occupied a large proportion of staff time and reduced the ability to focus on other areas of activity.

For these reasons a single, revised NPC was launched in October 2004 and has been very successful. We estimate that the NPC is accessed around 70 times per day.

2. Database improvements

AUSNUT Special Edition is the database used to support the NPC. It contains data for seven nutrients in around 4000 foods, including food processing ingredients such as modified starches and a number of food additives. The third edition of this database (AUSNUT SE3) was released in March 2004 with one major enhancement being the inclusion of around 50 new lines, focusing on food additives and ingredients such as spices where users had indicated they needed these data. A small number of data lines were removed if it was considered that their origin or quality was not sufficiently established.

Names and descriptions of included foods were also revised for AUSNUT SE3. Where possible, names were aligned with names used in the food industry or in common culinary use. In cases where a number of users had experienced difficulty in searching for an ingredient, alternative spellings were included in the name (for example, Chilli (chili) powder). Where possible, descriptions of foods were altered to clarify the food referred to (for example, the description for Honeycomb now indicates that the data refer to a confectionery product, not to the waxy lining of the beehive).

3. Simplified user guide

In response to ongoing user complaints that the instructions for using the NPC were too long, complex and slow to download when using a dial-up internet connection, we prepared a Quick Reference Guide that contained a minimum amount of information to successfully operate the NPC. The Guide was prepared using simple, informal language and the document length was reduced from 76 to 12 pages.
Experience gained over 3 years of managing the NPC has reinforced the importance of considering the needs of the intended audience for food composition publications. Consideration of the audience is as important for technical publications as it is for all other publications.

**Revised Australian database of nutrient values**

The second major food composition activity undertaken in Australia in the past 3 years is the compilation of data for a new set of Australian food composition tables. It is now approximately 10 years since the last release of a set of primarily analysis-based nutrient data for Australian foods (NUTTAB 95 and its 1997 Supplement). It is approximately 6 years since the release of the National Nutrition Survey database AUSNUT, which comprised a mix of analytical, calculated and borrowed data (Australia New Zealand Food Authority, 1999).

The revised tables will contain data that are predominantly derived by analysis of foods as supplied and consumed in Australia. The use of recipe calculation, imputation or borrowing will be restricted and used primarily where it is considered that there is a real need for data that overrides any concerns about data quality. Particular attention will be paid to appropriate names and descriptions of foods. Information on sample composition, time and location of purchase, or method of imputation will be included.

Where appropriate, the tables will integrate previously published and newer, unpublished data. However, where it is considered that the food in question has undergone significant change in production practices in recent years, older data will be replaced.

Nutrients not previously reported in either NUTTAB or AUSNUT will be included. This will include iodine, selenium, vitamin B12, beta-, delta- and gamma-tocopherol, tocotrienols and vitamin D. Folate values will primarily be Australian analytical values rather than values that were borrowed from other countries' tables, as was the case with AUSNUT.

Compilation of the data is ongoing and has been a much larger task than originally envisaged. It is planned to release the data in stages, with the first release planned (subject to change) for August 2005, with subsequent releases as major food groups are completed. A name for the database is not yet finalised and at the moment we are using the working title of NUTTAB05.

The data compilation process has highlighted a number of fairly fundamental issues, such as when and how to integrate old and new data and whether it is better to have poorer quality data than no data at all.

**Analytical programs**

With priorities focused on data compilation activities, analytical programs have been limited in the time since the last OCEANIAFOODS meeting. Programs have focused on addressing specific data gaps that impose limitations on FSANZ's standards development work. Six analytical programs have been started since the beginning of 2002 and these are described briefly below.

1. **Analysis of instant and simmer soups**

These products are popular winter foods in Australia and are sold as powders that are prepared either by the addition of boiling water to powder contained in a cup (instant soups) or by heating with water in a saucepan for several minutes (simmer soups). Fifteen samples of these soups were analysed, the majority in powder form, with two soup types also analysed after reconstitution according to label instructions. A wide range of proximate, mineral and vitamin nutrients were analysed as FSANZ did not previously hold nutrient data for these products.
A major issue in the analysis of these foods was the complexity of the matrices, which generally contained large amounts of modified starches, oligosaccharides and salt. A number of the samples produced unacceptably low sums of proximates. This may in part be explained by the fact that analysis of oligosaccharides was not undertaken because the method available at that time was not considered adequate for our purposes.

2. Minerals in fruits and vegetables
FSANZ receives ongoing queries from consumers concerned that the nutrient quality of Australia’s food supply is deteriorating. In order to go some way towards generating information to address such concerns, FSANZ commissioned a small survey of levels of potassium, sodium, calcium, magnesium, iron and zinc in 44 types of Australian fruits and vegetables. The samples analysed were retained samples from earlier analyses of vitamins in common types of fruits and vegetables purchased in Melbourne, Australia in 2000 or 2001. Results were compared with the results of analyses conducted between 1981 and 1985 for the same items of produce purchased in Sydney, Australia.

Comparison of values at the two time periods did not indicate that there have been significant or consistent changes in the content of these minerals over this time. Overall mean potassium content of these items in 2000/01 and 1981-85 respectively was 230 and 220 mg/100 g, sodium was 9 and 8 mg/100 g, magnesium 15 and 11 mg/100 g, calcium 18 and 16 mg/100 g, iron 0.3 and 0.5 mg/100 g and zinc 0.2 and 0.3 mg/100 g. Comparisons of mineral levels measured at these two times must be made with caution as samples were collected in different locations, sometimes at different times of the year, possibly at different stages of ripeness, and in many cases were different varieties. In addition, the older analyses were conducted using a less sensitive analytical technique than the method used in 2000/01.

The release of the report of this survey (Cunningham et al. 2004b) generated significant media attention and illustrates that there is considerable community interest in the nutrient composition of foods.

3. Iodine in Australian foods
As evidence emerges of potential suboptimal iodine status among Australians, it is vital that up-to-date food composition data are available to support researchers and policy makers. Because there was little existing data on iodine in Australian foods, data were required across a broad range of foods. It was therefore decided to initiate a total diet survey using samples collected across Australia in two seasons. Samples for analysis were selected either because they are widely consumed in significant amounts (e.g. beef) and/or because they are anticipated to make significant contributions to iodine intake (e.g. milk, sushi).

This analytical program has only recently been completed and has not yet been made public. Data will be incorporated into the new food composition publication and are expected to also be released as a separate report.

4. Folates in Australian foods
A study is being conducted at present, with the University of New South Wales, to determine the level of folates and folic acid in 30 foods. As for the iodine survey, foods were selected for analysis either because they are widely consumed in significant amounts and/or because they are anticipated to make significant contributions to intake of naturally occurring folates or of added folic acid (e.g. fortified breakfast cereals). In contrast to the iodine survey, a considerable amount of Australian analytical data for folates has been generated in recent years, so the range of foods selected for analysis was narrower than for iodine. The analyses are being undertaken using the triple enzyme method and consideration has been given to reanalysis of previously analysed foods where prior use of the single enzyme method is
considered likely to have underestimated folate content (e.g. breads). Results of this analytical program will be incorporated into the new food composition publication.

5. Caffeine in Australian foods and drinks

In association with the Environmental Health & Chemistry Unit at Primary Industries Research Victoria - Werribee Centre, FSANZ undertook a survey of the caffeine content of caffeine-containing foods available in Australia. Food and beverages included coffees and teas (including the increasingly popular espresso and cappuccino styles of coffee), soft drinks and energy drinks, and products containing chocolate such as biscuits, drink bases and breakfast cereals. Results of this analytical program will be incorporated into the new food composition publication and have also been extremely valuable to FSANZ in undertaking standards development work.

Vitamin D in Australian foods

A small number of vitamin D analyses (25-hydroxy vitamin D and cholecalciferol) in fish, eggs and baked goods were undertaken shortly before the 6th OCEANIAFOODS meeting. Detectable levels of 25-hydroxy vitamin D were found only in fried shark and calamari. Detectable levels of cholecalciferol were found only in carrot cake, egg yolk, canned salmon, tuna and sardines, bream, flathead and mulloway, with all values close to the detection limit (1 μg/100 g). Surprisingly, detectable vitamin D levels were also found in scones containing fruit. Scones generally have low fat contents and do not usually contain eggs or large amounts of butter. The findings suggest the need for a more robust method of analysis with lower detection and reporting limits.

Food composition activities outside FSANZ

The following material is not a comprehensive summary of food composition work undertaken outside FSANZ but is intended simply to provide indicative information about the range of work performed in recent years.

MLA (formerly Meat and Livestock Australia) has recently undertaken analysis of nutrients in a range of popular cuts of beef, veal, lamb and mutton. It is hoped that the results of this study will be released publicly in the future.

Dr Jayashree Arcot and her students at the University of New South Wales have been working on projects to analyse the folic acid contents of selected fortified cereals using the microbiological assay and LC-MS techniques. There have been a few publications in the area, notably Iwatani et al. (2003). Current work is focusing on the analysis of individual forms of folates in foods using LC-MS/MS techniques and validation of this method.

At Monash University, Jimaima Lako is undertaking research on anthocyanins in Australian and Fijian produce.

Queensland Health Scientific Services (QHSS) has been involved in iodine analyses and is currently re-analysing a range of cereal samples for iodine as part of some method validation for this analyte. A major focus of QHSS’s work has been on contaminant metals and in particular total and organic mercury in fish. Of other interest has been the speciation of fish using DNA sequencing, which may be relevant when identifying fish associated with consumer illness such as escolar, ciguatera or scombroid poisoning.

There are several commercially prepared programs available in Australia for purposes such as calculating nutrient intakes or preparing nutrition information panels, which draw on Australian nutrient data. For example, Xyris Software released FoodWorks Nutrition Labelling Edition using AUSNUT Special Edition data in 2002. They also released Food Choices the IT Way, a curriculum resource for secondary schools and colleges. The next major upgrade of
all FoodWorks editions is due in early 2005, with subsequent updates to include the new NUTTAB food composition data, and new Nutrient Reference Intakes for Australia and New Zealand once these are released.

Conclusion
Some significant food composition activities have taken place in Australia since the last OCEANIAFOODS meeting. It is hoped that the release of the next edition of NUTTAB will raise awareness of the importance of gathering high quality, current data on the levels of nutrients in Australian foods.

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COUNTRY REPORT– NEW ZEALAND FOOD COMPOSITION DATABASE (NZFCDB)

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Introduction

The New Zealand Institute for Crop & Food Research (CFR) and New Zealand’s Ministry of Health (MoH) jointly own the New Zealand Food Composition Database (NZFCDB). In July 2004, the Ministry renewed CFR’s contract for maintaining the NZFCDB for a further 3 years. Since the 6th OCEANIAFOODS meeting, there have been several developments relating to the database.

Dr Heather Greenfield reviewed the NZFCDB in 2003. A number of recommendations from the review (Greenfield 2003) have been incorporated in the renewed contract.

Approximately 2600 New Zealand source values are added annually. To date, the NZFCDB contains information on 2884 foods and a total of more than 252,900 values; 49.64% of these are from New Zealand sources and the other 50.36% are either from overseas, or are calculated or imputed values. Publications over the past 3 years include the sixth edition of the Concise Food Composition Tables (Athar et al. 2003), which was released in April 2003 and the revised version of the FOODfiles software program, which was released in October 2004 (Athar et al. 2004). To assist food manufacturers, information on the seven nutrients that must by law appear on nutrition information panels on food products is available free on the CFR website at www.crop.cri.nz.

The development of a web-enabled, relational database management system is nearly complete. The new system will improve the flexibility, usability and functionality of the database. Currently, features of the new system are being tested.

Several additional quality control measures have been implemented in the programme including the purchase of Reference Materials for vitamin B12, folate and selenium, and participation in the Swedish NFA proficiency testing programme for analysis of foods for proximates, vitamins and elements. In addition, work on quality indicators for data included in the database has been started to inform users of the quality of the data.

History of database partnership

The partnership between CFR (previously known as DSIR) and MoH goes back to the early 1980s when work on the food composition database was started. Since this time, the NZFCDB has grown considerably. The focus of this work has been on the ongoing analysis of foods, maintenance of the database resource and provision of publications and services for users.

NZFCDB is jointly owned by CFR and MoH and investment is being made by both parties. The MoH’s investment is mainly directed to the analysis of priority foods and data dissemination and CFR’s investment to the database management system.
Update

Database review

The recent database review, commissioned by the MoH and undertaken by Dr Heather Greenfield, is proof of a long-term commitment from MoH and CFR. The report (Greenfield 2003) is available on the MoH website and was carried out between February and June 2003. It includes a review of all relevant MoH NZFCDB files and documents; a review of current practice, documents and NZFCDB products of CFR; interviews with key stakeholders, users and suppliers of the service; interviews with members of the Food Composition Steering Committee (FCSC); and a review of data held within the NZFCDB.

Key results from the review of the NZFCD

Dr Greenfield’s key recommendations (Greenfield 2003) are summarised as follows:

- CFR was providing an excellent service to the MoH as per contract.
- Programme policy was focused on frequent outputs but output could be reduced to a biennial rather than an annual issue of FOODfiles and a triennial rather than biennial issue of the Concise New Zealand Food Composition Tables. Other outputs should remain the same as before.
- Current analytical facilities and sampling practices are now adequate to permit the replacement of many non-analytical data with original NZ analytical data.
- The Key Foods concept could be applied in developing a rolling programme of analyses to keep data up to date.
- Data quality was a major driver of the current laboratory analytical programme. This could be extended so that quality codes are shown for all data held in the NZFCDB.
- Data scrutiny for the compilation process could be undertaken by experts from the FCSC or from food industry groups.
- The NZFCDB investment could be more extensively exploited by using its data within food balance sheets, food monitoring, and other research on the NZ food and nutrition landscape.
- Discussions with Maori and with Pacific peoples should be revived to seek input and maintain relevance for them.
- More input from all stakeholders is needed, particularly from community health organisations, the food industry, agricultural experts and software providers.
- The NZFCDB software products should be cheaper to purchase, and available in a range of formats. Marketing and publicity could be improved.
- Urgent discussions with Australia are needed, in view of the adoption of the joint Food Code, to cover compliance of the NZFCDB with Standard 1.2.8, harmonising of the two national databases, inclusion of data on food ingredients, data sharing and exchange, product pricing and the development of reference materials on regional food composition.
- Priced training modules are needed for food composition data users.
- The complete report is available on the New Zealand Ministry, Public Health Intelligence website under Publications. www.moh.govt.nz/phi
New database contract

In July 2004, the contract was renewed for 3 years ending June 2007. The key elements of the contract are:

Ongoing development of food and nutrient datasets including the analysis of priority foods and implementation of review recommendations. This includes the release of FOODfiles biannually and the release of concise tables every 3 years, plus the adoption of a key foods and nutrients approach in prioritising foods for analysis.

Interacting with the user community involved in the formation of the Food and Nutrition Advisory Group (FNAG) to monitor and discuss the development of the food composition database. The revised FNAG represents dietitians, nutritionists, the food industry and academia.

Explore the ways to use food composition in nutrition epidemiology research.

NZ Food Composition Database

To date, the NZFCDB contains information on more than 2700 foods. In total, there are more than 229 000 values in the dataset. Of these, roughly 50% are NZ-sourced and are focused on issues of importance in NZ such as food supply, staples etc. The other 50% are a combination of overseas, calculated and imputed values. There is comprehensive documentation on the sampling and analytical plans and, where possible, information on mean, standard deviation and standard error.

Addition of new foods to the database

The analysis of food is ongoing and under the MoH contract we are committed to add 2600 NZ source values annually. Hence, every 6 months we prioritise approximately 27 foods for analysis. The selection of foods for the analyses is based on user demand, market share, food industry practice, request from public health organisations, food related legislation, public health significance and to replace overseas values.

Quality control measures

To ensure the reliability and reproducibility of the data, we have maintained our involvement in the AOAC interlaboratory trials for fatty acids, and a Swedish proficiency trial for proximates, vitamins and elements.

Standard Reference Materials are being purchased from NIST (National Institute of Standard and Technology) for folate, vitamin B12 and selenium.

Once the data are entered in the database, several integrity tests are performed before data dissemination, for example sum of proximates, sum of fatty acids per 100 g of total fatty acids, and sum of fatty acids per 100 g of edible fat.

The check samples are also sent regularly with other samples to ensure the reliability of the results.

Latest releases of printed and computer products

Once the new data have passed all the quality checks, the data are made available to users via computer and printed product. FOODfiles, an electronic version of a subset of the NZFCDB, is released biannually around September/October.

FOODfiles 2004, published in October 2004, has more than 2600 foods with complete information on 48 nutrients and is available on CD-Rom with an electronic PDF format FOODfiles Manual.
The Concise New Zealand Food Composition Tables, a printed copy consisting of approximately 900 foods and 28 components, is now released every 3 years. The sixth edition of the concise tables was released in April 2003, containing information for both 100g edible portions and common servings of each food.

The NZFCDB also annually updates the information on fortified foods which is supplied by the Manufactured Food Database.

Information on 700 dietary supplements is also available with FOODfiles on request at no additional cost. This information has been compiled by the Institute of Environmental Science and Research.

**Nutrition Information Panel (NIP) website**

The NIP dataset has information on seven nutrients for 2550 food ingredients and is available on CFR’s website: www.crop.cri.nz/home/products-services/nutrition/index.jsp. These seven nutrients are mandatory for nutrient labelling in Australia and New Zealand: energy (kJ), protein, carbohydrate, sugar, fat, saturated fat and sodium. This dataset is specifically designed for food manufacturers for calculating the NIP values of their food products.

**New Zealand Food Composition Database website**

The NZFCDB website is being redesigned to make it more interactive. There will be a facility to receive and respond to user queries, information on anomalies in the database, and updates on new foods and nutrients. Users will become familiar with an outline of the process used to select priority foods, and will be able to access information on new database products and consultancy services, and upcoming national and international meetings. This website will also outline the role of the Food and Nutrition Advisory Group (FNAG) and list the members of FNAG.

**New Database Management System**

The NZ Food Composition Data has been on an Advanced Revelation Database Management System for the past 14 years, but this has outlived its use in recent years. This old management system is client-based, has a pre-set reporting format, lacks flexibility, and has become inefficient due to loss of some if its functionality. Hence, it was necessary to make a change. The new web-enabled Relational Database Management System will offer more flexibility, usability and functionality and is due for completion in mid-2006.

The new system is designed to accommodate foods, nutrients and recipe changes with ease. For reporting purpose, foods and components can be grouped together in any number of user-defined combinations. The new system can give a lot more information to users, such as “it is gluten free”, “it is halal”, “it contains traces of peanuts”.

**References**


USING FOOD COMPOSITION DATA IN THE PACIFIC ISLANDS – SPC PERSPECTIVE

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Keywords: Risk communication, food composition, publications, nutrition.

Abstract

The Secretariat of the Pacific Community (SPC), based in New Caledonia, includes the Lifestyle Health Section which has a role to support its member countries in improving nutrition and dealing with the problem of non-communicable diseases. SPC covers 22 Pacific Island countries and territories and also has a sub-office in Fiji. While previously the LHS was more actively involved in the food analysis area, including a role in the development of the first edition of the Pacific Islands Food Composition Tables, this is no longer part of its remit, and it now relies on other organisations within the region to fulfil that role - particularly the Institute of Applied Sciences in Fiji. It continues to support analysis work as its budget permits.

Increasingly the LHS has focused on information dissemination and capacity building, in order to complement other agencies' activities. The dissemination of food data throughout the region is vital yet difficult given the region's geography and communication links. SPC is ideally placed to take on this role as it is a regional organisation, with a number of established communication tools at its disposal. SPC also includes a number of other relevant sections, including Agriculture and Fisheries sections, and a Community Education Training Centre. All of these have also been involved in supporting information dissemination.

Examples of some activities over recent years:

- Information dissemination and risk communication: newsletter articles, email notices (via listserv), posters, factsheets, leaflets, handbooks, website.
- Capacity building and technical support: email-based and in-country on request support, informal training sessions on software.

Introduction

The Secretariat of the Pacific Community (SPC), based in New Caledonia, includes the Lifestyle Health Section which has a role to support its member countries in improving nutrition and dealing with the problem of non-communicable diseases. SPC covers 22 Pacific Island countries and territories and also has a sub-office in Fiji. While previously the LHS was more actively involved in the food analysis area, including a role in the development of the first edition of the Pacific Islands Food Composition Tables, this is no longer part of its remit, and it now relies on other organisations within the region to fulfil that role - particularly the Institute of Applied Sciences in Fiji. Increasingly the LHS has focused on information dissemination and capacity building, in order to complement other agencies' activities.
Background

While the name of the section has changed several times, SPC has had a section covering nutrition for decades. It has also during this time been involved in food composition work.


1980s: Food composition co-ordinator - support for two Pacific laboratories and assessment analysis needs.

1980s - 1990s: More food analysis. Publication Leaves We Eat (Bailey 1992) was completed.

1994: Pacific Islands Food Composition Tables (Dignan et al. 1994) launched (with INFOODS and NZ Institute for Crop and Food Research). Computer software was also developed: Diet1.

In the intervening years SPC has continued to support countries with their use of food composition data and the use of Diet1, acting as an advisory service and also the main distribution point for both the software and handbook.

In 1999 the handbook Staples We Eat (Malolo et al. 1999) was released, and was followed in 2001 by Fruits We Eat (Malolo et al. 2001) and in 2003 by Les feuilles vertes que nous mangeons (Bailey 2003).

During the 1980s and 1990s, the set of food leaflets on Pacific Island foods was begun. This set now numbers 18 and continues to be one of the most popular resources for community education and awareness-raising.

The French version of the 1994 Pacific Islands Food Composition Tables was completed in 2003 (Table de Composition des Aliments du Pacifique).

Update

Ongoing role of SPC

The dissemination of food data throughout the region is vital, yet difficult given the region’s geography and communication links. SPC is ideally placed to take on this role as it is a regional organisation, with a number of established communication tools at its disposal.

Information dissemination and risk communication

An important element of information dissemination is ensuring that the target audience can understand the information provided. One key problem in the region is the lack of trained nutritionists who are able to interpret food composition data. This means that SPC needs to ensure that the in-country staff are supported in their use of data, by presenting data in easy-to-use formats, along with background information and also by providing training. Some examples in recent years include:

Articles in our regular newsletter PIN, for example on mercury in fish, vitamin A, iron and zinc. PIN has a distribution of 1000+, but also has wider dissemination via reproduction of some articles in other national newsletters and in local media.

Email notices on our listserv pacnut. The distribution list is only about 150, but is extensively shared and used as a source for media releases articles.

Posters which present composition data in an easy to follow manner, for example hidden fats and sugars in foods, nutrient-based food groups.
Factsheets on key nutrients (e.g. fats, sugars, vitamin A) which include lists of rich sources.

Planned update and expansion of food leaflet series (funding pending).

Use of other media e.g. website: www.spc.org.nc/lifestyle/

Within the region, countries are using data and the software in a variety of ways, including:

- For assessment of individual diets during dietetic consultations.
- For identification of nutrient-rich foods for promotional activities (for example iron-rich foods for women with anaemia).
- For analysis of nutrition survey data.

**Capacity-building and technical support**

Email based and in-country technical support as requested. Typical queries might be on good sources of a particular nutrient, how to interpret data on cooked versus raw foods and on how to compare local vegetables with imported ones.

Training has included in-country workshops on the three food groups and food guide.

Informal training sessions on Foodworks (Foodworks software from Xyris, Australia). Xyris donated a copy of Foodworks to SPC, and this enabled us to offer informal one-to-one training for staff in-country and at all regional workshops.

**Use within SPC**

The food composition data are frequently referred to in our daily work, not only to answer queries from the region, but also to support the development of articles and resources. For example, the Diet1 software was used in the analysis of country diets for the research involved in developing the Pacific Food Guide (SPC 2002). More recently, Foodworks was used to assist the SPC's statistics session in their development of a healthy food basket for poverty assessment studies.

Other sections and programmes within SPC also use food composition data. For example, the Fisheries section has been using the PIN article on mercury in fish as a handout during some of its fisheries training. The Agriculture section uses data on nutrient values in a similar way. The Community Education Training Centre (CETC) training course incorporates nutrition information, including food composition.

**Conclusion**

The health problems of Pacific Islanders are changing. Many countries may now be less interested in iron levels, and more interested in fat and cholesterol. Nutritional composition and contaminant data remain a vital tool for health workers and others within countries and at the regional level. As evidence of links between foods and drinks and health expands, we also need the data available on Pacific Islands foods to keep pace. It was good to see that the most recent tables now include cholesterol. Hopefully the next will include types of fats, possibly more information on antioxidants, and even the glycaemic index!

Analysis of local foods needs to keep pace with analysis being done in our neighbouring countries, so that we can continue to effectively promote our local foods as being beneficial to health. Imported foods are becoming more accessible – and often their attractive packaging and clever marketing can suggest they are superior to local foods nutritionally. We therefore need good data on local foods to be used in marketing strategies for local foods.
Another ongoing challenge will be in ensuring that the data is used effectively and with care within countries. It is easy for data to be misinterpreted by those who have not been trained. In this region, this is certainly a problem as we are short of trained staff – particularly in nutrition. In this regard the use of communication tools such as the three-food-group system (SPC 2002a) will continue to be important.

Acknowledgement
I would like to finally acknowledge the work of the Institute of Applied Sciences at the University of the South Pacific for their ongoing work in food analysis. Without them the region would be much poorer in terms of food data, and we at SPC appreciate their collaboration.

References
COUNTRY REPORT: FIJI

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Abstract

The main activity during the period since the 6th OCEANIAFOODS meeting has been centered around the regional Food and Agriculture Organisation (FAO) project “Strengthening Food Analytical Capabilities in the Pacific Region.” The goals of the project were to:

- upgrade analytical capacity in Fiji, Tonga, Samoa, Solomon Islands and Vanuatu, especially in proximate analyses;
- generate data for priority foods and nutrients not currently present in the Pacific Island Food Composition Tables (PIFCTs);
- train a group of technicians in food composition data compilation and pesticide and heavy metal analysis;
- get accreditation of the IAS Laboratory;
- publish the second edition of the PIFCTs.

The project ran from April 2002 until August 2004 and was successful in meeting all of the project goals. It was agreed that the participating national laboratories focus on developing and improving their capacity to do proximate analyses and the more complex analyses would mainly be done at the regional laboratory at USP. The food nutrient laboratory was formally accredited by International Accreditation New Zealand (IANZ) in July, 2004. The second edition of the PIFCTs was published in August, 2004.

Current work at IAS is focused mainly on performing the first Total Diet Study for Fiji. Contaminant and iron analyses are being conducted for 35 foods in 10 food groups. These data, along with food composition data obtained by the Fiji National Food and Nutrition Centre from their Second National Nutrition Survey, will be used to estimate weekly intakes of iron, cadmium, arsenic, lead, mercury and organochlorine and organophosphate pesticides.

The laboratory has also carried out targeted contaminant studies on mercury in fish, arsenic in water, cadmium in taro, cyanide in cassava and Salmonella spp in poultry products, mainly for the World Health Organisation. Finally, a postgraduate student has validated a HPLC niacin method discussed at previous OCEANIAFOODS meetings that does not require use of cyanogen bromide.

Introduction

The main analytical work for food nutrients in Fiji is done at the Institute of Applied Sciences (IAS) at the University of the South Pacific (USP). Work on proximates is also done at the Government Agricultural Laboratory.

Users of these data include the Ministry of Health, mainly through its National Food and Nutrition Centre, and the food industry. Because USP is a regional facility, it also services 11 other Pacific Island countries and works closely with the Secretariat of the Pacific Community (SPC) in New Caledonia and the regional offices of WHO and FAO.
Background

The Institute of Applied Sciences at USP was set up in 1977 to provide scientific services to the region. Its core facility is the Analytical Laboratory. Proximate and mineral analyses were set up at the outset as part of its core set of analyses. In 1983, a project to investigate nutrient changes during traditional breadfruit fermentation added three vitamins (thiamin, riboflavin and ascorbic acid). In the early 1980s, regional meetings had called for more local nutrient analysis of Pacific foods (SPC 1988). An SPC project followed in the late 1980s to look at the regional capability of possible laboratories and also worked with New Zealand to publish the Pacific Island Food Composition Tables (PIFCT). An associated initiative to assist Pacific nutrient laboratories was the establishment of the OCEANIAFOODS group, which had its first meeting in May 1987.

Further major advances at the USP nutrient laboratory have been dependent on major external funding with minimal maintenance activities in the interim. These have been facilitated by endorsement and active support from OCEANIAFOODS and its members. The development of a reasonably full modern nutrient analytical facility was achieved through a project with the Australian Centre for International Agricultural Research (ACIAR) and the Australian Government Analytical Laboratory in the mid-1990s. Carbohydrate fraction analysis was implemented together with vitamin analyses using high performance liquid chromatography (HPLC). A number of Pacific Islands fruits, nuts and green leaves were analysed during this project (English et al. 1996).

At the 5th OCEANIAFOODS meeting in 1998, Dr Barbara Burlingame suggested a follow-up funding proposal be formulated for submission to FAO. This was done in 1999 but funding was not approved until 2002. In the interim, a postgraduate student undertook a project to look at nutrient changes when traditional foods are cooked in a traditional earth oven (Aalbersberg & Kumar 2002).

Update

The FAO project was the focus of work during this period. In addition to continuing nutrient analysis, it was hoped that the new analytical values generated since the publication of the PIFCT could be included in a second edition. Important missing foods and other improvements had been suggested at the regional workshop in 1994 at which the original tables had been launched. It was also hoped that the IAS laboratory could complete the requirements to receive international accreditation.

Given the enhanced importance of food contaminants in international trade, as well as health, the project also sought to expand the range of these activities at IAS. Pesticide analyses for a screen of organochlorines and organophosphates were to be developed, as well as enhanced skills in detecting low-level residues of heavy metals. To satisfy the requirements of the FAO Technical Cooperation for Developing Countries initiative, the project also included a regional component to enhance the food analysis capabilities and infrastructure in five Pacific Island countries. The list of expected outputs of the project is given below:

Output 1: An assessment of the analytical capacity of food laboratories in five participating countries.

Output 2: Upgraded analytical capability for food analysis in the participating countries.

Output 5: A minimum of 10 technicians trained in food data compilation.

Output 6: A minimum of 10 technicians trained in basic food analysis.

Output 7/8: A minimum of 10 technicians trained in pesticide/heavy metal analysis.
Output 9: A regional workshop at the end of the project.
Output 11: Achievement of International Accreditation at IAS.

In the main the objectives were met, except for the number of technicians trained in food data compilation (one only). Adjustments needed to be made because it was realised that many Pacific Island countries would be stretched to implement food analyses beyond basic proximate analyses, and so in training less emphasis was placed on food contaminants and more training was focused on quality assurance for existing analyses. It was also challenging to navigate the FAO administrative system, with different tasks performed in Apia, Bangkok, Suva and Rome.

The second edition of the PIFCTs (Dignan et al. 2004) included new analyses in the following groups:
- green leaves (25)
- fruits/nuts (20)
- legumes (3)
- sea foods (12)
- “lovo” foods (24)
- snacks (6)
- drinks (8).

In addition, missing nutrient data were obtained either by analysis or from other tables for about 300 of the 1000 entries in the table. Niacin data were given to one decimal place rather than simply as whole numbers. In addition, an entry was made for retinol-equivalent activity to reflect recent research findings about the lower retinol activity of carotenes than previously determined (FNB, IOM, 2000).

IAS had for some years been working on setting up its quality management system. This received further impetus when Douglas Pharmaceuticals of New Zealand set up operations in Fiji in 1998 and sought to use IAS services, but required it to follow good laboratory practice. The initial Douglas Pharmaceuticals management in Fiji were helpful in sharing their knowledge and standard operating procedures.

Under the FAO project, an informal audit of the IAS quality system was made by Environmental Science and Research Ltd. of New Zealand. The initial focus of the accreditation was food nutrient analysis, because much of the quality assurance work for this had been performed as part of the ACIAR project. The assessment by International Accreditation New Zealand was done in December 2003 and accreditation was recommended once a few corrective actions were carried out. These were done and accreditation was awarded in June 2004. Assessment has also now been carried out for water quality analysis and microbiological analyses of food and water, and both have been recommended for accreditation.

A gas chromatograph system was set up for organochlorine and organophosphate analysis. Excellent results have been obtained in proficiency studies. A project with the SPC Agricultural Division has used the IAS laboratory to ascertain residues in taro samples treated with different organophosphates for taro beetle control.
Polychlorinated biphenyl samples have also been analysed to check oil and soil samples as part of monitoring under the Stockholm Convention, an international agreement to stop the production and use of persistent organic pollutants (POPs).

These pesticide analyses are also being done on food samples from the Fiji Total Diet Study. This project was formulated to use the new skills developed under the FAO project on food contaminants and also to determine the average weekly intake of pesticides and heavy metals in a Pacific Island country. Funding is generously being provided by the New Zealand government.

A procedure manual has been prepared, which consists of the following:

- Project Management
- Food Purchasing Instruction
- Food Preparation Procedures
- Project Timeline
- Sampling Schedules
- Analytical Plan
- Purchasing Checklists
- Sample Receipt Checklists.

The selection of the food list was based on the National Nutrition Survey 1993 performed by NFNC, on the ACIAR Food Choices data for 24 hours recall, as well as from the:

- selection of regional foods most commonly available in municipal markets and road stalls in terms of staples, meat, fruits and vegetables;
- most commonly available national food items in the food group that contribute towards 70% of the supermarket share; and
- particularly from market observations on what is commonly distributed, available and cheap to buy in all supermarkets and municipal markets, corner stores and road stalls.

Thirty-five (35) food items have been identified as commonly consumed. The food items are grouped in 11 major food groups (see table below). There are six food categories in the national food list with a total of 17 food items, and seven food categories with 18 food items in the regional food list. National foods are expected to have uniform contaminant levels throughout Fiji, whereas regional foods are mainly agricultural products grown locally. Owing to the possibility of geographical and seasonal variations, regional food samples will be collected at two separate locations over two different seasons.

Table 1: Food groups and foods in Fiji Total Diet Study.

| A | grains | wheat flour, rice |
| B | poultry and meats | whole chicken, eggs, corned mutton, corned beef, beef cuts |
| C | seafood | tinned mackerel, reef fish, mussels, tuna flakes |
| D | drinks | beer, water sources (4) |
| E | oils | soya bean, ghee, canola, coconut cream |
| F | dairy products | milk, butter, ice cream |
| G | root crops | taro, cassava |
| H | fruits | pawpaw, bananas, pineapples |
| I | legumes | long beans, split peas, eggplant |
| J | vegetables | taro leaves, Chinese cabbage, amaranth |
| K | sugar | |
Foods will, in general, be analysed as composites of food groups. Analysis of iron in the samples will also be done, as well as pesticides and heavy metals, due to the high incidence of anaemia in Fiji. Some samples will also be analysed in New Zealand, especially when lower detection levels are required. The levels of analyte in each group when multiplied by the weekly food consumption of the food group will give the weekly analyte consumption. Food consumption data have been collected in the 2004 National Nutrition Survey and are currently being analysed.

**Other uses of analytical data**

Besides their eventual use in the National Nutrition Survey to determine national nutrient intake, the PIFCT data have also been used for an ACIAR-Ministry of Health project on Food Choices. Modelling software was developed to determine low-cost diets that also meet daily nutrient requirements.

For the past 2 years, the IAS laboratory has also been doing monthly analyses of feed samples to help Crest Chicken (Goodman Fielder) to develop chicken feeds from local ingredients. Nutrient analyses were also done to prepare a few nutrient labels and, in association with Dr Lois Englberger, to determine superior cultivars of traditional foods in Micronesia (Englberger et al. 2006). Other food contaminant work is also presented in Aalbersberg (2006).

**Future plans**

In the area of nutrient analysis, major Pacific foods have now been included in the latest version of the PIFCT. The laboratory is considering extending the range of analytes to include trans fatty acids and folates.

For food contaminant work the main initiative is to establish the laboratory as a regional centre for the analysis of POPs under the Stockholm Convention. One article in the Convention requires that monitoring be undertaken to judge the effectiveness of the Convention, which will mean that samples will need to be taken around the world. It is likely that human milk and air samples will be the matrices for a minimum assessment of health and environmental effects.

**References**


EXPANDING THE CANCER RESEARCH CENTER OF HAWAII’S FOOD COMPOSITION TABLE FOR USE IN OTHER PACIFIC ISLANDS

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Keywords: food composition databases, database developers, dietary assessment programs

Abstract

Objective: Food composition data for the United States mainland are often not appropriate for use in the state of Hawaii, and are even more problematic for use in other Pacific Island locations. Therefore, the Cancer Research Center of Hawaii (CRCH) has developed a food composition table which includes common foods in Hawaii, and is in the process of expanding it for possible use in other Pacific Islands.

Method: We supplement food composition data from the US Department of Agriculture with food analyses, recipes, and published data from other food composition tables. An analytic laboratory at CRCH provides analyses of nutrients and other components of local foods. Recipes for mixtures are obtained primarily from recipe books. Data from the Pacific Islands food composition tables are particularly relevant if the CRCH database is to be used in other Pacific locations.

Results: Although approximately 28% of the 2300 food items on the CRCH database are unique to Hawaii, the majority of these unique items are mixtures rather than basic food ingredients. An examination of diets in Guam also shows that the mixtures, rather than the ingredients, are more likely to be unique to Guam. Thus, to expand the CRCH database for use in Guam, we are currently entering data for approximately 100 local recipes. We are also collecting information on diets and recipes in several other Pacific Island locations, with the goal of further expanding the CRCH database. Eventually, we plan to incorporate the database into a publicly available web-based dietary assessment program (PacTrac).

Conclusion: The combination of an expanded food composition table and a readily-available dietary assessment program may be useful to researchers and educators who wish to analyse diets for selected Pacific Island populations.

Recommendation: Collaborations between developers of food composition databases in various Pacific Island locations may be beneficial in providing databases that are appropriate for use in multiple settings.

Introduction

Cancer Research Center of Hawaii (CRCH)

The Cancer Research Center of Hawaii (CRCH) is a research unit within the University of Hawaii. A major focus of the research conducted at CRCH is on associations between dietary intakes and cancer risk. These studies are unique owing to the multicultural environment of the state of Hawaii. In the year 2000, the state had 1.2 million residents, of which 24% were Caucasian, 20% Native Hawaiian, 19% Japanese American, and 17% Filipino. The remaining 20% of the population was primarily of Asian ethnicity, including Chinese, Korean, and Southeast Asian. Most of these ethnic groups maintain distinct food habits, and also have
different cancer incidence rates. Thus, this is an ideal population in which to study dietary factors that might either increase or decrease the risk of various types of cancer. Several ongoing studies of diet and health require accurate and current food composition data.

**Multi-Ethnic Cohort (MEC)**

To take advantage of this unique environment, a large Multi-Ethnic Cohort (MEC) was established in 1993-96 (Kolonel et al. 2000; Stram et al. 2000). The MEC includes over 215,000 participants from the three major ethnic groups in Hawaii (Caucasian, Native Hawaiian, and Japanese-American) as well as two ethnic groups recruited from California (African-American and Latino). At baseline, each participant completed a 26-page mailed questionnaire that included a quantitative food frequency questionnaire, as well as information on demographics and lifestyle variables. Since baseline, additional information has been collected periodically by mail, and cancer incidence and mortality is determined through cancer registries as well as from death records.

**Partnership with University of Guam**

The CRCH and the University of Guam have undertaken a pilot study to evaluate risk factors for chronic disease among adults in Guam. The goal is to develop instruments and methods for measuring dietary and anthropometric risk factors, with a particular focus on cancer risk. In particular, the project will build on the protocols and databases developed at CRCH, including a food composition table, a recipe database, and a food frequency questionnaire. A survey is being conducted of a sample of 120 adult Chamorros and Filipinos living in Guam.

**Healthy Living in the Pacific Islands (HLPI) Initiative**

The Healthy Living in the Pacific Islands (HLPI) initiative is conducted by the Department of Human Nutrition, Food and Animal Sciences at the University of Hawaii. The goal of the HLPI is to reduce the disparity in the prevalence of chronic diseases by respecting cultural values using community-based, holistic, collaborative, sustainable approaches in Pacific Island communities. One of the objectives of this initiative is to increase production and consumption of healthy, locally-produced foods. Several Pacific Island communities are currently collecting dietary data for approximately 50 residents, with the goal of identifying commonly-consumed foods and recipes to include in a dietary assessment system for use in these locations.

**Healthy Pacific Child Program (HPCP)**

The Healthy Pacific Child Program (HPCP) builds on the collaborations established as part of the HLPI to conduct both dietary surveys and intervention studies to promote healthy diets for children in the Pacific Islands. An initial dietary survey is in process in the Commonwealth of the Northern Mariana Islands (CNMI), and pilot studies have been conducted among children and their mothers in Hawaii.

**Need for food composition data for the Pacific Islands**

All of these studies include a dietary assessment component, and thus will require food composition data to determine nutrient intakes. Furthermore, the collaborating institutions have a need for a dietary assessment system that can be incorporated into local education programs and can also be used to evaluate the outcomes of future dietary intervention programs.
Methodology

Sources of food and supplement composition data

The CRCH food composition table is primarily a compiled user database. The data come from the US Department of Agriculture Standard Reference Database, release 16.1 (USDA 2004), as well as from various international and commercial publications. In addition, selected local foods are analyzed in the laboratory to obtain estimated values for components such as flavonoids, isoflavonoids, ascorbic acid, carotenoids, and tocopherols. For mixtures, recipes are developed using data from USDA (2000b), as well as information from local cookbooks. Dietary supplement labels are the primary source of composition data for the CRCH supplement composition table. These data are frequently available at manufacturers’ web sites, and also may be collected from the labels of purchased dietary supplements.

When expanding these composition tables for use in other Pacific Islands, two primary resources are being used. Recent analytical data for Pacific Island foods are available from Dignan et al. (2004). Recipe data for mixtures in Guam have been compiled by the University of Guam Extension Service (Benavente et al. 1999). Typical recipes for other Pacific Island locations (CNMI, Palau, Chuuk, and the Marshall Islands) are being collected as part of the HLPI initiative.

Interactive Healthy Eating Index (IHEI) program

The Interactive Healthy Eating Index (IHEI) is a user-friendly, web-based dietary data evaluation program. The IHEI was developed by the U.S. Department of Agriculture (USDA, 2005). For the data collection component, users enter the foods consumed in a day, along with the portion sizes for each. Food names are selected from an extensive list using a word search feature. The IHEI also has an informative evaluation component. It provides nutrition education to users by evaluating the person’s dietary intake using national dietary recommendations. The food list and the food composition database for the IHEI were developed for use with the U.S. national nutrition surveys. Data are available for 25 nutrients for over 6000 foods. In addition, the servings of six food groups, corresponding to the Food Guide Pyramid food groups (1992), are available for each food on the database.

The IHEI was modified for use with Pacific Island populations. The food composition table was updated to contain local foods for Hawaii. Another change to the IHEI program was to separate the data collection and educational components, so the program could be used in longitudinal studies in which feedback to the participants was not desired. Other minor changes were made to facilitate use of the program in dietary research studies. The resulting modified program is called “PacTrac” (Pacific Tracker).

Results and discussion

Several inter-related databases have been developed to analyse dietary data from Hawaii residents, and are being expanded for use in other Pacific Islands. Ultimately, the PacTrac dietary assessment program will use these databases to provide a convenient, web-based system for use in both dietary research studies and nutrition education programs.

CRCH food composition database

The CRCH has a unique and extensive food composition database containing foods commonly eaten by several ethnic groups in both Hawaii and California; it is regularly updated and expanded. Currently the database contains 1532 foods and ingredients. This database is proprietary and is available only to members of the Cancer Research Center of Hawaii. However, specific values can be viewed through the PacTrac program.
(www.crch.hawaii.edu/pactrac). The database contains levels of 146 nutrients and food components per 100 grams. The dietary components were selected with a particular focus on those thought to be associated with the causes and prevention of cancer. In addition to a wide array of macronutrients and micronutrients, the CRCH database includes values for flavonoids (quercetin, rutin, kaempferol, myricetin, hesperidin glycosides, naringin glycosides), isoflavonoids (genistein, daidzein, glycitein), lignans (secoisolariciresinol, matairesinol), conjugated linoleic acid (rumenic acid: c-9, t-11 isomer), and glycaemic load. The basic food ingredients on this database will be expanded to include unique Pacific Island foods, such as the Karat banana.

**CRCH supplement composition database**

A supplement composition database is also maintained because dietary supplements are widely used in Hawaii (Foote et al. 2003). The CRCH database contains composition information for 3405 dietary supplements, including 347 single nutrient products, 419 multivitamin products, 230 multimineral products, 2167 multivitamin plus multimineral products, and 242 herbal or non-nutrient products. The supplement database has the same 146 nutrients and food components as the food composition database, plus an additional 60 nutrients, food components, and herbs (e.g., fluoride, soy protein, Echinacea) per dose of the supplement. Although there are currently no funds to update this database with supplements that are unique to other Pacific Islands, or to include the analysis of supplements in the PacTrac system, it is a longer-term goal to add this feature.

**Supporting databases**

A recipe file is used to determine the ingredients in food mixtures reported by study participants. This database contains the proportion for each ingredient, as well as the yield of the recipe. The CRCH database currently has approximately 840 recipes, over half of which were locally developed. Approximately 100 recipes from Guam are currently being added to the file, and will be available through the PacTrac system (pactrac.crch.hawaii.edu). As they become available, recipes from other Pacific Islands will be included as well.

A food group servings database indicates the servings of 30 different food groups that are contained in each food item on the MEC food frequency questionnaire, using the recipe file to determine the ingredients in mixtures. For example, a cup of chili would contain 0.5 servings of legumes and 0.3 servings of tomatoes. The servings are from a database supplied by the U.S. Department of Agriculture (2000a), and are based on the Food Guide Pyramid, a consumer guide to healthy eating that was developed by USDA (USDA 1992). Using this information, it is possible to calculate the number of servings consumed from each of the 30 food categories, and also to compare intakes with recommendations (e.g., whether a subject is consuming at least five servings of fruits and vegetables per day). As foods are added to the CRCH food composition table, the food servings database is also updated. Thus, both nutrient intakes and food group servings may be calculated for dietary data entered through the PacTrac system.

A third supporting database contains gram weight equivalents for various common (“household”) measures of foods (e.g., cups, slices, cans). This database will be expanded to include common measures for each of the Pacific Island foods and recipes, using data collected as part of the 24-hour dietary recalls.
PacTrac dietary assessment program

Initial updates to the PacTrac program have been completed, and the food composition database and the supporting databases have been updated to include all foods and recipes from the appropriate CRCH databases. These updates are continuing, and will include foods consumed in Guam and CNMI within the next few months. The PacTrac system is available through the CRCH website (pactrac.crch.hawaii.edu).

Conclusions and recommendations

Although approximately 28% of the 2372 foods and recipes on the CRCH databases are unique to Hawaii, the majority of these unique items are mixtures rather than basic food ingredients. An examination of typical diets in Guam also shows that the mixtures are more country-specific than the basic food items. Thus, future updates to the databases will focus on the collection of accurate recipe data, as well as on adding basic foods to the food composition table. The resulting expanded food composition table, incorporated into a readily-available dietary assessment program (PacTrac), may be useful to other researchers and educators who wish to analyze the diets of selected Pacific Island populations.

Collaborations between CRCH and developers of food composition data in other Pacific locations may be beneficial in providing databases that are appropriate for use in multiple settings. Specifically, given the state of Hawaii’s unique geographical location, it would logically belong to both Noramfoods and OceaniaFOODS. Membership in both Infoods regions would facilitate the sharing of composition data, as well as collaboration on data collection and analyses.

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THE USE OF FOOD COMPOSITION DATA IN THE DEVELOPMENT OF FOOD STANDARDS

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Keywords: food composition data, dietary modelling, food labelling, food standards.

Abstract

Comprehensive, scientifically robust food composition data are essential for the New Zealand Food Safety Authority (NZFSA) to deliver on its mission to protect and promote public health and safety through ensuring a safe and suitable food supply. The development of food standards takes place in a risk management framework. Food labelling and composition standards must be based on up-to-date, scientifically sound food composition data. This paper outlines how food composition data, for both caffeine and vitamin D, are being used in the development of food standards.

Introduction

The addition of caffeine to foods and beverages

At the Australia New Zealand Food Regulation Ministerial Council (ANZFRMC) meeting in April 2003, concerns were expressed regarding perceived high intakes of caffeine in children. As a result of this, both Australia and New Zealand were asked to determine caffeine intakes in vulnerable subgroups such as children. The purpose of this research was for the results to feed directly into the development of food standards for the addition of caffeine to foods and beverages as a means of managing caffeine intakes in children. Food Standards Australia New Zealand (FSANZ) was also asked to investigate a definition for cola. It was expected that developing a definition for cola would subsequently restrict the addition of caffeine to foods and beverages, thus restricting caffeine intakes.

New Zealand was well placed to undertake an estimate of caffeine intakes, as it had comprehensive, up-to-date food consumption data for children in the form of the 2002 National Children’s Nutrition Survey (CNS). The CNS provides robust intake data for 3275 children aged 5 to 14 years. Caffeine is not routinely analysed as part of the New Zealand food composition database, but caffeine concentrations in selected foods and beverages were provided by FSANZ from the Australian food composition program. The food composition data for caffeine were then incorporated into the CNS food database by Crop & Food Research. This was achieved by developing a nutrient line for caffeine in the database. The new data files expressed caffeine concentrations in foods commonly consumed by New Zealand children. The composition data were then sent to the Life in New Zealand Activity and Health Research Unit at the University of Otago where they were used to estimate caffeine intakes of New Zealand children using consumption data from the CNS.

Results of the research on caffeine intakes of New Zealand children

Caffeine intakes in New Zealand children aged 5 to 14 years were low. An average consumer among children in this age group would consume 15 mg of caffeine per day, which is equivalent to the amount in half a can of cola beverage.

Eighty-one percent of the sample population had consumed a caffeine-containing food or beverage. In either the whole sample population or caffeine consumers only, no demographic
subgroup exceeded the 3 mg/kg ‘safe’ (Pepsi Cola Canada 2002; Smith 2000) level at the 95th percentile for daily intake. The 95th percentile for daily intake in the whole sample population was 1.76 mg/kg body weight.

The main contributors of caffeine in the diets of New Zealand children were beverages (75%), of which the majority was soft drinks (46%) followed closely by tea (38%). Caffeine-containing energy drinks such as Red Bull and V contributed only 5% to caffeine intakes and they were the only source of guarana in the diet of New Zealand children.

At the ANZFRMC meeting in March this year, FSANZ advised that the search for a definition for cola had been unsuccessful. Because of this, and the fact that caffeine intakes in children were low, the ANZFRMC agreed to discontinue searching for a definition for cola. The management of caffeine intakes was deemed unnecessary, thus there was no longer a need to alter or develop new regulations for the addition of caffeine to foods and beverages.

**Nutrient fortification**

Dietary modelling, which is an essential component in the development of food standards relating to nutrient fortification, relies heavily on comprehensive, up-to-date food composition data. The NZFSA undertook dietary modelling of vitamin D intakes as a component of the research it commissioned on the vitamin D status of New Zealand adults and adolescents.

The diet is not the major source of vitamin D for New Zealanders, as very few foods are naturally rich in vitamin D and few foods are fortified. In New Zealand the majority of our vitamin D comes from exposure to sunlight. Vitamin D is synthesized in our bodies through the action of ultraviolet B light in the skin, therefore anything limiting the amount of light reaching the skin such as skin colour, sunscreen use, latitude, and season will reduce the skin’s synthesis of vitamin D. With the growing trend away from spending time in the sun, it is possible that vitamin D levels in the New Zealand population may be inadequate. The NZFSA therefore commissioned research on the vitamin D status of New Zealand adults and adolescents.

**Results of the research on the vitamin D status of New Zealand adults and adolescents**

Blood samples collected and stored as part of the 1997 National Nutrition Survey were measured for 25-hydroxyvitamin D, which is considered the best indicator of vitamin D status as it reflects the sum of vitamin D from the diet and exposure to sunlight. Serum 25-hydroxyvitamin D was determined using a DioSorin radioimmunoassay (Stillwater, MN) that measures both 25-hydroxyvitamin D₃ and 25-hydroxyvitamin D₂ equally. A cutoff of 37.5 nmol/L was used to define vitamin D insufficiency (Skeaff & Green, 2004).

The key findings from the research were that almost one third of participants had vitamin D concentrations indicative of insufficiency, placing them at an increased risk of developing osteoporosis and possibly other chronic diseases such as cancer. Pacific peoples were particularly affected, with 50% having vitamin D insufficiency, compared with 41% and 25% amongst Māori and New Zealand Europeans respectively. Using a cutoff of 17.5 nmol/L, 2.8% of New Zealand adults and adolescents had serum 25-hydroxyvitamin D concentrations indicative of vitamin D deficiency (Skeaff & Green, 2004). The vitamin D status of New Zealand children, as determined from additional research funded by the Ministry of Health, was virtually identical to the adult survey results. Using a 25-hydroxyvitamin D cutoff of 17.5 and 37.5 nmol/L for vitamin D deficiency and insufficiency respectively, 4% of New Zealand children had concentrations indicative of vitamin D deficiency and 31% had concentrations indicative of vitamin D insufficiency (Green et al. 2004).
Given the association between sunlight exposure and the development of skin cancer, promoting increased time in the sun as a means of improving vitamin D status may not be recommended. A strategy that increases vitamin D levels through dietary intervention such as mandatory fortification may be a more acceptable option.

**The use of dietary modelling**

Dietary modelling is the technique of combining data on food chemical concentrations in specific foods with food consumption data, in order to estimate dietary exposure to food chemicals. The term 'food chemical' includes food additives, contaminants, agricultural and veterinary drug residues, nutrients and food ingredients.

The primary objective in developing food standards is to protect public health and safety. As part of this, a scientific risk analysis must be conducted and comprises three major components, namely risk assessment, risk management and risk communication. Dietary modelling is predominately used in risk assessment but it is also used in risk management.

As part of a risk assessment, dietary exposure to the food chemical from all sources including diet, water and the environment is estimated. Dietary exposure assessments are used to assess the potential risk to health associated with proposed changes to the food supply. To determine if the estimated exposure to a food chemical is a concern to public health and safety, the estimated exposures are compared with reference health standards such as recommended daily intakes.

FSANZ currently conducts dietary exposure assessments for the development of food standards. They use a custom-made computer program called DIAMOND (Dietary Modelling of Nutritional Data). This is the dietary modelling software that the NZFSA used to look at various scenarios of fortification with vitamin D. Only very preliminary dietary modelling was conducted and if current fortification permissions for vitamin D were extended or mandated, a full risk analysis including comprehensive dietary modelling would be required.

**Future work**

An area that would be of interest to the NZFSA is the compositional analysis of wild foods in New Zealand. Wild foods can be defined as food which is gathered for non-commercial purposes, and includes many species of feral land animals, birds, fish, insects, fungi and fruit. It is important to recognize the diversity of the New Zealand food supply and the foods contributing to it. Future research could involve an expansion of the database looking at levels of nutrients and contaminants of wild foods in New Zealand.

There is an emerging international trend to label levels of trans fatty acids on foods. New Zealand would require comprehensive food composition data on trans fatty acids, to be able to look into the area of mandatory labelling of trans fats.

Work is currently being conducted on the development of food standards relating to nutrient fortification, in particular folic acid and iodine. There is an increasing range of fortified foods available on the New Zealand market, and the development of food standards in this area could lead to more being marketed. This has the potential to alter the composition of the food supply. Comprehensive, up-to-date food composition data, is an essential component for monitoring and ensuring the safety and suitability of the food supply.

**Conclusion**

It is a given that food composition data are essential for the development of food labelling and composition standards. Comprehensive, scientifically sound food composition data are essential for the NZFSA to deliver a safe and suitable food supply to all New Zealanders. In
the development of food standards, food composition and food consumption data are often used in tandem. It is important to have high quality types of both data, and the synergy that exists between the two should be highlighted.

Finally, there is an increasing variety of fortified foods on the market. The emergence and proliferation of functional and novel foods, and the increasing diversity of the food supply through an increasing popularity for ethnic foods, means the composition of our food supply could change considerably. The NZFSA believes that it is not only important to expand the database to accommodate for these changes, but there is also value in maintaining up-to-date, robust data on foods already in the database.

References


KEYNOTE ADDRESS

AUDIT OF THE NEW ZEALAND FOOD COMPOSITION DATABASE SERVICE 2003

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Keywords: audit, Ministry of Health, Crop & Food Research, food composition, programme.

Abstract

A contract between the Ministry of Health and Dr Heather Greenfield specified that “The Ministry requires an audit to assist with ensuring that the New Zealand Crown Research Institute, Crop and Food Research Ltd (C&FR) provides a quality New Zealand Food Composition Database (NZFCD) service. The audit will also assist the Ministry to ensure the satisfaction of the health sector and other key stakeholders in terms of the strategic overview of C&FR’s work and its defined outputs. The Contractor’s report will make recommendations to the Ministry about the NZFCD and the work of C&FR.”

Introduction

The current New Zealand food composition programme seems to have evolved in the 1980s with its origins in the Department of Scientific and Industrial Research (DSIR, Harris 1987). The Ministry of Health (MoH) has also always been involved with food composition work in New Zealand and has been the prime funding agency since the early 1980s. At that time, the programme consisted of three databases: the main nutritional database of raw data from New Zealand (NZ) laboratories; the New Zealand Food Composition Database (NZFCD) based on the United Kingdom (UK) tables (Paul & Southgate 1978) with additional and substituted NZ data; a therapeutic database of manufactured food products (Harris 1987; Burlingame 1990).

There was little guidance in the literature as to the appropriate methods for an audit of a food composition database programme. The only previous example obtained was an earlier review of the NZFCD Programme carried out by English (1991) for the Department of Health. This review focused on the needs of local users and had two main outcomes: first, the separation of the Therapeutic Database from the Food Composition Database (now referred to as the Manufactured Food Database, MFD), and, second, the recommendation to provide a concise tabulated version of the food composition data, in a spiral-back format for ready reference by users, notably dietitians, nutritionists, teachers and students.

The recommendations of the English review were accepted by the Department of Health and implemented. Since no dissatisfaction was expressed about these changes it seemed that they had worked well and did not require revisiting.

For the 2003 audit, it seemed appropriate (given that the programme had operated for over 15 years) to review the programme with three major approaches:

- The programme could be evaluated against international criteria if any could be located;
- The programme could be compared with other national programmes in industrialised countries (e.g. Australia, the UK, the USA, Scandinavian countries);
The programme could be evaluated simply against its own stated goals, and the needs and desires of the user community and other stakeholders in New Zealand.

It was decided to conduct the evaluation by ascertaining the extent to which the Programme was meeting international standards and expectations as suggested by international organisations including INFOODS (International Network of Food Data Systems) at the Food and Agriculture Organization (FAO).

Considerable information was available in the literature and on the internet about general expectations of countries in regard to food and nutrition data. However, despite a rigorous search the only comprehensive criteria which could be located that were specific for food composition databases and database programmes were those published in 1992 by Greenfield & Southgate under the auspices of INFOODS. These criteria were rather broad, but this meant that they also encompassed all aspects of the three major approaches suggested above.

**Methodology**

Methods included: acquisition of Government and C&FR documents from New Zealand; literature and internet searches; email list; INFOODS listserv; publicising the audit and soliciting inputs; compiling a checklist of issues relevant to the Audit; telephone and face-to-face interviews with stakeholders; visit to New Zealand, meetings, talks, focus groups (March 03); submissions to the auditor by email; and FOODfiles examination.

**Results and discussion**

It was found that:

- C&FR was providing an excellent service to the MoH as per the contractual requirements; programme policy was focused on frequent outputs: an annual issue of FOODfiles, biennial issue of the Concise Food Composition Tables (CT), twice-yearly progress reports; and servicing the twice-yearly meetings of the FCSC. Given the evidence of C&FR’s capacity to comply with the output requirements, consideration should be given to reducing output to: a biennial issue of FOODfiles and triennial issue of the CT. Other outputs should remain the same as before.

- The NZFCD was too dependent on the use of non-analytical data, many of foreign or imputed origin. While this had been necessary in the past, it was considered that current analytical facilities and sampling practices were adequate to now permit the replacement of many non-analytical data with original NZ analytical data. Non-analytical or foreign data could continue to be used for foods which are very minor contributors of nutrients to the NZ food supply, or for imported foods where data were of sufficient quality.

- Data holdings for many foods and nutrients were out-of-date. This particularly applied to major food groups such as meat and milk; and nutrients such as fat, vitamin A, iron, calcium, and folate. It is suggested that the use of the Key Foods concept could be applied to developing a rolling programme of analyses, with built-in provision of analyses for specific projects such as national nutrition surveys.

- Data quality was a major driver of the current laboratory analytical programme. It is suggested that this could be extended so that quality codes are shown for all data held in the NZFCD; and, data scrutiny for the compilation process could be improved by arranging for data review by experts from the FCSC or from food industry groups.
Since the NZFCD represented a major investment over many years; it could be more extensively exploited by use within food balance sheets, food monitoring, and research directed towards expanding knowledge about the NZ food and nutrition landscape;

Discussions with Maori and with Pacific peoples should be revived to seek input and ensure the currency of the NZFCD with their needs and expectations.

More effort was required to ensure input from all stakeholders, particularly from community organisations concerned with health issues such as heart disease, diabetes, cancer, infant feeding; from the food industry and from agricultural experts; and from software providers.

Consideration should be given to making the NZFCD products cheaper to purchase and available in a range of formats (from multimedia products to ready reckoners and simplified software products). Marketing and publicity could be improved.

It was recommended that:

Discussions with Australia should take place as a matter of urgency, especially in view of the adoption of the joint Food Code, to cover matters such as compliance of the NZFCD with Standard 1.2.8, harmonising of the two national databases, inclusion of data on food ingredients, data sharing and exchange, product pricing and matters such as the development of regional food composition reference materials, and,

Professional organisations in the region should devise and deliver priced training modules to users, to improve understanding of food composition data production, management and use.

The full report (Greenfield 2003) is available on-line.

**Conclusion**

It was concluded that the criteria used for auditing the NZFCD were adequate, provided that some additional issues were included such as copyright, and relationships with food standards, particularly those covering nutritional labeling.

Finally, the experience of the audit did reveal, in some cases, inadequate training and knowledge of food composition by local users, an issue which they themselves raised. Clearly, there could be merit in professionals in the Oceania region working together to ensure that regional awareness and knowledge is improved. Perhaps OCEANIAFOODS meetings could, in future, be combined with short training courses. This would be particularly important if expansions of common regional food standards are to be introduced.

**References**


KEYNOTE ADDRESS

DEVELOPMENT OF DATABASES FOR BIOACTIVE COMPOUNDS IN FOODS

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Keywords: Special Interest Database, data quality, bioactive compounds.

Abstract

Special Interest Databases for bioactive compounds other than nutrients are essential tools for supporting health research concerning these specific compounds. The investigation of health hypotheses related to the dietary intake of bioactive compounds is an iterative process that may include the expansion of these efforts to larger database applications.

Introduction

Bioactive compounds, unlike traditional nutrients, are not essential. However, they may have beneficial health effects. They are present in small amounts in foods and may modify the risk of disease through their various properties – antioxidative, antiproliferative, anti-inflammatory, etc. (Kris-Etherton et al. 2004). Dietary bioactive compounds in foods and in dietary supplements include: thousands of phytochemicals or allelochemicals, such as carotenoids, flavonoids, indoles, and isothiocyanates in plants; zoochemicals, such as peptides, conjugated linoleic acid and n-3 fatty acids in animal products and fungochemicals.

Many foods contain naturally occurring bioactive compounds but new products are being developed and fortified with compounds of interest (e.g. lycopene, omega-3-fatty acids). These new products, sometimes called functional foods, are defined as “any modified food or food ingredient that may provide a health benefit beyond that of the traditional nutrients it contains” (Thomas & Earl 1994). These include beverages containing ginkgo, ginseng (red, green or black tea) or candy bars such as PowerBar® or CocoaVia®. Even traditional products such as pasta have been modified to contain ALA (alpha linolenic acid, omega-3-fatty acids; Barilla PLUS® is one such example).

Numerous dietary supplements, including pills, extracts and botanicals have also entered the market. The nationally representative U.S. National Health Interview Surveys (NHIS) showed that daily vitamin supplement intake increased from 23.2% in 1987 to 33.9% in 2000, and 6% of the people interviewed reported taking a non-vitamin/non-mineral supplement daily (Millen et al. 2003). Supplements, along with traditional and modified foods, have become an important component of dietary intake studies.

Although diets rich in fruits and vegetables are correlated with a reduced risk of chronic diseases, intakes of specific nutrients in those foods do not show a striking correlation with reductions in disease risk. Interest has focused on the multitude of other compounds in foods, particularly of plant origin, which may have bioactive functions beyond the role of traditional nutrients. Bioactive compounds of plant origin (phytochemicals) occur as secondary plant metabolites and are augmented in response to environmental stress conditions. Evidence in support of the health benefits of bioactive compounds comes from numerous epidemiological, in vitro cellular and animal studies (Seddon et al. 1994; Hertog et al. 1996; Zava & Duwe
Several possible ways in which these compounds exert their influence in reducing the risk of cardiovascular diseases (CVDs) and cancer have been proposed. Flavonoids and proanthocyanidins are antioxidative (inhibition of liposome and lipid oxidation), anti-inflammatory (antiatherosclerotic), antithrombotic (decreased platelet aggregation), and are associated with nitric oxide (NO)-dependent vasodilation and inhibition of ACE activity (reduced vasoconstriction), and as such may reduce the risk of CVDs (Beecher 2004). Processes involved in the reduction of cancer risk may also include genetic and epigenetic events including the effects of nutrients on cell differentiation, cell signalling, cell cycle and cell apoptosis, hormonal regulation, and DNA repair (Milner 2004). As a result, interest in bioactive components has increased in the scientific community.

Since 1993 the US Department of Agriculture (USDA) has developed a series of Special Interest Databases with regard to these emerging dietary components. These databases complement the USDA’s National Nutrient Database for Standard Reference (SR), the authoritative US source of food composition data. SR contains values for more than 7000 foods and provides the foundation for most other databases such as USDA’s Food and Nutrient Database for Dietary Studies (FNDDS – www.barc.usda.gov/bhnrc/foodsurvey), National Health and Nutrition Surveys, and other therapeutic, clinical and research databases. Also the SR database is used as a basis for nutrition policy and nutrient requirements, product development, food labelling and regulations (Nutrient Labeling and Education Act – NLEA, www.fda.gov/opacom/laws/).

**Methods**

Food and dietary supplement composition databases are a key element in understanding the role of these various compounds on human health status. A Special Interest Database is a focused compilation of acceptable existing data for a specific component or a class of components, usually containing a limited list of 150-200 foods.

**Data collection**

The general approach to preparing a Special Interest Database includes the collection and evaluation of published literature as well as available unpublished analytical data for a class of compounds. Specific compounds presumed to have health-promoting bioactivity are identified and literature is searched using keywords. Abstracts are reviewed and relevant articles with analytical data retrieved. The merits of available analytical procedures are reviewed. Acceptable analytical methods are then defined and confirmed by experienced analysts. Articles that report the results of food analysis using these methods are then evaluated for data quality.

**Data quality evaluation**

At this point it is important to determine the reliability of existing data and provide documentation of data reliability to users. The quality of data for each food and compound is rated using procedures defined by scientists at NDL (Holden et al. 2002), including information on sampling plan, sample handling, number of samples, analytical methodology and analytical quality control.

Lists of questions comprising standard templates are prepared for all categories. For analytical methodology, the list varies depending on the compound or nutrient of interest. For analytical methodology, questions about critical steps in the analysis are defined in consultation with specific experts involved in the analysis of the compound of interest. Available information pertaining to critical steps in the analytical process, i.e. questions on sample processing (extraction/digestion, physical/chemical environment) and
analysis/quantitation (specificity of method, separation of compounds, standards used, identification criteria, etc.), is reviewed. Questions about the sampling plan indicate the representativeness of sample units for the population of interest, while questions for sample handling indicate the appropriateness of storage and homogenisation of sample units. The number of samples refers to the number of individual analytical samples analysed, not to the replicates of the same homogenate, the objective being to consider the adequacy of the number of samples analysed to obtain a reliable estimate of the mean and estimate of sample-to-sample variability. The category of analytical quality control assesses accuracy and precision throughout the analytical process, i.e. day-to-day precision. For most classes of bioactive compounds, Certified or Standard reference materials (CRM or SRM) are not yet available. Therefore the use of in-house reference or quality control materials is crucial and affects the data quality rating (Table 1).

**Table 1: Examples of critical questions**

How were the sample units collected?

Were the sample units handled properly?

Were the sample units homogenised when necessary?

Was the analysis done for edible portion of food only?

Were the samples stored correctly?

How many individual sample units were analysed?

Was the analytical method validated?

Was the analytical quality control information available?

Information on each of the five categories is rated on a continuous scale of 0-20. The ratings for the five categories for each food and compound are summed to yield a Quality Index (QI) with a maximum possible score of 100 points. A Confidence Code (CC) is derived from the QI to indicate the relative quality of the data and the reliability of the given mean. The CCs are assigned as follows:

<table>
<thead>
<tr>
<th>QI</th>
<th>CC</th>
</tr>
</thead>
<tbody>
<tr>
<td>75-100</td>
<td>A (exceptional)</td>
</tr>
<tr>
<td>74-50</td>
<td>B (above average)</td>
</tr>
<tr>
<td>49-25</td>
<td>C (average)</td>
</tr>
<tr>
<td>&lt;25</td>
<td>D (below average)</td>
</tr>
</tbody>
</table>

**Structure of the database**

The structure of the final database depends on the nature of the available data. The compiled data are carefully scrutinised for food descriptions and statistical parameters (outliers) and changes are made accordingly. Decisions are made on the level and specificity of the compounds to be included in the database, e.g. number of compounds, chemical structure of compounds (glucosides? aglycone?), individual compounds or totals by class of compounds, units of measurements and statistical parameters. Confidence codes are released for each compound for each food in the database to provide an indication of data reliability for these data.
Results

Since 1999, NDL has released databases for isoflavones, flavonoids, proanthocyanidins, choline, and fluoride (Table 2). The number of foods in the various databases ranges from 128 to 434 foods. The individual carotenoids database was first released in 1993 and was updated in 1998. The values have now been incorporated into the SR and expanded to other foods by calculation of values for related foods. NDL, with the Office of Dietary Supplements (ODS) of the National Institutes of Health (NIH), has launched a project to prepare a Dietary Supplements Ingredients Database (DSID) which will contain analytically validated values for some supplement types.

Table 2: USDA’s databases for bioactive compounds.

<table>
<thead>
<tr>
<th>Database</th>
<th>No. of foods</th>
<th>Compounds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Isoflavones (1999)</td>
<td>128</td>
<td>Genistein, daidzein, glycitein</td>
</tr>
<tr>
<td>Flavonoids</td>
<td>220</td>
<td>Flavonols, flavones, flavanones, flavan-3-ols, anthocyanidins</td>
</tr>
<tr>
<td>Proanthocyanidins (2004)</td>
<td>205</td>
<td>Monomers thru polymers of flavan-3-ols</td>
</tr>
<tr>
<td>Choline (2004)</td>
<td>434</td>
<td>Betaine, free choline, phospho-glycerophospho-, phosphotidyl choline, spingomyelin</td>
</tr>
<tr>
<td>Fluoride (2004)</td>
<td>400</td>
<td>Fluoride</td>
</tr>
</tbody>
</table>

Special interest databases serve many requirements of the scientific community:
1. Provide critically evaluated databases with relative indicators of data reliability.
2. Generate archive databases for background decisions made and points assigned within each category as a basis of the final confidence code.
3. Develop analytical priorities for future work.
5. Provide basis to extrapolate high quality values to other related foods.

Conclusion

Updates and future of NDL’s special interest databases

NDL plans to update the Flavonoids Database with literature sources from 2001 to 2004 and data generated by the USDA’s Food Composition Laboratory (FCL) on 59 U.S. fruits, vegetables and nuts sampled nationally. The database will be released in 2006 at the NDL website: www.ars.usda.gov/nutrientdata.

Databases for other important components such as glucosinolates/isothiocyanates, phenolic acids and lignans, as well as updating of the isoflavones database, are under consideration.

Challenges for bioactive component databases

The most challenging aspect of generating data on new components is the development of reliable analytical methods. Valid and precise methods monitored by quality control materials are essential to the assessment and partitioning of variation within foods due to cultivar, soil, climate, etc. Description of samples, details of analytical method and reporting of analytical quality control are very important to overcome some of the hurdles these challenges pose. Often validation of the analytical methods for bioactive components is difficult because of the lack of pure and stable standards and reference materials.
References


The concept that food can do more than just provide nutrients to keep us alive is not new. In 400 B.C. Hippocrates stated, “Let your food be your medicine and your medicine be your food”. Despite this, early research on diet and disease focused mostly on diseases of deficiency and dietary components thought to increase disease risk (e.g. saturated fats, salt). Similarly, food composition databases generally focus on core macro- and micro-nutrients.

In addition to these components, fruit and vegetables contain a vast array of phytochemicals. Historically these compounds were largely ignored because they were assumed to be biologically inert, but it is now recognised that many have health-enhancing properties. Examples include lycopene in tomatoes and anthocyanins in berry fruit. It is known that there are thousands of different phytochemicals in plant foods and no doubt more will be discovered. The number of phytochemicals and their chemical diversity present challenges for their incorporation in food composition databases.

Recently we have seen the advent of some phytochemical databases (e.g. USDA databases for carotenoids and flavonoids: http://www.nal.usda.gov/fnic/foodcomp /index). However, there are still questions and issues to be dealt with in the construction of this type of database. First there is the cost of performing the analyses. In addition, the range of phytochemicals able to be included is often limited to the most common compounds. Hence, some products may not appear to contain much of a particular group of phytochemicals simply because the compound(s) they contain have not been analysed and included in a database. In some cases, the phytochemical groupings used may not be sufficient to account for factors such as differences in bioavailability and biological activity. Finally, a key issue is whether these databases provide nutritionists/dietitians/the public with sufficient information to be useful in optimising health. This paper discusses some of these issues and provides examples using New Zealand data.
ANALYSES OF TRACE ELEMENTS IN FOODS

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Keywords: ICPMS, digestion, detection limits, Quality Assurance.

Abstract

This paper will discuss the methods that have been used for determining the levels of trace elements in foods in New Zealand since the 1980s; the associated improvements in detection limits; and the quality of results that have gone with these improvements. This discussion will be about elements analysed as part of the early New Zealand Total Diet Survey studies. However, new instruments can analyse many more elements and this will also be discussed.

In the 1980s, the most common method for determining trace elements was Flame Atomic Absorption Spectroscopy (AA) or Graphite Furnace Atomic Absorption Spectroscopy (GFAA). In the early 1990s Inductively Coupled Plasma Mass Spectrometry (ICPMS) was introduced to New Zealand and this revolutionised trace element analysis.

Improvements in quality with the use of ICPMS were due to simultaneous analysis of many elements, speed of analysis, instrument stability, simpler digestion methods, and use of reference materials.

Future interest in trace elements and metal speciation is also mentioned briefly.

Introduction

Our initial work with trace elements involved monitoring foods for compliance with the Food Regulations but this soon became extended into project work. The New Zealand Total Diet Survey is an example of such work. These were carried out in association with the Department of Health and were designed to look at the typical intake of New Zealanders to see if there were any problem areas (Pickston et al. 1985).

Much of this early work on trace elements used AA. The detection limits for these elements was not very low, so the samples had to be prepared so that the sample was not diluted. These methods are referenced in the paper by Pickston et al. (1985), but a brief summary of methods is given below.

Cadmium, chromium, cobalt, copper, iron, lead, manganese, nickel, tin, zinc: 25 g sample ashed at 450°C over 2 days. Ash dissolved in hydrochloric acid and made up to 25 ml. Elements were determined by AA.

Calcium, magnesium, potassium, sodium: 25 g sample ashed at 450°C over 2 days. Ash dissolved in nitric acid and made up to 25 ml. Samples diluted with an ionisation buffer and determined by Flame Emission Spectroscopy.

Arsenic: 15 g sample & 15 ml 33% MgNO3 were ashed at 550°C. Ash dissolved in hydrochloric acid and made up to 50 ml. Hydride generation followed by flameless Atomic Absorption.

Selenium: 2 g sample digested with nitric and perchloric acid. Fluorometric method used to determine selenium.

Mercury: 2 g sample wet digested with nitric, hydrochloric and sulphuric acid. Mercury reduced followed by flameless Atomic Absorption.
**Phosphorus**: 2 g sample digested with sulphuric acid and a catalyst. Phosphorus determined colorimetrically.

**Iodine**: Sample ashed under alkaline conditions. Iodine measured colorimetrically.

The 1982 New Zealand Total Diet Study (Pickston et al. 1985) had approximately 264 samples that needed analysing. Using the methods described, it took about 200 days just to digest the samples.

**Methodology and discussion**

Since the 1982 New Zealand Diet Study, other techniques have become available.

Graphite Furnace Atomic Absorption Spectroscopy (GFAA) with Zeeman Background (a method of correcting for interferences using polarised light and a magnetic field which switches on and off) became the next best technique to use, but despite lower detection limits it had its own problems. Like AA it needed a full digestion of the sample to minimise interferences. However, with AA it took a few seconds to measure the concentration of an element in a sample, but with GFAA it took 5-10 minutes.

Inductively Coupled Plasma Optical Emission Spectroscopy (ICPOES) also became available but we did not have access to it. With the early instruments, the purchaser had to choose which elements they wanted to measure before buying the instrument and the ICPOES had to be in a carefully temperature-controlled environment to avoid drift.

Inductively Coupled Plasma Mass Spectrometry became available in the 1980s and a machine was purchased by Environment and Scientific Research (ESR) in 1990. Its advantages over other technology included the following:

- Due to the high temperature of the plasma (about 6000 K), a complete digestion of the sample is not necessary, so simpler digestion techniques can be used with less risk of contamination. Samples are now digested for 1 hour at 100°C in disposable 50 ml polypropylene tubes with nitric acid. Hydrochloric acid or hydrofluoric acid may also be added. Except for iodine, all the elements analysed in the 1982 New Zealand Diet Survey can be prepared with one digest.

- A number of elements can now be analysed sequentially very quickly, typically taking 20-100 milliseconds per element. In a normal routine run, it takes 2-4 minutes to measure 30 elements. A prescribed number of elements can be measured, but the instrument is normally set to measure all elements of interest each time it operates.

- Non-target elements can also be looked at if necessary. It is simpler to analyse approximately 30 elements on all samples but only interpret the elements required.

- Better instrument stability means that it is easier to run more quality control measures such as reference materials, duplicates, spikes, etc.

- Detection limits are lower.

- Most elements in the periodic table can be determined, including iodine and bromine.
Table 1: Detection limits of elements in solution.

<table>
<thead>
<tr>
<th>Element</th>
<th>Parts per million</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AA</td>
</tr>
<tr>
<td>Arsenic</td>
<td>0.02</td>
</tr>
<tr>
<td>Cadmium</td>
<td>0.005</td>
</tr>
<tr>
<td>Chromium</td>
<td>0.02</td>
</tr>
<tr>
<td>Cobalt</td>
<td>0.05</td>
</tr>
<tr>
<td>Copper</td>
<td>0.05</td>
</tr>
<tr>
<td>Lead</td>
<td>0.05</td>
</tr>
<tr>
<td>Manganese</td>
<td>0.05</td>
</tr>
<tr>
<td>Mercury</td>
<td>0.0001</td>
</tr>
<tr>
<td>Nickel</td>
<td>0.05</td>
</tr>
<tr>
<td>Tin</td>
<td>1</td>
</tr>
</tbody>
</table>

Sample preparation

As already mentioned, the digestion process can be carried out in 1 hour and with a normal commercial waterbath, and up to 60 samples can be digested at a time. In theory, the 264 samples for the 1982 New Zealand Total Diet could have been digested in 1 day. Samples for iodine can be digested in a similar manner but an alkaline digestion is required, and tetramethyl ammonium hydroxide is used for this (Fecher et al. 1998).

The only disadvantage is that only 1 g of dry sample or up to 4 g of wet sample is analysed. This means that the sample must be very homogenous.

Quality assurance

The speed of analysing samples means that it is now easier to have more quality assurance measures. These are typically:

- Check standards – independent standards spread throughout a run to check for drift
- Blanks
- Duplicates
- Interlaboratory trials
- In-house reference materials
- Certified reference materials.

Inductively Coupled Plasma Optical Emission Spectroscopy (ICPOES) has come a long way since it was introduced, especially with the introduction of CCD (Charge Coupled Device) technology. It is the preferred method for a number of major elements such as calcium, potassium, magnesium, sodium, phosphorus and sulphur. It is also the preferred technique for iron, as it has fewer interferences than ICPMS. ICPOES works well for other elements when low detection limits are required.

Conclusion

What is the future for analysing trace elements in foods?

Looking at the importance of other elements

ICPMS is an ideal tool for looking at other elements in foods because it can measure most of the elements in the periodic table. From our experience, caesium, rubidium, lanthanum,
lithium, molybdenum, strontium, bromine and boron are present in many foods at levels, well above the limit of quantitation for these elements. Other elements present at much lower levels, such as the rare earth elements, may be of significance to human health.

**Getting lower detection limits**

There are still some elements for which it would be useful to have lower detection limits, such as mercury and selenium, particularly for diet surveys. ICPMS technology is improving all the time and may prove one way of achieving this. Most manufacturers offer some method of removing polyatomic interferences. For example, Perkin Elmer has a “Dynamic Reaction Cell”, and Agilent has an “Octopole”. In addition, other new methods may be developed.

**Metal speciation**

Metal speciation has been talked about for a long time but has been very slow to develop. Speciation is achieved by extracting the element out of the food without changing its form, doing some sort of separation and then measuring the concentration of each form. High Performance Liquid Chromatography – ICPMS is an ideal way of doing this, but progress in this area has been held up by the cost of running the ICPMS for this purpose. Research in this area has therefore been confined to the university environment, for example, the University of Canberra (Maher et al. 1999). Until there is some requirement to do this type of work, such as by regulation, it will stay in the realms of research.

**References**


Maher, W.; Goessler, W.; Kirby, J.; Raber, G. 1999: Arsenic concentrations and speciation in the tissues and blood of sea mullet (Mugil cephalus) from Lake Macquarie NSW, Australia.

DETERMINATION OF SELENIUM AT TRACE LEVELS IN FOODS

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Keywords: trace element, nutritional deficiency, inductively coupled plasma-mass spectrometry, atomic fluorescence spectroscopy

Abstract
The nutritional deficiency of selenium in the New Zealand diet has led to a growing demand for the analysis of this important trace element in foods and food ingredients. The challenge for the analyst is to develop and validate methods, which are accurate and precise, robust, and capable of measuring selenium at parts per billion (ppb) levels in a range of different food materials.

This laboratory has developed two different methods for analysing selenium at ppb levels in foods and dairy products, namely, as total selenium determined by Inductively Coupled Plasma-Mass Spectrometry (ICP-MS, Niu & Hook 1996; USEPA) and as the selenium hydride derivative determined by atomic fluorescence spectroscopy (PS Analytical; APHA 1998).

These methods are described in principle and their advantages and disadvantages are compared. One of the major advantages of the ICP-MS technique is the ability to analyse multiple elements at the same time, making this a cost effective option. Atomic fluorescence is a very sensitive single element technique and is generally the preferred option for samples requiring selenium at very low levels. Analytical considerations including sampling, sample digestion, approaches to method validation and quality control are discussed and examples of validation work related to some particular foods are presented. This paper reports selenium data for a range of foods consumed in New Zealand, typically ranging from low part per billion levels up to 1 part per million.

Introduction
Selenium is a relatively rare element, present at levels of approximately 0.05 mg/kg in the earth’s crust. It is typically extracted as a by-product from copper ore. The name “selenium” comes from the Greek word “selene”, meaning moon. Selenium can have semi-conducting properties, and it is commonly used as a photoreceptor in photocopy machines. It is also often used in anti-dandruff shampoos at a concentration of around 1% Se.

Selenium is a very important element for human and animal nutrition, and it has a very narrow margin between deficiency and toxicity. This makes it an important element to measure accurately and reliably at often very low levels in a wide range of sample types, from plant and animal, food etc, through to human tissue.

Because of their volcanic origin, New Zealand soils are typically deficient in selenium, causing a deficiency in our pastures and consequently in our farmed plants and animals and food supplies.

The changing patterns of human nutrition in New Zealand, with the trend towards consumption of more fast food and processed ingredients, has resulted in a heightened awareness of the importance of selenium among nutritionists and medical researchers, with
some researchers associating selenium deficiency with an increased risk of cancer and potentially decreased reproductive function.

This paper describes the analysis of selenium at trace levels in food samples, with a comparison between two analytical methods used in our laboratory. Some aspects of method performance and quality control measures are discussed, and a range of selenium data in common New Zealand foods is presented.

**Methodology**

**Laboratory testing of selenium in food and food ingredients**

Since selenium is typically present at extremely low levels in New Zealand foods, the collection of representative samples is vitally important, especially if the selenium is not homogeneously distributed throughout the sample. The sample stability and likelihood of spoilage in transit will generally determine whether the food is submitted fresh, chilled or frozen.

Once received at the laboratory the sample is held chilled or frozen prior to analysis, then it is blended to obtain a representative material for sub-sampling for acid digestion and analysis. The homogenisation of the sample is important, as the sub-sample taken for analysis is usually in the order of 0.5 to 5 g.

**Choice of analytical method**

The choice of analytical method this depends upon a number of factors such as; will the scope of the method be appropriate for the samples being analysed? What preparation of samples is required prior to analysis? How specific is the method – is it potentially subject to interferences or contamination? How accurate and precise is the method – what is the associated uncertainty of measurement? What is the limit of detection of the method – is it capable of measuring down to the required level in the samples? What concentration range is spanned – will the samples often have to be diluted to within the working range? What resources and capital costs are necessary, and what technical skills and experience are required to analyse samples using the method?

In summary, the key issues governing method choice are a sound knowledge of the samples to be analysed and the clients' requirements, whether the method will produce accurate and precise results with a sufficiently low limit of detection to analyse selenium at ppb and lower levels, and whether the testing facility has the resources to correctly operate the equipment and produce quality results in a cost-effective and timely manner.

**Inductively coupled plasma – mass spectrometry (ICP-MS)**

Using this technique, samples need to be in liquid form and this is usually achieved by digesting the samples with concentrated acids at high temperature. An aerosol spray is then formed from the liquid sample, and this spray is introduced into an argon plasma, operating at around 8000 degrees C. The intense heat drives the water off the samples and breaks the samples down into atoms, and then drives off an electron to generate positive ions. The ions are then separated according to their mass and counted at each atomic mass unit, with reference to calibrating standards, to obtain a concentration of selenium (and/or other elements) in the sample.
Advantages of ICP-MS

ICP-MS is a multi-element technique, has a fast analysis time (generally 1 to 3 minutes per sample) and is a fast and cost-effective method for analysing samples for trace elements. It is a very sensitive technique, having detection limits down to sub part-per-billion levels. It is very specific, having few interferences, and is quite accurate and precise as well as spanning a very large concentration range, not often requiring samples to be diluted and re-analysed.

Disadvantages of ICP-MS

Since a liquid sample is required, samples are subject to a dissolution or digestion procedure prior to analysis. It is important that this preparation be correctly performed to ensure complete recovery and no loss of selenium from the original sample. ICP-MS instruments are very expensive (typically > NZ$400,000), have rather high operating costs and require specialist instrument operators to generate optimum results. There are also some analytical interferences that operators must be aware of and take into account to ensure the most accurate results possible.

Hydride generation atomic fluorescence (HG-AF):

This technique involves the analysis of a liquid sample as with ICP-MS, with samples being digested with concentrated acids at an elevated temperature. The liquid sample is then ‘reduced’ to convert the selenium species to the selenium (IV) oxidation state. The samples are then reacted with borohydride solution to generate the selenium hydride derivative, which is then introduced into the analyser. The hydrogen formed as part of this reaction is ignited to produce a flame, which is then used to atomise the sample. Light at a wavelength specific to selenium is focused onto the sample, causing the selenium atoms to become excited to higher energy levels. As the selenium atoms decay in energy, they emit fluorescence which can be measured and compared to calibrating standards to obtain a concentration of selenium in the samples.

Advantages of HG-AF

This is a very specific technique, which is accurate and precise with a fast analysis time (typically 2 minutes per sample). The instrumentation is significantly cheaper than ICP-MS with analysers costing in the order of NZ$60,000. Operating costs are also much lower than ICP-MS. HG-AF is an extremely sensitive technique, with levels of detection in the sub part-per-billion or even part-per-trillion level, making it ideal for measuring very small amounts of selenium in NZ foods.

Disadvantages of HG-AF

Again, a liquid sample is needed, necessitating an acid digestion prior to analysis. Also, since sample reduction is required to convert selenium into a species capable of forming the hydride derivative, the digestion is more complex than that required for ICP-MS analysis. HG-AF is a single element technique, meaning that if other elements are required, alternative methods must be used for these, increasing the overall analysis cost compared to ICP-MS. HG-AF has a more limited concentration range than ICP-MS, with samples more frequently requiring dilutions to within the analytical working range, which increases the time of analysis and the operating costs. While substantially cheaper than ICP-MS, HG-AF still requires a considerable capital outlay, and experienced technical staff to operate the equipment and prepare the samples. There are still some interferences that operators must be aware of and consider when analysing samples.
Table 1: Comparison of the two methods for analysis of selenium at low levels in food samples.

<table>
<thead>
<tr>
<th>Method characteristics</th>
<th>ICP-MS</th>
<th>HG-AF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equipment/ capital</td>
<td>very expensive</td>
<td>moderate</td>
</tr>
<tr>
<td>Running costs</td>
<td>expensive</td>
<td>moderate</td>
</tr>
<tr>
<td>Selenium recovery¹</td>
<td>excellent</td>
<td>excellent</td>
</tr>
<tr>
<td>Specificity for selenium</td>
<td>good</td>
<td>good</td>
</tr>
<tr>
<td>Subject to contamination²</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>Measurement range³</td>
<td>very good (&gt; 6 orders)</td>
<td>moderate (2-3 orders)</td>
</tr>
<tr>
<td>Sensitivity as MDL⁴,⁵</td>
<td>ppb levels</td>
<td>ppt-ppb levels</td>
</tr>
<tr>
<td>Sample throughput</td>
<td>very good</td>
<td>very good</td>
</tr>
<tr>
<td>Technical skills required</td>
<td>highly technical</td>
<td>technical</td>
</tr>
</tbody>
</table>

¹ The amount of selenium typically recovered from the sample as determined by spike recovery experiments.

² The tendency for samples to be contaminated by external sources of selenium or interfering species - this is monitored by procedural blank samples.

³ The linear range across which selenium can be measured and generally expressed in ‘orders of magnitude’.

⁴ Sensitivity expressed as the ‘method detection limit’ (MDL), which is specific to the method and for the particular test sample.

⁵ Method detection limits vary depending on the dry matter content of test samples.

Method performance and quality control in the laboratory

A number of quality control criteria are used in testing laboratories to monitor the performance of a method. These include procedural blanks, which are blank samples put through the sample preparation procedure and used to check for random or systematic contamination. Replicate samples are multiple preparations of the same sample analysed and checked to ascertain repeatability or precision, or to highlight sample heterogeneity issues, a particularly important issue for elements such as selenium which are present at extremely low levels in foods. For homogenous samples, agreement within 10% between replicates is desirable. Spiked samples involve adding a known amount of selenium (or other elements) to a sample and monitoring the recovery as the amount measured compared to amount added. This is a useful technique to check for interferences, and to ensure complete recovery and no loss of the selenium from the sample matrix during sample preparation and analysis. Recoveries of 90-110% are desirable.

Accuracy of test methods is typically determined using Certified Reference Materials (CRMs), which are materials prepared in bulk, thoroughly homogenised, then analysed by a large number of laboratories, often using a number of different analytical techniques, to determine a mean result with associated uncertainty (precision) – usually reported as 95% confidence limits, namely ± two standard deviations. Laboratories then purchase small amounts of these (usually very expensive) CRMs and analyse them, checking that the mean result observed and associated uncertainty falls within the certified limits provided by the CRM manufacturer.
Table 2 shows results from several food CRMs analysed for selenium at Hill Laboratories. It can be seen that the results obtained agree well with the certified results, indicating that both ICP-MS and HG-AF provide accurate selenium analyses in food samples, with acceptable precision.

Uncertainty of Measurement (UoM) is a term encompassing method precision, sample preparation, sampling, and all other uncertainties involved in the generation of an analytical result. By analysing CRMs on multiple occasions, analysing replicate samples, and thoroughly evaluating all aspects of the analytical method, laboratories can gain an understanding of the UoM associated with a particular test. However, since much of the UoM for an analysis is related to sampling and sample preparation, it is also important that the client has a good understanding of these principles and procedures to minimise UoM. The heterogeneous nature of most prepared foods is a major component of the UoM achieved when analysing selenium in these materials, and statistical analysis of large numbers of duplicate food sets indicates that the UoM depends largely on the particular food and the amount of selenium that it contains.

Inter-Laboratory Comparison Programmes (ILCPs) are also useful tools, consisting of common samples, analysed by a number of different laboratories, with statistical analysis used to evaluate method performance. For elements such as selenium in food samples, few laboratories are capable of analysing down to the very low levels found in NZ foods, and as a result there are limited ILCP programmes covering this element in NZ. Hill Laboratories also participates in international ILCPs wherever possible.

Table 2: Accuracy and precision of selenium results from CRMs.

<table>
<thead>
<tr>
<th>CRM (Certified value for selenium)¹</th>
<th>ICP-MS obtained value for selenium²</th>
<th>HG-AF obtained value for selenium²</th>
</tr>
</thead>
<tbody>
<tr>
<td>NIST 8435 (whole milk powder)</td>
<td>0.12 ± 0.03 mg/kg</td>
<td>0.13 ± 0.01 mg/kg</td>
</tr>
<tr>
<td>0.13 ± 0.014 mg/kg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NIST 1549 (skim milk powder)</td>
<td>0.11 ± 0.02 mg/kg</td>
<td>0.12 ± 0.02 mg/kg</td>
</tr>
<tr>
<td>0.11 ± 0.01 mg/kg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NIST 1577b (bovine liver)</td>
<td>0.69 ± 0.09 mg/kg</td>
<td>0.76 ± 0.07 mg/kg</td>
</tr>
<tr>
<td>0.73 ± 0.06 mg/kg</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

¹A median result ± two standard deviations (95% confidence limits) obtained by a number of international laboratories for this CRM.

²Mean results ± two standard deviations (95% confidence limits) obtained by our laboratory. These data represent ‘Intermediate Precision’ rather than total Uncertainty of Measurement (UoM).

Summary of comparison between methods

At Hill Laboratories we have the ability and resources to analyse selenium by both ICP-MS and HG-AF techniques, so the choice of method comes down to practical factors. For samples requiring selenium only, at very low levels, HG-AF is the technique of choice. For samples requiring other elements as well as selenium, it is most efficient to analyse these by ICP-MS, where the higher cost of analysis is offset by the ability to perform multi-element analysis. Samples at higher levels are best analysed by ICP-MS where the wide concentration range able to be measured ensures minimum dilutions and faster throughput. It is beneficial to be able to use either technique, as should there be any technical problems such as instrument breakdowns or scheduled maintenance, the ability to perform the tests using another piece of equipment helps to ensure that client’s turnaround times are still met. It
is also invaluable for method development and validation to be able to check results against an independent technique.

**Results and discussion**

**Food selenium results – examples**

One example of the importance of low level selenium analysis in foods and food products is highlighted by the 2003-04 New Zealand Total Diet Survey, comparing bread baked in the North Island with bread baked in the South Island (Table 3).

**Table 3: New Zealand North Island vs South Island bread selenium levels.**

<table>
<thead>
<tr>
<th></th>
<th>Se in white bread (mg/kg)</th>
<th></th>
<th></th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Quarter 1</td>
<td>Quarter 3</td>
<td>Mean</td>
<td></td>
</tr>
<tr>
<td>Auckland (North Island)</td>
<td>0.022</td>
<td>0.101</td>
<td>0.062</td>
<td></td>
</tr>
<tr>
<td>Napier (North Island)</td>
<td>0.038</td>
<td>0.102</td>
<td>0.070</td>
<td></td>
</tr>
<tr>
<td>Christchurch (South Island)</td>
<td>&lt; 0.010</td>
<td>&lt; 0.010</td>
<td>&lt; 0.010</td>
<td></td>
</tr>
<tr>
<td>Dunedin (South Island)</td>
<td>&lt; 0.010</td>
<td>&lt; 0.010</td>
<td>&lt; 0.010</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Se in wholemeal bread (mg/kg)</th>
<th></th>
<th></th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Quarter 1</td>
<td>Quarter 3</td>
<td>Mean</td>
<td></td>
</tr>
<tr>
<td>Auckland (North Island)</td>
<td>0.054</td>
<td>0.131</td>
<td>0.093</td>
<td></td>
</tr>
<tr>
<td>Napier (North Island)</td>
<td>0.046</td>
<td>0.099</td>
<td>0.073</td>
<td></td>
</tr>
<tr>
<td>Christchurch (South Island)</td>
<td>&lt; 0.010</td>
<td>&lt; 0.010</td>
<td>&lt; 0.010</td>
<td></td>
</tr>
<tr>
<td>Dunedin (South Island)</td>
<td>&lt; 0.010</td>
<td>&lt; 0.010</td>
<td>&lt; 0.010</td>
<td></td>
</tr>
</tbody>
</table>

Bread baked in the North Island typically uses Australian flour, which has acceptable levels of selenium, and this can be seen from the data. Bread baked in the South Island commonly uses South Island grown flour, which is deficient in selenium due to the soil being deficient in selenium. Consequently, the bread has low selenium levels as can be seen from the data above.

Another interesting example involves the selenium content of Brazil nuts, which are widely reported to contain high levels of selenium and to be good natural dietary sources of this element. However, this is only the case if they are grown in soil with adequate selenium levels! New Zealand soils that are deficient in selenium cannot produce Brazil nuts with high levels of selenium (without selenium being added to the soil). Hill Laboratories has tested a number of different sources of Brazil nuts, and found levels ranging from less than 1 mg/kg to over 1000 mg/kg, with good agreement between both ICP-MS and HG-AF methods for the analyses of these materials.

The typical low selenium intakes of New Zealanders are further illustrated by hair selenium levels as illustrated in Table 4. Hair can be an indication of body levels of many elements including selenium, and provides a more realistic reflection of body selenium status than blood or urine tests.

**Table 4: Comparison of hair selenium ‘normal range’ levels taken from typical hair analysis reports from Hill Laboratories and several overseas commercial hair testing laboratories.**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>New Zealand typical hair selenium levels:</td>
<td>0.3 – 0.7 mg/kg</td>
</tr>
<tr>
<td>United Kingdom typical hair selenium levels:</td>
<td>0.8 – 3.0 mg/kg</td>
</tr>
<tr>
<td>United States typical hair selenium levels:</td>
<td>0.9 – 1.7 mg/kg</td>
</tr>
</tbody>
</table>
Typical sources of selenium in the diet (Coory 2001):

- Recommended Daily Intake (RDI): men = 85 µg, women = 70 µg selenium
- eggs (2 medium sized) = 15 µg
- white bread (4 slices) = 4 µg
- wholemeal bread (4 slices) = 28 µg
- fish (100 g snapper) = 120 µg
- beef / lamb (100 g) = 4 µg
- chicken (100 g) = 15 µg
- Brazil nuts (1/3 cup) = 125 – 2650 µg (depending on soil selenium levels).

Selenium levels in New Zealand foods

The 2003-04 New Zealand Total Diet Survey has recently reported updated information on selenium levels in commonly consumed New Zealand foods, and this data has shown that most of the foods surveyed contain low levels of selenium. The best sources of selenium are generally of marine origin such as mussels, oysters, and fish. Other important foods with moderate levels of selenium include poultry products (particularly eggs); and pork products.

![Selenium from 2003-04 Total Diet Survey](chart.png)

**Figure 1: Food selenium levels taken from the 2003-04 New Zealand Total Diet Survey.**

Figure 1 is based on data taken from the Total Diet Survey and demonstrates relative differences in selenium levels for some of the food types discussed above. Mussels, eggs and fish are very good sources of selenium, with levels ranging from 0.3 mg/kg (which is equivalent to 30 µg/100 g of an edible portion) to around 0.6 mg/kg (60 µg/100 g).

Conversely, staple foods such as milk and bread have low to negligible amounts of selenium. Many other vegetables and fruit types do not register selenium at the detection limit <0.01 mg/kg (<1 µg/100 g).
References


USEPA 200.3 – Sample preparation procedure for spectrochemical determination of total recoverable elements in biological tissues.

USEPA 200.8 – Determination of trace elements in water & wastes by inductively coupled plasma – mass spectrometry.
TOWARDS THE QUANTIFICATION OF FOLATES IN FOODS USING LC-MS/MS

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Keywords: Folates, tandem mass spectrometry, mass to charge ratio, stable isotope dilution assay, internal standards.

Abstract
The project aim is the development and optimisation of a robust method to detect and quantify folic acid and naturally-occurring folates in various food matrices. This is a challenging task due to the presence of various chemical forms of folate, which differ in stability and bioavailability, and their existence in low concentrations. The microbiological assay has always been the method of choice. However, this method cannot differentiate between the different forms of folate. In the present scenario of folate fortification there is an underestimation of the amounts actually present in foods and declared on labels, due to the lack of a robust analytical method to distinguish between the added and natural forms of folates. We are using liquid chromatography-tandem mass spectrometry (LC-MS/MS) as a sensitive and specific analytical tool capable of discriminating between the different vitamers and quantifying them accurately. LC is being performed on a C18 reverse phase column with a binary gradient of aqueous formic acid and acetonitrile. The LC is interfaced to an ion trap mass spectrometer using positive mode electrospray ionisation. Folate vitamers are recognised by their individual m/z values, or specific fragment ions when using tandem mass spectrometry. Quantification of folates will be performed using external and internal standards. Results to date include development of a fast LC-MS method, ongoing validation of this method using commercially-available folate standards, assessment of the instrumentation’s abilities to quantify using MS and MS/MS, and the evaluation of a solid-phase clean-up method to ensure the sample’s compatibility with mass spectrometry. LC-MS/MS promises to be a valuable tool for the specific and quantitative analysis of low-level compounds from foods.

Introduction
Folates, a group of interconvertible water soluble nutrients, have assumed greater significance in recent years in the area of human nutrition and health. This is particularly true in view of its documented linkage with the reduction of neural tube defects, and reduced risk factors for heart disease and certain types of cancer. In the present scenario of folate fortification in Australia and New Zealand, the public will derive folate not only through added folic acid but also from natural sources. There may be an underestimation of the amounts actually present in foods and declared on labels due to inadequate methods for determining all folate vitamers in foods. Adequate measurement protocols exist for the measurement of added synthetic folic acid and for the measurement of total folate. The current accepted method of analysis is the microbiological assay, which has been a routine assay to determine the concentration of total folates in foods. Highly specific HPLC separation techniques with UV and/or fluorescent detection have been developed to detect the different vitamer forms of folate. These methods yield varying degrees of accuracy depending on the food matrix. Hence there is a need to develop specific and quantitative assays to distinguish between the natural and synthetic forms of folate, which differ in their bioavailability and stability. Some
recent reports have described the application of LC-MS to folate analysis (Garbis et al. 2001; Stokes & Webb, 1999, Freisleben et al. 2003)

The project aims to develop and optimise a robust method by using the most sensitive and specific liquid chromatography mass spectrometry technique as an analytical tool to quantify these small molecules present in low concentrations, thereby contributing to the development of reliable databases on food folate composition. This paper outlines the development of a fast LC-MS method, ongoing validation of this method using commercially-available folate standards, assessment of the instrumentation’s abilities to quantify using MS and MS/MS, and the evaluation of a solid-phase clean-up method to ensure compatibility with mass spectrometry and in-house synthesis of an internal standard.

Methodology

Folate compounds

Folic acid, 5-methyl tetrahydrofolic acid, 5-formyl tetrahydrofolic acid, 10-formyl folic acid, tetrahydrofolic acid and dihydrotetrahydrofolic acid were obtained from Dr. B. Schircks laboratories, Jona, Switzerland. All reagents were of analytical grade and Milli Q water with a conductivity of 18 mΩ cm-1 was used.

Folate standard solutions

Stock solutions (1 mg/ml) were prepared by dissolving them in 0.05 M HEPES-CHES buffer, PH 7.85 containing 2% sodium ascorbate and 0.01 M 2-Mercaptoethanol.

As folate derivatives are easily degraded by light and are oxidisable, all folate stock solutions were prepared under subdued light. When not in use, solid powders and stock solutions were stored at -20°C.

LC-MS instrumentation

LC was performed on a C18 reversed phase column (Zorbax Eclipse, 5 micron, 2.1 mm by 150 mm). The LC-MS system used in this study consists of a LC and autosampler coupled directly to an ion trap mass spectrometer via an electrospray interface (ThermoFinnigan LCQ Deca XP Plus). The electrospray interface was operated in the positive ion mode with a spray voltage of 5 kV. The heated capillary was maintained at 250°C. Ion optics were optimised for sensitivity using the Xcalibur software (ThermoFinnigan) ‘autotune’ function on a continually infused 10 ug/ml folic acid solution. Scan range in MS mode was 441-476 Th.

Standards clean up

Purification was carried out using C18 Solid Phase extraction cartridges (3 ml/500 mg of quaternary amine N+, counterion Cl-, No. 57017, Supelco 24-port visrep vacuum manifold). First the cartridges were conditioned with 3 ml hexane, methanol and water and then equilibrated with 10 ml of 0.01 M phosphate buffer. Then 3 ml aliquots of the standard solutions were slowly loaded on to the cartridge at the rate of < 1 ml /min. This was followed by washing the cartridge twice with 1.5 ml of conditioning buffer. Finally, folate compounds were eluted with 2.5 ml of 0.1 M acetate buffer/elution buffer with the flow rate of <0.3 ml/min.

LC-MS analysis of folates

A flow rate of 0.2 ml/min was used. A gradient program was used for analyte separation with variable mixtures of aqueous formic acid (0.1%) and acetonitrile. Recording of the chromatograms and evaluation of peaks were done using ThermoFinnigan Xcalibur software. Folate species were detected as their protonated molecules.
Internal standards
The method involves the use of commercially available carbon-labelled isotopes of the folate standards as internal standards from Eprova, Switzerland to make up for the losses during extraction and differences in ionisation efficiency. The only unavailable vitamer (10-formyl folic acid) is being synthesised in-house based on the reaction in which folic acid reacts with formic acid under heat at 50-60°C to yield 10-formyl folic acid.

Results and discussion
Separation and identification of folate compounds using LC-MS and LC-MS/MS
The adapted gradient elution using C18 reversed phase column showed a good separation of folate compounds within 30 min. A peak for DHF (Dihydrofolate) was not found, probably due to its poor stability. ESI (Electrospray ion mode) was chosen as it gives a better signal to noise ratio than atmospheric pressure chemical ionisation (APCI) for analysis of folates (Stokes & Webb, 1999). Confirmation of the compound’s identity was obtained by performing tandem mass spectrometry (MS/MS) experiments where fragmentation of the molecular ions was achieved by collision-induced dissociation (CID), and the structurally-diagnostic fragment ions produced were detected. The use of tandem mass spectrometry also allows highly specific detection of the folate vitamers when employing Selective Reaction Monitoring (SRM) SPE-SAX (Solid Phase Extraction – Strong Anion Exchange) purification, which has been proven effective for folate standards (Ginting & Arcot, 2002) and which helped to protect the mass spectrometer from the buffer ions which might otherwise dirty the instrument and cause signal suppression.

Figure 1: LCMS chromatograms of folate vitamers separated and identified based on the mass/charge ratio with positive ESI mode.
Internal standards are needed to make up for the losses during extraction and differences in the ionisation efficiency. Stable Isotope Dilution assay, which is based on the use of deuterated or carbon-labelled isotopes, helps to overcome the extraction and instrument bias (Rychlik et al., 2003). The requirements of stable isotopic labelling of vitamins are similar to those encountered in studies with other organic nutrients: a) the isotopic labelling of vitamins...
must not undergo chemical losses during analysis; b) the extent of labelling must be sufficient to avoid interference in LC-MS analysis from natural abundance of these isotopes, which usually requires that the labelled compound be at least 2 mass units greater than the naturally occurring form (Gregory & Toth 1988).

Preliminary experiments with unlabelled folic acid were promising for the synthesis of carbon-labelled 10-formyl folic acid from carbon-labelled folic acid. LC-MS study done by injecting the product shows a peak at mass 470 (10-formyl folic acid) and no peak at 442 (folic acid) which confirmed that the synthesis was successful.

Percentage purity of the compound will be calculated based on quantitative NMR in future.

Figure 4: Chromatogram confirming the synthesis of 10-formyl folic acid.

Conclusion and recommendations

An LC-MS system capable of separating and detecting the five main folate vitamers has been developed and suitable confirmation ions for each one have been identified. Thorough validation of the method will be done after optimisation of instrumental conditions and the successful introduction of internal standards. We anticipate potential problems when applying the method to “real” food samples due to matrix interferences. The matrix effects will be overcome by giving importance to the preparative phase of chromatography. The impact of this research will be the building of a repository of information on the types and amounts of
folate found in the Australian food supply. Information on the proportion of synthetic and natural forms of folic acid in the food supply will be useful in judging the impact of enrichment programs in general. LC-MS/MS promises to be a valuable tool for the specific and quantitative analysis of low-level compounds from foods, which will form a solid base for future bioavailability studies.

**Acknowledgements**

The authors thank Dr. George Smythe and Dr. Michael Guilhaus (BMSF facility, UNSW) for helping to gain access to liquid chromatography mass spectrometry.

**References**


THE ANALYSIS OF IODINE IN FOODS

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**Keywords:** trace element, mass spectrometry, quality control, colorimetric.

**Abstract**

The important trace element iodine has long been known as an essential part of the diet for humans and for animals. Marine fish and milk are two common sources of iodine, and the importance of the dairy industry in New Zealand has led to a primary interest in the analysis of iodine in dairy products, and then to an extended range of other foods.

There are many ways to analyse iodine in foods, plant tissue, and biological materials. This paper describes our experience with the routine measurement of iodine in dairy products and foods using the classic iodine method of Moxon & Dixon (1980) based on a kinetic colorimetric procedure, and more recently, with the development and application of a method based on Inductively Coupled Plasma-Mass Spectrometry (ICP-MS, Fecher et al. 1998). The colorimetric method can be done with inexpensive laboratory equipment and instrumentation although it is subject to interferences and loss of iodine during sample preparation. The ICP-MS procedure has lower method detection limits and a much wider linear range but it does require expensive instrumentation and skilled technical support.

Routine quality control (QC) measures for the determination of iodine in foods, which include the use of blanks, duplicates, spikes and certified reference materials, are discussed in the context of food survey work. These QC measures are of critical importance especially when an analytical result is produced that may lead to product recall.

**Introduction**

Iodine is an essential trace nutrient for human and animal nutrition, and a dietary deficiency results in enlargement of the thyroid gland and the formation of goitre. New Zealand soils are known to be deficient in iodine. Consequently, this important trace element is not present in our pasture and crop materials, animal tissue and cows’ milk at levels sufficient to meet our nutritional needs. The dietary iodine requirement in New Zealand was addressed in the 1930s with the introduction of iodised salt but in recent years our intake of iodised salt has been decreasing along with other changes to our diet.

One of the means of monitoring changes to our iodine intake is through regular surveys of our diet, and this is being done in New Zealand with ‘Total Diet Surveys’ assessed approximately every 5 years. The accurate analysis of iodine is an important component of these surveys and the testing laboratory faces particular challenges because of the very wide range of different food types likely to be submitted for analysis, the low levels of iodine present in almost all of these foods, and the technical demands involved.

This paper discusses the analysis of iodine in food samples from a laboratory perspective and describes our laboratory’s experience with two different methods used for determining iodine in food and dairy products, some aspects of method performance, and the quality control (QC) measures that are employed in the laboratory for trace element analyses. The importance of QC is demonstrated with examples of iodine testing in foods in which the results did not meet expectation, and a range of iodine data from some New Zealand typical foods is presented.
Methodology

Sample collection and storage

The importance of sample collection cannot be overstated. Foods, particularly prepared foods, are generally not entirely homogeneous, so it is critically important that samples collected for submission to the laboratory are fully representative of the food types of interest. The issue of whether some foods should be submitted in a raw or cooked condition will depend on the basis on which the client wishes to receive results. The sample stability and its tendency to spoil will generally dictate whether the food should be submitted in a fresh, chilled or frozen state. Often, the testing laboratory may be unable to process samples immediately on receipt, so it is important that these issues are discussed and agreed with laboratory staff prior to sample collection. Having received a food sample, the laboratory must then decide how to physically reduce this material to a homogeneous consistency because the sub-samples taken for iodine testing using modern analytical methods are very small, generally in the order of 0.5-2.5 g.

Choice of analytical method

The choice of a suitable method for determining iodine in foods and food ingredients will depend on a number of factors including the following:

- will the method scope be appropriate for the food types of interest;
- will it produce a result that is ‘fit-for-purpose’;
- will it be specific for the determination of iodine;
- will it be subject to interferences or contamination during testing;
- will it have sufficiently low method detection limits for determining iodine at low parts per billion (ppb) levels;
- is it accurate and precise for iodine at ppb levels; and
- are appropriate technical skill and equipment available?

In summary, the key issues that dictate method choice concern a sound knowledge of the sample types and the clients’ requirements, whether the method will produce accurate and precise results with sufficient method detection limits to analyse iodine at ppb levels, and whether the laboratory has the resources to set up and validate the procedure and then produce quality results in a timely manner.

Options for iodine testing in foods and food ingredients

1. Alkaline dry ashing/colorimetry

The classic dry ashing-colorimetric method reported by Moxon & Dixon (1980) was used in our laboratory for the analysis of iodine in dairy products for many years. Sample preparation entails a two-stage ashing procedure in the presence of potassium hydroxide at temperatures up to 550°C to destroy the organic component of the sample matrix. The ashed residue is then slurried in water and the released iodine is subsequently determined in a kinetic colorimetric reaction where it catalyses the destruction of iron (III) thiocyanate by nitrite. The method is relatively easy to set up but it does have a number of shortcomings. The ashing step is time-consuming and some iodine is lost during this step, so a correction is needed to account for this loss. The method can be subject to random contamination and when this occurs, the entire batch has to be re-tested.
2. Alkaline digestion/inductively coupled plasma-mass spectrometry (ICP-MS)

Hills Laboratory recently introduced a new method for the analysis of iodine in dairy products, subsequently extended to food samples, using the ICP-MS procedure reported by Fecher et al. (1998). This procedure uses a solution of tetramethylammonium hydroxide (TMAH) to digest samples at high temperatures. Iodine is then determined specifically by ICP-MS. ICP-MS is a multi-element instrumental technique which operates by introducing each sample digest, in the form of an aerosol, into an argon plasma burning at several thousand degrees C. This very high energy source completely converts samples to their constituent atoms and then to positive ions by the removal of an electron, and each element is then determined by mass spectrometry. Iodine is quantified specifically as the mass ion 127I+. As shown in Table 1, this method has many advantages compared with the colorimetric method, but it does require a major investment in the purchase and maintenance of expensive instrumentation.

Table 1: Strengths and weaknesses of two iodine methods.

<table>
<thead>
<tr>
<th>Method characteristics</th>
<th>Ashing/colorimetric (Moxon &amp; Dixon)</th>
<th>TMAH/ICP-MS (Fecher et al.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equipment/capital costs</td>
<td>moderate</td>
<td>expensive</td>
</tr>
<tr>
<td>Iodine recovery¹</td>
<td>poor to variable recovery</td>
<td>specific recovery</td>
</tr>
<tr>
<td>Specificity</td>
<td>indirect measurement of iodine</td>
<td>measurement of iodine</td>
</tr>
<tr>
<td>Subject to contamination²</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Range³</td>
<td>limited (≤ two orders)</td>
<td>good (three-four orders plus)</td>
</tr>
<tr>
<td>Method detection limit⁴</td>
<td>&lt; 0.05 mg/kg (for ‘dry’ foods⁵)</td>
<td>&lt; 0.01 mg/kg (for ‘dry’ foods⁵)</td>
</tr>
<tr>
<td>Sample throughput</td>
<td>poor</td>
<td>good</td>
</tr>
<tr>
<td>Technical skill required</td>
<td>requires skilled manual input</td>
<td>requires spectroscopy experience</td>
</tr>
</tbody>
</table>

¹ The amount of iodine typically recovered from the sample as determined by spike recovery work.
² The tendency for samples to be contaminated by external sources of iodine or interfering substances and this is monitored by procedural blank samples.
³ The linear range across which iodine can be measured and generally expressed in ‘orders of magnitude’.
⁴ Method detection limit which is specific to the method and for each particular sample matrix.
⁵ Method detection limits may vary depending on the dry matter content of test samples.

We now use the ICP-MS method routinely for all foods and food ingredients. We did, however, use the ashing/colorimetric method to provide an ‘alternative method comparison’ to validate the ICP-MS method for dairy products. A wide range of dairy products including whole and skim milk powders, milks, creams, yoghurts, cheeses, fortified nutritional products, and a vitamin pre-mix were analysed by both methods. The results from the two methods compared very well across a wide range of iodine levels for a diverse set of sample matrices and were shown to be highly correlated. Figure 1 shows the linear regression for 61 dairy product samples. The equation for this regression has a slope very close to unity and a very small intercept;

\[ Y = 0.989X + 0.019 \ (r^2 = 0.987) \]

Hills Laboratory has settled on the ICP-MS procedure because of the wide range of food and biological sample types that are encompassed within its scope and its speed of sample throughput.
Method performance and quality control in the laboratory

Test method accuracy is usually evaluated by analysing certified reference materials (CRMs) in parallel with routine testing. It is preferable to choose CRM matrices as closely related to the food samples of interest as possible. Unfortunately, there are few food-based CRMs available with values quoted for iodine so we have used milk powder and other material CRMs to check method accuracy. Table 2 gives iodine results obtained from a whole milk powder and an apple leaves CRM and shows that the mean iodine values agree well with the certified values. Method precision is now defined by the term ‘Uncertainty of Measurement’ (UoM). UoM is generally reported as ± two standard deviations at the 95% confidence limit, and for CRMs, these limits indicate the homogeneity of the material and the ability of a large number of laboratories to obtain a result close to the ‘true’ value. Table 2 shows the UoM typically observed with CRMs. The non-homogeneous nature of most prepared foods constitutes a major component of the UoM when analysing iodine in these materials, and statistical analysis of all analytical factors show that the UoM depends largely on the particular food and the amount of iodine that it contains.

Table 2: Accuracy and precision of iodine results from CRMs.

<table>
<thead>
<tr>
<th>CRM</th>
<th>Certified value for iodine (mg/kg)$^1$</th>
<th>Obtained value for iodine (mg/kg)$^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>NIST 8435 (whole milk powder)</td>
<td>2.3 ± 0.4</td>
<td>2.28 ± 0.21</td>
</tr>
<tr>
<td>NIST 1515 (apple leaves)</td>
<td>0.3 (no limits specified)</td>
<td>0.29 ± 0.01</td>
</tr>
</tbody>
</table>

$^1$ A mean result ± two standard deviations obtained by a number of international laboratories for this CRM.

$^2$ Mean results ± two standard deviations obtained by our laboratory.
All laboratories use a range of QC measures to monitor test method performance. These give the laboratory confidence that the method is giving consistently acceptable results which are ‘fit-for-purpose’ for the client. QC is particularly important for iodine testing in foods because this analyte is commonly present at extremely low levels, or it is reported as less than a stated detection limit. ‘Procedural blanks’ are important for trace element analyses as they provide a ‘baseline’ for each batch of data, but they also indicate whether the results may have been affected by random or systematic contamination incurred during analysis. A duplicate of at least one sample in each batch is fortified or ‘spiked’ with a known amount of iodine prior to analysis. The spike recovery, reported as a percentage of the theoretical amount added, provides a check on the accuracy of the procedure, and may indicate whether the sample matrix is interfering with the measurement of iodine in the sample. Recoveries of between 80–120% are usually regarded as acceptable for most trace element analyses. Duplicate analyses are determined from random samples within batches to monitor method repeatability, but random repeats in succeeding batches give the analyst a more realistic assessment of the UoM for the method. In-house QC samples are commonly used to monitor ‘method drift’ between batches, as well as giving further information on method precision. The analysis of CRMs has already been discussed above although they are analysed less frequently because of their cost. Finally, laboratories should participate in Inter-Laboratory Comparison Programmes (ILCPs) whereby a common sample or samples are analysed by a number of laboratories. Statistical analysis of the pooled results is invaluable in checking method performance against other labs, but ILCPs for some sample types and some analytes may not be available because there are not enough participants to warrant running the programmes. This is certainly the case for testing iodine in food samples in the Australasian laboratory sector.

Results and discussion

Iodine levels in New Zealand foods

The 2003-04 New Zealand Total Diet Survey recently reported updated information on iodine levels in commonly consumed New Zealand foods and these data showed that most of the foods surveyed contained little or no iodine. The best sources of iodine were generally of marine origin such as mussels, oysters, fish etc. Other important foods with moderate levels of iodine included poultry products (particularly eggs), pork products, and dairy products such as cheese, yoghurt, ice cream and milk. Some prepared and takeaway foods contained lower but measurable levels of iodine, for example, commonly consumed foods such as muffins, cake, pizza and chips. One food ingredient not surveyed, but still an important component of our diet, was iodised salt.
Figure 2 demonstrates relative differences in iodine levels for some of the food types discussed above. Mussels, eggs and fish were very good sources of iodine with levels ranging from 0.3 mg/kg to over 1.5 mg/kg. Conversely, staple foods such as milk and potatoes had low to negligible amounts of iodine. Milk iodine levels in New Zealand currently vary between approximately 0.05-0.10 mg/kg and have fallen in recent decades due to the reduced use of iodine sanitisers in dairy farms. Potatoes contain barely detectable levels of iodine (about 0.010 mg/kg) and are typical of other vegetables and fruit types, many of which do not register iodine above the detection limit of < 0.002 mg/kg, which is equivalent to < 0.2 μg/100g of edible portion. (Convention for expression of nutrients in foods is per 100 g edible portion)

**Food iodine results and clients’ expectations**

The importance of sound QC procedures in every batch of samples is highlighted when iodine results do not meet clients’ expectations. It is often inferred that the laboratory must have made a mistake, and although this may happen occasionally, there are numerous examples where the accuracy of the results are confirmed. In extreme cases, non-compliant iodine results may indicate a failure to meet a label claim and this can lead to product withdrawal from supermarket shelves and the serious outcomes that this entails.

One interesting example in our laboratory involved testing several wafer composites for iodine where each composite was composed of a number of commercial wafer products. Three of the composites contained approximately 0.05 mg/kg of iodine whereas the fourth composite was reported at 20 mg/kg, an extremely high level of iodine for any prepared food product. The original data could not be faulted and the high result was duly confirmed by extensive
re-testing, which included replicated analyses, sample spikes and accuracy checks against CRMs. Subsequent communication with the client eventually established that the problem composite contained a highly coloured wafer and that the source of the excess iodine was traced to a food colouring additive.

Another case involved a set of soy milk samples purchased from supermarket shelves as part of a food survey. One of the four iodine results exceeded the other results by over two orders of magnitude so the process of re-checking initial data and re-testing was instigated urgently. The label claim for this product was also exceeded by a considerable margin so the client submitted a number of different batches of the product to check the possibility of a production error. Again, the high result was reproduced in conjunction with QC checks, and this was also confirmed independently by another laboratory and ultimately traced back to the fortification of the soy milk with a seaweed concentrate. These examples illustrate the problems and pressures that may confront the laboratory and they demonstrate the importance of adopting sound QC procedures during all aspects of testing.

References


MEASUREMENT OF BLOOD GLUCOSE RESPONSE TO FOODS

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Keywords: Glycaemic Glucose Equivalents, carbohydrate, Glycaemic Index, Glycaemic Load

Abstract
The Glycaemic Index (GI) is a measure of the blood glucose response to carbohydrate in a food as a percentage of the response to an equal weight of glucose. The use of GI to compare foods is limited because the calculation is based on glycaemic carbohydrate only and not on the response to the whole food. Because foods contain different amounts of carbohydrate, ranking foods by GI will not necessarily rank them according to the effect they have on blood sugar. In order to address these problems, another measure has been developed known as Glycaemic Glucose Equivalent (GGE). GGE is the amount of glucose in grams that would induce a glycaemic response equal to the portion of food specified. It is measured by determining the blood glucose response to a defined portion of a food and comparing it with the blood glucose response to a glucose reference of known glucose concentration. The GGE of the value is estimated based on data from 10-12 individuals. Individuals can then use this information to guide their food choices. In particular, this information can help individuals with diabetes to control their blood glucose levels. Foods with a low blood glucose response may also promote weight loss. Knowledge of the blood glucose response to foods can also be tailored to improve athletes’ performance.

Introduction
Why are we interested in blood glucose response to foods?
Blood glucose control is especially important for people with diabetes, because high levels of circulating glucose can cause cellular damage and increase the risk of coronary heart disease as well as conditions such as blindness, kidney failure and gangrene (Mann 2002). Studies have shown that consuming a diet containing a large proportion of foods with a low blood glucose response may help improve control of blood glucose in individuals with diabetes (Brand-Miller et al. 2003). Studies have also suggested that foods with a low blood glucose response can aid in weight loss, by increasing satiety, so that individuals eat less at the next meal and wait longer until they eat their next meal (Slabber et al. 1994; Ludwig et al. 1999; Speith et al. 2000; Brand-Miller et al. 2002; Pawlik et al. 2002; Raben 2002; Ball et al. 2003; Ebbeling et al. 2003). In addition, some studies have shown that consuming a diet containing a lot of foods with a low blood glucose response foods may prevent individuals from developing diabetes (Salmeron et al. 1997a; Salmeron et al. 1997b; Augustin et al. 2002; Brand-Miller 2003). Epidemiological studies also suggest that low blood glucose response diets may help to reduce an individual’s risk of heart disease (Liu et al. 2000; Stampfer et al. 2000; Augustin et al. 2002; Brand-Miller 2003). However, it is important to realise that although eating patterns that feature an abundance of lower blood glucose response foods are associated with better health outcomes, foods with a higher blood glucose response are
also useful because they add dietary variety and provide other nutrients that low GI foods may not. A high blood glucose response food is also beneficial for normalising the blood sugar levels of diabetics whose levels have fallen too low (Mann 2002) and for replenishing muscle fuel in athletes after exercise (Walton & Rhodes 1997; Burke et al. 1998).

What are the different measures of blood glucose response to foods?

1. Glycaemic Index

The Glycaemic Index (GI) is a method of ranking foods on the basis of the blood glucose response they produce for a given amount of carbohydrate (Jenkins et al. 1981). It has been defined by the Food and Agriculture Organization (FAO) of the United Nations and World Health Organization as “the incremental area under the blood glucose response curve for a 50 g carbohydrate portion of a test food expressed as a percent of the response to the same amount of carbohydrate from a standard food taken by the same subject” (FAO/WHO 1998). For foods containing the same amount of carbohydrate, the GI indicates what effect the food will have on an individual’s blood glucose levels.

2. Glycaemic Glucose Equivalents

Glycaemic Glucose Equivalents (GGE) is the amount of glucose in grams that would induce a glycaemic response equal to the specified portion of the food (Monro 1997; Monro 1999a; Monro 1999b; Monro & Williams 2000; Monro 2001; Monro 2002; Monro 2003a; Monro 2003b). For example, if a food has a GGE of 6 g, it has the same response as 6 grams of glucose. GGE is the most up to date and easy to use measure for managing blood glucose levels. It provides consumers with information that can guide them in making healthy food choices.

3. How does Glycaemic Glucose Equivalents differ from Glycaemic Index?

The Glycaemic Index (GI) is a measure of the blood glucose response to available carbohydrate in a food as a percentage of the response to an equal weight of glucose. For foods containing the same amount of carbohydrate, the GI indicates the effect of the food on an individual’s blood glucose levels. It must, however, be noted that GI is calculated for the glycaemic carbohydrate component of the food, not the response to the whole food. Because foods contain different amounts of carbohydrate, ranking foods by GI will not necessarily rank them according to the effect that equal weight servings will have on blood sugars.

For example, if the GI of an apricot is 57 and the GI of a banana is 58, it would be assumed that if an individual ate either of these, it would result in the same blood glucose response. However, an apricot has only 5 g of available carbohydrate whereas a banana has 31 g, so one banana will raise blood glucose levels six times higher than one apricot because it contains six times more carbohydrate and is more than twice the size of the apricot. This cannot be demonstrated by the GI value of the food. The GGE of an apricot and banana would be 3 and 18 respectively, which effectively communicates the real blood glucose impact of the food to a consumer. In other words the apricot would have an effect equivalent to 3 g glucose and the banana 18 g glucose.

In addition, since GI is a ratio, it does not change with food intake. So a muesli bar has the same GI whether the person eats 50 g of the bar or 150 g, whilst obviously the impact on blood glucose for 150 g of the bar should be 3 times the impact of 50 g of the bar.

GGE accounts for these problems by measuring the glycaemic response of a given serve size of the whole food rather than just the carbohydrate portion. GGE is the amount of glucose in grams that will induce the same glycaemic response as a given weight of food. As GGE is not just a ratio, it is responsive to changes in food intake, and as it measures the blood glucose
response of the whole food, it can be used to compare foods containing different amounts of carbohydrates. Consumers will then be able to make more meaningful comparisons between foods because GGE allows consumers to compare foods both within and across food categories, in exactly the same format as other food components currently displayed on food labels.

4. What is Glycaemic Load and how does it differ from GGEs?

Glycaemic Load is an estimate of the GGE value of the food for 100 g of the food. It is calculated by multiplying the GI of the food by the proportion of available carbohydrate.

**Methodology**

**Measurement of blood glucose response to foods**

Measurement of GGEs is carried out in 10-12 individuals by finger prick samples (capillary blood). The individuals are tested after a 12-hour fast (that is, they are allowed nothing to eat or drink for 12 hours before the test). They are also asked not to exercise from 6 pm the night before and asked to make their evening meal prior to the testing high in carbohydrates. When they come into the clinic, two fasting blood glucose samples are taken. The individual is then given a portion size of the test food. For example, the person is given a 45 g (3/4 cup) of All Bran OR two Ryvita crackers (these are the serve sizes as stated on the Nutrition Information Panel). Blood samples are then taken every 15 minutes for the first hour, then every half hour for the second hour. During this time the individuals stay seated with minimal movement. The blood samples are analysed for blood glucose and plotted on a curve. The incremental area under the curve (IAUC) for the food over 120 minutes is then calculated. The blood glucose response of a glucose drink is also determined for the test food. The amount of glucose in the reference drink is approximately equal to the available carbohydrate content of the food.

Often a 25 g or 50 g glucose reference is used. The GGE of the test food/serve is calculated by dividing the IAUC for the test food by the IAUC for the reference food and multiplying by the difference in portion size between the food and the amount of glucose in the reference.

Then for example, suppose the GGE of a defined portion size of 100 g of a muesli bar is required.

\[
\text{GGE} = \frac{\text{IAUC for 100 g bar}}{\text{IAUC for 25 g glucose}} \times \frac{\text{amount of glucose (g) in reference}}{\text{portion size of food tested}} \times \text{defined portion size of food}
\]

\[
= \frac{200}{400} \times \frac{25}{100} \times 100 = 12.5 \text{ g}
\]

The GGE of the food for each individual is calculated and the GGE of the food is taken as the average result for the 10-12 individuals.

**Results and discussion**

**Table: Comparison of GI and GGE in a selection of common foods**

<table>
<thead>
<tr>
<th>Food item</th>
<th>Weight (g)</th>
<th>GI</th>
<th>GGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 apricot</td>
<td>30</td>
<td>57 (medium GI)</td>
<td>3.1 (low GGE)</td>
</tr>
<tr>
<td>1 banana</td>
<td>150</td>
<td>58 (medium GI)</td>
<td>18 (medium GGE)</td>
</tr>
<tr>
<td>1 can Fanta™</td>
<td>375</td>
<td>68 (medium GI)</td>
<td>35 (high GGE)</td>
</tr>
<tr>
<td>2 slices pineapple</td>
<td>125</td>
<td>66 (medium GI)</td>
<td>6.6 (low GGE)</td>
</tr>
<tr>
<td>1 glass orange juice</td>
<td>256</td>
<td>46 (low GI)</td>
<td>9.9 (low GGE)</td>
</tr>
<tr>
<td>1 slice banana cake</td>
<td>80</td>
<td>47 (low GI)</td>
<td>22 (high GGE)</td>
</tr>
</tbody>
</table>
The significance of GGEs is that they allow foods to be ranked according to their effects on blood glucose and hence they are able to be used to guide food choices. Figure 1 gives an example of how the blood glucose response curves may differ in the same individual for a high GGE food versus a low GGE food. Note that the area under the high GGE food is greater than under the low GGE food. Because the blood glucose response is based on a defined portion of the food, it is necessary to state the serving size of the food along with its GGE. As Figure 1 demonstrates, a high GGE is characterised by a greater peak in blood glucose level than a low GGE food and the blood glucose value of a high GGE food returns to baseline much faster. Therefore, a low GGE food is much better for individuals with diabetes as it will limit their exposure to high levels of circulating glucose (Mann 2003).

![Blood glucose response curves](image)

*Figure 1: Comparison of the blood glucose response curves of a high GGE food, for example 100 g white bread, with a low GGE food, for example 100 g 50% grain bread.*

In addition, when a person eats a high GGE food, their blood glucose returns to baseline after 1½ hours, whereas for the low GGE, it remains just above baseline after 4 hours. It is believed that the hormones associated with hunger are released and a desire to eat is registered when blood glucose levels drop to levels of fasting, so when the person eats a low GGE food they will feel fuller for longer and hence wait longer until they eat their next meal. They will also eat less at their next meal (Slabber et al. 1994; Ludwig et al. 1999; Speith et al. 2000; Brand-Miller et al. 2002; Pawlak et al. 2002; Raben 2002; Ball et al. 2003; Ebbeling et al. 2003).

As is often seen with high GGE foods, insulin overcompensates for the surge of glucose and glucose levels drop below fasting. Examples of high GGE foods, along with their portion sizes, are ¾ cup Cocoa Pops, 1 bagel, 1 cup white rice, 15 jelly beans and 375 ml Fanta. Examples of foods with a low GGE are ½ cup All Bran, 200 g yoghurt, 1 cup tomato soup, ½ cup chickpeas, ½ cup kidney beans, 1 peach, 1 orange, 2 apricots.
Conclusion and recommendations

Because GI is a measure of the blood glucose response of 50 g available carbohydrate relative to 50 g glucose, it can only be used to compare foods containing equal amounts of carbohydrate and it can sometimes misclassify foods because the actual portion people eat is much larger or smaller than 50 g. Hence, GGEs, a measure of the whole blood glucose response of the food based on a normal portion of food that a person would consume is a much more meaningful measure of blood glucose response. GGEs would provide useful information to manufacturers who could place the details on food labels, making it accessible to consumers.

References


VIRTUAL FOOD COMPONENTS: THE EXAMPLE OF GLYCAEMIC GLUCOSE EQUIVALENTS

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Keywords: Glycaemia, diabetes, food composition database

Abstract

A virtual food component is a food value that expresses a particular physiological effect of a food in terms of the weight of a reference material or food of known activity. Because the food effect is expressed in the same manner as a food component, as a weight, it is termed a virtual food component (VFC). The glycaemic glucose equivalent (GGE), defined as the weight of glucose that will induce the same glycaemic response as a given weight of food, is a virtual food component that has been developed to express the glycaemic effect of foods. As in the case of real food components, GGE can be used to express the relative glycaemic potency of any reasonable quantity of food on a per-serving basis, to gauge the effect on blood glucose of usual food intakes. GGE can also be used on a per-100 g basis, to allow equal weight comparison of foods. Because it expresses glycaemic impact in the format of a nutrient, it may be used concurrently with nutrients in food composition database-linked nutrition management systems to provide a more complete nutritional profile of a food intake than is provided by actual nutrients alone. It is, therefore, potentially well suited for managing postprandial glycaemia while achieving nutritional balance, or for use in designing diets to reduce the diet-dependent complications of diabetes, such as coronary artery disease. In developing a GGE database there are a number of challenges to overcome. Further research is needed in establishing the accuracy of GGE values, the derivation and evaluation of various interim estimates of GGE for foods that are too numerous for immediate clinical assessment, the applications of a GGE database, and the use of GGE alongside other virtual food components to provide functional balance in a diet.

Introduction

What are virtual food components?

A virtual food component (VFC) is a value that expresses a functional effect of a food in the format of a food component (Monro 2004). VFCs were created to provide consumers, including nutritionists, regulators and food producers, with a means of discriminating between foods according to their efficacy. At present it is almost impossible to predict food effects from the information provided in food labels, because current nutrient analyses do not take into account factors such as the physicochemical properties of food components and the modulating effect of food structure, which is intentionally destroyed when samples are prepared for food analysis (Monro 2000).

For a VFC to represent a food effect, it must be expressed in grams - the same unit used to express a quantity of nutrient. This is achieved by identifying a reference material of known activity per unit weight. Then, the bioactivity of the food can be expressed as gram equivalents of the reference material.
Two virtual food components have been proposed to date:

Glycaemic Glucose Equivalents (GGE): the postprandial glycaemic load imposed by a given amount of food, expressed as the amount of glucose that would induce a glycaemic response equal to that of the food (Monro & Williams 2000).

Wheat bran equivalents (WBE$_b$): the faecal bulking capacity of a given amount of food expressed as the amount of wheat bran reference that would contribute to faecal bulk to the same extent as the food (Monro 2001). Bulk in the colon has a number of direct and indirect benefits (Monro 2004), but WBE$_b$ will not be discussed here.

In this paper the focus is on GGE. Postprandial glycaemia has been implicated in a range of diseases that are complications of exposure to high blood glucose levels, such as occur in diabetes. The insulinaemic responses associated with high blood sugars are thought to be damaging in their own right. The combined effects of hyperglycaemia and hyperinsulinaemia, lead to the generalised damage that is responsible for the syndromic complications associated with diabetes, including heart disease, and failure of micro-capillary circulation involving kidneys, eyes and extremities (Brownlie 2001).

**Why use virtual food components?**

At present, many physiological effects of food cannot be represented adequately by the values displayed in nutrient information panels. Food effects depend on much more than food components *per se*. Food structure, properties of food constituents and of foods that are neither measured in nutrient and food analysis nor attributable to discrete nutrients or known combinations of them, but that are emergent holistic variables, may influence response to a food (Monro 2000).

Health or nutrient claims used to guide food choices often allow only very coarse discrimination between foods, and are unlikely to be trusted by consumers when there are no data on efficacy that would allow direct comparison of products. VFCs provide a quantitative measure of the relative effects of foods, enabling accurate food choices based on efficacy. Another important result of expressing food effects as VFCs is that because they are in the same format as nutrients they may be used concurrently in nutrient management systems to show not only what a food is, but also what it does (Monro & Williams, 2000).

By expressing the relative effects of foods as quantitative food values, VFCs have the potential to empower consumers and nutritionists to make healthier food choices, while at the same time providing an opportunity for food manufacturers to demonstrate the relative efficacy of any superior products they make.

**Methodology**

**Glycaemic glucose equivalent (GGE)**

GGE is defined as the weight of glucose in grams that would induce a postprandial glycaemic response equal to that of a given weight of food. GGEs are designed to act as nutrient-like values to reflect the relative glycaemic potency of a food, as well as the effects of food intake on glycaemic response.

GGE is intended to overcome the limitations of glycaemic index (GI) as a guide to food choice. GI is necessarily limited by its intended purpose of allowing exchanges within groups of foods having a similar composition and available carbohydrate content, but differing in glycaemic impacts. It is inappropriate to use GI to choose between food items that differ in composition and available carbohydrate content. Furthermore, as GI is a static value that does not respond to food intake, it cannot reflect the effects of portion size or food intake on
glycaemic impact. A GI value is unlike values for other food components with which it is associated, because it refers to the glycaemic potency of a food component – available carbohydrate – and not to the food as a whole, so is likely to be misused by consumers, who deal in whole foods.

GGE should ideally be measured as the response to a relevant food quantity, relative to a related quantity of glucose reference. However, many GI values already exist and were measured as the glycaemic effect of an amount of food that would provide 50 g available carbohydrate (as required in GI determination) relative to 50 g glucose. The GGE content of a weight of food may also be estimated from GI and available carbohydrate (CHOAVL) content (%) of a food, using the equation:

\[ \text{GGE} = \text{Food weight} \times \% \text{CHOAVL}/100 \times \text{GI}/100 \]

Preliminary validation studies have shown that in a group of foods differing in GI and CHOAVL content, GGE was able to predict the effect of food intake on relative glycaemic impact well (R² = 0.88), whereas GI bore no relationship to glycaemic impact (R² = -0.2) because the study was not limited to the equi-carbohydrate comparisons required of GI (Liu et al. 2003).

Results and discussion

Tables of glycaemic glucose equivalents in New Zealand foods

GGEs were not designed for use in isolation, but rather to assist the integration of dietary management of glycaemia with balanced nutrition. They should, therefore, be present alongside other food composition data, and can be used in electronic nutrition management systems to design diets that are within the limits required by individuals. Table 1 shows part of the first page of the Tables of Glycaemic Glucose Equivalents in New Zealand Foods (Monro & McLaughlin 2005). A short commentary prefaces the tables to explain their use and to stress the importance of using GGE within a healthy diet.

A number of indicators may also be used to stress, for instance, the presence of more than 10% fat in a food, as shown by the shading in Table 1.

The tables include GI values so that users have the option of comparing foods according to the glycaemic potency of their available carbohydrates.
Table 1: Glycaemic Glucose Equivalents in New Zealand foods.

<table>
<thead>
<tr>
<th>Code</th>
<th>Food</th>
<th>Common standard measure (CSM)</th>
<th>Wt (g)</th>
<th>GGE (g)</th>
<th>GI</th>
<th>Energy (kJ)</th>
<th>Av. CHO (g)</th>
<th>NSP (g)</th>
<th>Tot. fat (g)</th>
<th>SAFA (g)</th>
<th>Protein (g)</th>
<th>Sodium (g)</th>
<th>Water (g)</th>
</tr>
</thead>
<tbody>
<tr>
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<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>BAKERY PRODUCTS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>A54</td>
<td>Bagels, plain</td>
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<td>33</td>
<td>72</td>
<td>936</td>
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<td>2.0</td>
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<td>0.2</td>
<td>7.7</td>
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<td>43</td>
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<td></td>
<td></td>
<td>1 bagel</td>
<td>74</td>
<td>24</td>
<td>72</td>
<td>693</td>
<td>34</td>
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<td>1.2</td>
<td>0.2</td>
<td>5.7</td>
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<td>32</td>
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<td>21</td>
<td>42</td>
<td>1930</td>
<td>51</td>
<td>1.6</td>
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<td>5.6</td>
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<td>1 biscuit</td>
<td>12</td>
<td>3</td>
<td>42</td>
<td>232</td>
<td>6</td>
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<td>3.2</td>
<td>2.1</td>
<td>0.7</td>
<td>19</td>
<td>2</td>
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<tr>
<td></td>
<td></td>
<td>Biscuit, flat</td>
<td>100</td>
<td>53</td>
<td>77</td>
<td>1390</td>
<td>69</td>
<td>2.7</td>
<td>4.7</td>
<td>2.2</td>
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<td>77</td>
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<td>0.6</td>
<td>0.3</td>
<td>0.6</td>
<td>23</td>
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</tr>
<tr>
<td>A68</td>
<td>Biscuit, flat fruit</td>
<td></td>
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<td>32</td>
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<td>57</td>
<td>6.1</td>
<td>18.3</td>
<td>3.9</td>
<td>10.0</td>
<td>1230</td>
<td>6</td>
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<td>1 biscuit</td>
<td>15</td>
<td>5</td>
<td>55</td>
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<td>0.6</td>
<td>1.5</td>
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<td>1</td>
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<td>Biscuit, plain, Digestive</td>
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<td>100</td>
<td>38</td>
<td>59</td>
<td>1900</td>
<td>65</td>
<td>3.6</td>
<td>18.9</td>
<td>9.0</td>
<td>7.0</td>
<td>330</td>
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<td></td>
<td>1 biscuit</td>
<td>13</td>
<td>5</td>
<td>59</td>
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<td>1.2</td>
<td>0.9</td>
<td>43</td>
<td>1</td>
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<td>1 biscuit</td>
<td>100</td>
<td>38</td>
<td>64</td>
<td>1980</td>
<td>60</td>
<td>1.9</td>
<td>23.9</td>
<td>12.2</td>
<td>5.5</td>
<td>280</td>
<td>4</td>
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<td>1 biscuit</td>
<td>12.5</td>
<td>5</td>
<td>64</td>
<td>248</td>
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<td>0.2</td>
<td>3.0</td>
<td>1.5</td>
<td>0.7</td>
<td>35</td>
<td>0</td>
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<td>Biscuits, 'Arrowroot'</td>
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<td>100</td>
<td>52</td>
<td>69</td>
<td>1760</td>
<td>76</td>
<td>4.1</td>
<td>10.4</td>
<td>4.4</td>
<td>6.9</td>
<td>277</td>
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<td></td>
<td></td>
<td>1 biscuit</td>
<td>8</td>
<td>4</td>
<td>69</td>
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<td>6</td>
<td>0.3</td>
<td>0.8</td>
<td>0.4</td>
<td>0.6</td>
<td>22</td>
<td>0</td>
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<tr>
<td>A40</td>
<td>Bread roll, white</td>
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<td>100</td>
<td>37</td>
<td>70</td>
<td>1090</td>
<td>53</td>
<td>3.0</td>
<td>1.6</td>
<td>0.2</td>
<td>9.2</td>
<td>480</td>
<td>34</td>
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<tr>
<td></td>
<td></td>
<td>1 long roll</td>
<td>77.2</td>
<td>29</td>
<td>70</td>
<td>841</td>
<td>41</td>
<td>2.3</td>
<td>1.2</td>
<td>0.2</td>
<td>7.1</td>
<td>371</td>
<td>26</td>
</tr>
<tr>
<td>A52</td>
<td>Bread roll, wholemeal</td>
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<td>100</td>
<td>32</td>
<td>71</td>
<td>1000</td>
<td>45</td>
<td>5.5</td>
<td>2.3</td>
<td>0.3</td>
<td>10.2</td>
<td>480</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 long roll</td>
<td>79.3</td>
<td>25</td>
<td>71</td>
<td>793</td>
<td>36</td>
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<td>1.8</td>
<td>0.2</td>
<td>8.1</td>
<td>381</td>
<td>27</td>
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<tr>
<td>A16</td>
<td>Bread, currant</td>
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<td>100</td>
<td>27</td>
<td>47</td>
<td>1150</td>
<td>57</td>
<td>3.4</td>
<td>1.4</td>
<td>0.3</td>
<td>9.1</td>
<td>351</td>
<td>27</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 slice</td>
<td>30.5</td>
<td>8</td>
<td>47</td>
<td>351</td>
<td>17</td>
<td>1.0</td>
<td>0.4</td>
<td>0.1</td>
<td>2.8</td>
<td>107</td>
<td>8</td>
</tr>
<tr>
<td>A181</td>
<td>Bread, currant</td>
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<td>100</td>
<td>31</td>
<td>54</td>
<td>1120</td>
<td>57</td>
<td>2.9</td>
<td>1.4</td>
<td>0.2</td>
<td>7.4</td>
<td>373</td>
<td>34</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 loaf</td>
<td>508.4</td>
<td>157</td>
<td>54</td>
<td>5694</td>
<td>291</td>
<td>14.6</td>
<td>7.3</td>
<td>1.2</td>
<td>37.7</td>
<td>1896</td>
<td>173</td>
</tr>
<tr>
<td>A207</td>
<td>Bread, multi-grain</td>
<td>1 slice</td>
<td>100</td>
<td>16</td>
<td>43</td>
<td>862</td>
<td>38</td>
<td>4.3</td>
<td>2.3</td>
<td>0.2</td>
<td>9.2</td>
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<td>45</td>
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<tr>
<td></td>
<td></td>
<td>1 slice</td>
<td>44.6</td>
<td>7</td>
<td>43</td>
<td>384</td>
<td>17</td>
<td>1.9</td>
<td>1.0</td>
<td>0.1</td>
<td>4.1</td>
<td>163</td>
<td>20</td>
</tr>
</tbody>
</table>

Grey shading indicates more than 10% fat.
Current challenges for VFCs in food composition databases

Several general criteria have been identified with which to assess the adequacy of VFCs. At present the criteria most in need of research relate to their linearity, accuracy, robustness, and comprehensiveness.

- **Linearity:** Can GGE be used as a linear variable over a wide enough range of food intakes to be useful in glycaemia management?

  A VFC, like a real food component, is most easily used if it is a linear function of food intake. However, it has long been known that the blood glucose response to glucose equivalent dose is better described as a quadratic function of intake. Recent research has shown that if a 40-50 g glucose reference is used, then the discrepancy between linear estimates (such as glycaemic load) of GGE and true quadratic determination is a maximum of about 5 GGE (Monro & Murphy 2005). However, if each food value in a food composition database was corrected for the discrepancy, the corrections could add to a considerable error in a meal, because the discrepancy applies only once to the total GGE intake. Therefore, it is probably best to use a linear calculation of GGE content determined with a 50 g glucose reference as is used currently in the determination of GI.

- **Accuracy:** Do GGE values accurately predict relative glycaemic responses to foods?

  As a virtual food component, GGE represents a pre-measured relative effect of a food that is used to predict the same relative effect when the food is consumed on a subsequent occasion. Apart from the problem of variability in human measurements when first establishing a GGE value for a food, a number of variables may intervene between measuring the GGE content of a food and the subsequent expression of the food effect to reduce the apparent accuracy of the GGE value first obtained. As for other food components, changes in food composition will always be a problem that will reduce the accuracy of database values for predicting the GGE content of an individual sample, especially in foods that undergo seasonal changes, such as fruit and vegetables.

  Human variability is often mentioned as a source of inaccuracy, but it should be remembered that GGE is a relative value, so a food that has twice the content of another will do so irrespective of the glycaemic responsiveness of the consumer or the occasion.

- **Robustness:** Can GGE predict relative glycaemic response over a wide enough range of conditions to be useful in the range of diets that consumers would normally wish to consume?

  Much more research is required to determine how robust GGE values are. However, it should be remembered that factors that affect the blood glucose response per unit GGE will not affect GGE per se if the response to a food and to the glucose reference are similarly affected.

- **Comprehensiveness:** Have the GGE contents of enough foods been determined for a GGE database to be applicable to the range of foods normally encountered in normal diets?

  The issue of comprehensiveness is discussed in the next section.
Compiling a GGE database

One of the main problems in developing a GGE database is that VFCs are based on the effects of foods on biomarkers linked to health endpoints. The most accurate determination of GGE values therefore requires in vivo measurement in humans, with the attendant problems of obtaining ethical approval, expense, compliance, inter and intra-subject variability, and demands of time and labour in clinical trials. It is difficult to obtain measurements rapidly or cheaply enough to keep up with the appearance of new products. This issue is particularly important as a flush of new products occurs in response to market demand for products of low glycaemic impact. But also, as the global incidence of obesity and Type 2 diabetes reaches epidemic proportions (Zimmet et al. 2001), the search for indigenous foods, preparation methods, cultivars and diets of reduced glycaemic potency becomes increasingly urgent, as does the need for interim data that will allow glycaemic potency of foods to be represented in food composition databases.

Several strategies are needed to provide interim GGE data that may be effective in reducing the glycaemic impact of food choices. Fortunately it is not necessary to start from scratch. Food composition tables already contain base data in the form of available carbohydrate values, which are already used in the management of glycaemic response to foods, despite the clinical studies that led to the introduction of the GI (Jenkins et al., 1981), and many since, having shown that available carbohydrate values are not an accurate guide to the glycaemic impact of foods.

We are therefore in the luxurious position of being able to adopt a number of strategies to obtain food data that will represent glycaemic potency, knowing that the results will reflect different degrees of improvement over the base available carbohydrate data. The challenge is to be able to maximise the improvement by choosing appropriate strategies.

Highest quality GGE data are obtained by measuring the effect of foods directly, under relevant conditions in humans, with realistic serving sizes. A possible ranking of measures of glycaemic potency, with the highest quality data first, could be as follows:

- GGE measured as the human response to a relevant food portion, such as a serving, using a glucose reference curve.
- GGE measured similarly using a single glucose reference, and adjusted for the shape of the glucose dose-glycaemic response curve.
- GGE calculated from the GI and CHOAVL of the same food, with a dose-transformation of the GI:
  
  If the GI and CHOAVL are measured on the same food, the CHOAVL value used to calculate the 50 g CHOAVL food dose necessary for GI analysis will not differ from the amount used to calculate GL from GI (GL/g = GI x %CHOAVL/10000), as an estimate of GGE. The GL calculation for a given GI value provides a linear extrapolation dependent on the food dose involved. However, as the blood glucose response is an approximately quadratic function of GGE intake, allowing for the curvature will provide a more accurate result. As the curvature is an intrinsic part of GI determination, the effect may be allowed for by using dose-transformed GI values (Shaw 2005).

- GGE calculated from GI and CHOAVL determined in different but matched samples:
  
  When CHOAVL values used to calculate the amount of sample required for GI determination have not been obtained from the same sample used to determine the blood glucose response, uncertainty is introduced because the amount of carbohydrate
to which the blood glucose response is attributed on the basis of CHOAVL values may not be the same as the amount in the sample consumed.

- GGE calculated from GI and CHOAVL determined in different but matched samples from the different countries.

- GGE calculated from glycaemic sugars released during digestion in vitro:

  Monosaccharides, disaccharides and sugar alcohols released during in vitro digestion are expressed analytically as glucose equivalents, and then adjusted by abatement factors, including the GI of the constituent sugars and sugar alcohols, and the effect of the digesta viscosity on diffusion, to give an in vitro GGE value. The method is validated against clinical values for the same foods.

  It is likely that reference curves for the relationship between in vitro values, and GI or GGE values measured clinically, would need to be constructed for individual food groupings with similar characteristics. With such reference curves, GGE values measured in vitro could be used to estimate the GGE content of various foods.

- GGE estimated from the monosaccharide and sugar alcohol composition.

  The constituent glycaemic carbohydrates in a food may be determined or obtained from a food composition database and their total value abated by the GI of the individual sugars and their individual quantities, to obtain a theoretical value for the maximum possible GGE contribution of the constituent carbohydrates if they were freely available. As food structure would have an additional effect, the theoretical maximum value would need to be adjusted downwards by the typical discrepancy between the measured GI or GGE content, and the theoretical maximum in similar foods.

- GGE not calculated, but CHOAVL values used.

  Clearly there is a large amount of work to be done to set up the various methods for estimating the glycaemic potency of foods, establishing their validity, and determining the likely errors involved.

**Applying virtual food components - VFCs in food labels**

Virtual food components were designed primarily to guide healthier food choices, and are explained with reference to Table 2, which shows how VFCs may be presented in the same format as nutrients. Table 2 shows GGE in a hypothetical nutrient information panel. The food shown is classified as having a low glycaemic index, which might suggest to the consumer that the muesli would cause a relatively small blood glucose response. But the GGE dose (glycaemic load) of 18 GGE in a single 65 g serving shows that it would have the same glycaemic impact as consuming 18 g (more than three teaspoons) of glucose, and could therefore be quite highly glycaemic per serving to someone who is glucose intolerant. The GGE per 100 g of food is also shown, and can be easily extrapolated to any reasonable quantity of the food by multiplying the food weight by GGE weight as a percentage (65 g x 28% = 18.2 g) to obtain the glycaemic load that the food quantity would impose, as GGE in grams.
Table 2: Possible format of a virtual food component representing glycaemic load – the glycaemic glucose equivalent.

Muesli, serving size – 65 g (approx)

<table>
<thead>
<tr>
<th></th>
<th>Per 65 g</th>
<th>Per 100 g</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy - kJ</td>
<td>1040</td>
<td>1600</td>
</tr>
<tr>
<td>Protein (g)</td>
<td>5.9</td>
<td>9.1</td>
</tr>
<tr>
<td>Fat (g)</td>
<td>5.1</td>
<td>7.8</td>
</tr>
<tr>
<td>Total carbohydrate (g)</td>
<td>46</td>
<td>70</td>
</tr>
<tr>
<td>Dietary fibre (g)</td>
<td>9.1</td>
<td>14</td>
</tr>
<tr>
<td>Tot. niacin equiv. (mg)</td>
<td>1.6</td>
<td>2.5</td>
</tr>
<tr>
<td>Glycaemic glucose equiv. (g)</td>
<td>18</td>
<td>28</td>
</tr>
</tbody>
</table>

Conclusion

Virtual food components that represent food effects may have a role to play in designing diets that are not only balanced with respect to food components, but that are compatible with the particular dietary requirements of individuals, such as a need to minimise glycaemic impact when there is a problem of glucose intolerance. Glycaemic glucose equivalents are intended for use in the control of postprandial glycaemic response to diet within a balanced diet. However, a large amount of development is required before the usefulness of a GGE database can be established.

References


Monro, J.A. McLaughlin, J. 2005: Tables of glycemic glucose equivalents in New Zealand foods. New Zealand Institute for Crop & Food Research Ltd.


TOTAL ANTHOCYANIN CONTENT OF SOME AUSTRALIAN AND FIJIAN FRUITS AND VEGETABLES

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Keywords: pH difference, phytochemicals, anthocyanin-rich foods, anthocyanidin, antioxidants.

Abstract
Frequent consumption of fruits and vegetables is reported to improve health and lower the risk of disease. This has been attributed to the presence of various forms of phytochemicals, e.g. carotenoids, flavonoids and anthocyanins, present in these foods. Violet-reddish-purplish colour in foods is an indication of anthocyanin-rich foods.

Objective: The objective of the study was to determine the total anthocyanins (TAT) content of selected violet-reddish-purplish coloured foods readily available in Australia and Fiji.

Method: The total anthocyanins content of selected foods was determined by the pH difference method using two buffer systems — potassium chloride buffer, pH 1.0 (0.025 M) and sodium acetate buffer, pH 4.5 (0.4 M). The 75 Fijian foods selected for the study were foods identified from previous nutrition surveys to be mostly cultivated and consumed by the indigenous population. Nine Australian foods were selected to validate the method against the usual techniques for method reliability. These foods were selected on the basis of their colour and also because they resembled and represented similar groups of food that were expected to be analysed in Fiji.

Results: Analysis of the nine Australian foods showed that blueberry contains the highest TAT (14 ± 0.1 mg/100 g), followed by red cabbage (5 ± 0.3 mg/100 g) and red onion (0.4 ± 0.0 mg/100 g). Out of the 75 Fijian plant foods analysed, total anthocyanins were detected in eight foods only (11%). The highest was found in local sour cherry (0.94 mg/100 g), followed by tannia (0.62 mg/100 g).

Conclusion: The data generated by this study will be used as a guide for further work on HPLC-MS to identify specific anthocyanins in traditional Fijian foods. This information may encourage the indigenous population to appreciate the value of their traditional foods and to cultivate and consume them more regularly.

Introduction
The consumption of fruits and vegetables has been reported to improve health and reduce the burden of disease, in part probably because these foods provide various forms of phytochemicals. One physical characteristic of phytochemical-rich foods is the intensity of colour present in them. Violet-reddish-purplish colour in foods is generally an indication of anthocyanin phytochemicals (Goldberg 2003).
Anthocyanins belong to the phenolic family of flavonoid compounds. These are widely distributed in nature and are responsible for pink, scarlet, red, mauve, violet and blue colours evident in the leaves, stems, seeds and root tissues of plants. They are considered flavonoids due to their characteristic C6C3C6 carbon skeleton. The base structure is the 2-phenylbenzopyrylium of flavylium salt, which distinguishes it from other flavonoids. There are six major classes of flavonoids, which include anthocyanins. They are classified according to their chemical structure, which depicts variations in the heterocyclic C-rings. Within each group are many different subgroup compounds of various colours depending on the substituents on rings A and B (von Elbe & Schwartz 1996).

Anthocyanins occurring in nature contain several anthocyanidins. However, the six that occur commonly in foods and higher plants are shown in Figure 1. Anthocyanins (anthocyanosides) are glycosylated derivatives of the 3,5,7,3'-tetrahydroxy-flavylium cation and exist as glycosides of polyhydroxy and polymethoxy derivatives of the salts (von Elbe & Schwartz 1996). Like other flavonoids, they differ in nature, number and sites of attachment of sugars of hydroxyl and/or methoxy groups. Hydrolysis of the sugar moiety releases the aglycone (anthocyanidin). Anthocyanins are the largest group of water-soluble pigments in the plant kingdom and have applications in the food industry as natural colourants (Takeoka et al. 1997) but their aglycone counterpart is much less water-soluble.

![Figure 1: Structure of anthocyanidins.](source: Meiers et al. (2001))

According to von Elbe & Schwartz (1996), anthocyanin pigments are relatively unstable. The major factors that cause anthocyanins to degrade are pH, temperature, and oxygen concentration. Enzymes, ascorbic acid, sulfur dioxide, metal ions, light and sugars also contribute to degradation. They are much more stable under acidic conditions, with the stability determined by the substituents on the aglycone. Foods rich in pelargonidin, cyanidin or delphinidin aglycones are more labile than foods rich in petunidin or malvidin aglycones. The stability of the latter groups is due to the blocking of reactive hydroxyl groups and their increased glycosylation activity.

Studies have shown that anthocyanins have strong antioxidant properties. It has been shown that anthocyanins and their related anthocyanidins inhibit lipid peroxidation, oxidative stress and tumor tissue cell growth in vitro (Meiers et al. 2001; Heo & Lee 2005; Viljanen et al. 2005; Zhang et al. 2005). Hence, the consumption of food rich in these pigments should be encouraged in the community. It has been suggested that such compounds should be used for therapeutic purposes in the prevention and treatment of chronic non-communicable diseases. In the food industry, anthocyanins are used as food preservatives to extend the
shelf life of food products, and also as natural colourants (Wang et al. 1997; Sellappan et al. 2002; Heo & Lee 2005).

In the South Pacific, information regarding the health benefits of violet-reddish-purplish coloured anthocyanins in the foods and diets of local communities is limited. In Fiji, it seems that among the indigenous Fijian community, the cultivation, availability and consumption of such coloured staples has virtually disappeared. Thus, the identification and determination of anthocyanins in traditional foods is of interest because of their health benefits, and the potential for economic development that they offer the region and growers of anthocyanin-rich foods. This study is expected to provide a basis for further investigations into traditional anthocyanin-rich foods.

The objective of the study was to determine the total anthocyanin (TAT) content of selected violet-reddish-purplish coloured foods readily available in Australia and Fiji.

**Methods**

Analytical determinations of total anthocyanins were performed using the UV-Vis spectrophotometric method of Sellappan et al. (2002). Prior to the measurement of total anthocyanins in Fijian foods, the method was validated by means of the usual techniques for reliability (Juniper 1995). The validation was performed at the PIRVic Food Chemistry Laboratory at DPI-Werribee, Victoria, Australia, while the analysis of Fijian foods was carried out at the Chemistry Department, The University of the South Pacific, Suva, Fiji.

**Reagents**

Hydrochloric acid, acetic acid and potassium chloride were obtained from BDH Chemicals (Kilsyth, Victoria, Australia). Sodium acetate was obtained from Ajax Chemicals (NSW, Australia). AR grade acetonitrile was obtained from Mallinckrodt Chemical (Australia).

**Validation**

For method validation, nine Australian foods were analysed for total anthocyanins using the UV-Vis spectrophotometric method (Sellappan et al. 2002). Reproducibility of results within and between days was at an average % coefficient variation (cv) of 6, although the widely acceptable level for any replication should be either less than 10% difference or less than or equal to 5% cv (Snyder et al. 1997a). Due to the low concentrations of total anthocyanins detected in the food samples in this study, the acceptable level was considered at less than or equal to 6% cv (Snyder et al. 1997b). These foods were selected on the basis of their colour and also because they resembled and represented similar groups of food that were expected to be analysed in Fiji. The selected fruits and vegetables were purchased from at least three major local supermarkets in the vicinity of DPI-Werribee, Victoria. All samples were analysed in triplicate in the raw state, and the mean of the three determinations reported.

**Sampling**

A total of 75 Fijian foods were sampled for the study. These were foods identified from previous nutrition surveys to be mostly cultivated and consumed by the indigenous population; thus, they were considered to represent foods consumed by the indigenous people in Fiji. Each food sample was prepared by compositing samples of the same variety or cultivar of foods purchased from at least three different sites: the two major food markets in the urban centres of Suva and Nausori and two other smaller outlets in the vicinity of Suva and Nausori. Food samples of different cultivars were all purchased on the same day. Food items that were not available in the markets at the time of the study were provided by the Fiji
Ministry of Agricultural Research Station. The identity of all foods and cultivars used in this study was confirmed by Fiji agricultural officers.

Sample preparation and storage

The edible portions of the foods were immediately washed and processed according to their usual consumption state. Foods usually eaten when cooked were either steamed or boiled in a stainless steel cooking pot depending on the food type. All the roots and tree staple crops were boiled for approximately 20-25 minutes with minimum water just to cover the food. All other leafy vegetables and other foods were steamed for approximately 3-5 minutes. Smaller food portions were steamed for approximately 3 minutes and the big portions for approximately 5 minutes. After cooling, each food sample was either diced or cut into smaller pieces and mixed thoroughly prior to storage at –20°C and TAT analysis. Similarly, fruits and vegetables usually eaten in their raw state were washed, diced or cut into smaller pieces, mixed well and stored at -20°C until analysis. All samples were analysed as soon as possible after preparation.

Sample extraction

Samples were extracted according to the method of Prior et al. (1998) and Sellappan et al. (2002) with some modifications. Briefly, approximately 10 g of food were mixed with 45 ml of acetonitrile containing 4% acetic acid and blended for 5 minutes with a hand-held Bamix mixer. The mixture was mechanically shaken for 30 mins and then centrifuged at 6540 rpm for 15 mins (Australia) or 3280 rpm for 30 mins (Fiji). The supernatant (water-soluble fraction) was recovered and the pulp was further washed with 45 ml/L of acetonitrile containing 4% acetic acid and centrifuged. The resulting supernatants were combined and the volume adjusted to 100 ml.

Total anthocyanin assay

The total anthocyanin content of the food was determined on a Shimadzu UV-Visible 1601 Spectrophotometer in Australia or a Cintra 5 UV-Visible Spectrophotometer in Fiji by the pH-differential method (Sellappan et al. 2002) using two buffer systems – potassium chloride buffer, pH 1.0 (0.025 M) and sodium acetate buffer, pH 4.5 (0.4 M). Briefly, 0.4 ml of the extract was mixed with 3.6 ml of corresponding buffers and read against a blank at 510 and 700 nm. Absorbance (A) was calculated as: A = (A510 – A700) pH 1.0 – (A510 – A700) pH 4.5. Monomeric anthocyanin pigment concentration in the extract was calculated as cyanidin-3-glucoside (mg/L) = A x MW x DF x 1000/(MA x 1) (Sellappan et al. 2002) where A = absorbance, MW = molecular weight (449.2), DF = dilution factor, and MA = molar absorptivity (26,900). The total anthocyanin content was expressed as cyanidin-3-glucoside (mg/100 g).

Results and discussion

Australia

As shown in Table 1, blueberry and red cabbage had high amounts of TAT (cyanidin-3-glucoside) compared with the seven other foods. The anthocyanin content of blueberry observed in the current study is consistent with that reported by Sellappan et al. (2002) that showed levels ranging from 16 to 197 mg/100 g. Of the nine food items analysed, orange sweet potato and brown onion had the lowest anthocyanin content. It has been demonstrated that total anthocyanin content varies between plants and ranges from about 20 mg/100 g fresh weight to as high as 600 mg (von Elbe & Schwartz 1996). Different factors affecting the formation of flavonoids in plants may also affect the formation of anthocyanins. These include light, plant genetics, environmental conditions, germination, degree of ripeness, processing
and storage, and species and varieties (Ross & Kasum 2002). Thus, variations are expected between cultivars according to maturity stage and parts of plants that are exposed to and affected by such factors.

**Table 1: TAT of Australian fruits and vegetables**

<table>
<thead>
<tr>
<th>Food</th>
<th>TAT (mean ± SD) C-3-G mg/100 g wet weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blueberry</td>
<td>13.5 ± 0.06</td>
</tr>
<tr>
<td>Red cabbage</td>
<td>5.3 ± 0.30</td>
</tr>
<tr>
<td>Red onion</td>
<td>0.40 ± 0.02</td>
</tr>
<tr>
<td>Pumpkin</td>
<td>0.34 ± 0.02</td>
</tr>
<tr>
<td>Tomato</td>
<td>0.21 ± 0.02</td>
</tr>
<tr>
<td>Red capsicum</td>
<td>0.11 ± 0.04</td>
</tr>
<tr>
<td>Green capsicum</td>
<td>0.09 ± 0.01</td>
</tr>
<tr>
<td>Orange sweet potato</td>
<td>0.07 ± 0.03</td>
</tr>
<tr>
<td>Brown onion</td>
<td>0.05 ± 0.00</td>
</tr>
</tbody>
</table>

(values are average of n=3).

**Fiji**

Generally, the common violet-reddish-purplish deep coloured fruits such as the berry, grape and cherry families that are normally associated with being anthocyanin-rich are not cultivated and grown in Fiji. Therefore, fruits, root staples and other foods with a relatively dark colour were selected. Of the 75 plant foods analysed, total anthocyanins were detected at considerable levels in eight foods only (11%) as shown in Table 2. The highest was found in local sour cherry followed by red tannia, red yam and red eggplant. Some were detected at lower levels, but these are not reported. Low levels of anthocyanins were observed in cooked Fijian foods, presumably because the pigments were drained into the cooking liquid during cooking.

Apparently, the consumption of violet-reddish-purplish coloured foods by Fijian people is very low. This was evident from the few violet-reddish-purplish coloured foods that were sold in the market place during the sampling period. Thus, samples were obtained from the Fiji Ministry of Agriculture’s cultivar bank at Koronivia Research Station, Suva. The only violet-reddish-purplish coloured food readily found in the market was red eggplant. However, according to the 1993 Fiji National Food and Nutrition Survey (FNFNC 1995), where a one-day 24-hour recall was used to estimate daily food consumption, only 8.8% of indigenous Fijians ate the food at least once a day (8.3% ate the food once a day, 0.5% twice a day) compared with around 22% (16% and 5.3%) among the Indian population.

**Table 2: TAT of Fijian fruits and vegetables**

<table>
<thead>
<tr>
<th>Food</th>
<th>TAT (C-3-G) (mean ± SD) mg/100g wet weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cherry sour, local</td>
<td>0.94 ± 0.12</td>
</tr>
<tr>
<td>Tannia (red)</td>
<td>0.62 ± 0.01</td>
</tr>
<tr>
<td>Veiwa yam (red)</td>
<td>0.47 ± 0.08</td>
</tr>
<tr>
<td>Eggplant (red)</td>
<td>0.41 ± 0.04</td>
</tr>
<tr>
<td>French bean</td>
<td>0.11 ± 0.03</td>
</tr>
<tr>
<td>Sweet yam (red)</td>
<td>0.09 ± 0.00</td>
</tr>
<tr>
<td>Hawaiian papaya</td>
<td>0.06 ± 0.03</td>
</tr>
<tr>
<td>Tumeric ginger (yellow)</td>
<td>0.05 ± 0.02</td>
</tr>
</tbody>
</table>

1 steamed, 2 boiled, 3 raw, (values are average of n=2).
It is worth noting that the total anthocyanin content of the yam sample in this study was relatively low. This may be because the cultivar (Veiva) selected for the current study was a lighter shade of purple than other darker purple cultivars previously reported.

The results presented in this paper are important in view of reports that show the strong inverse association between antioxidant consumption and ageing diseases (Willett 1994). Anthocyanins and their related anthocyanidins have showed strong antioxidant properties by inhibiting lipid peroxidation, oxidative stress and tumor cell growth in vitro (Meiers et al. 2001; Heo & Lee 2005; Viljanen et al. 2005; Zhang et al. 2005). Epidemiological studies have also revealed the health benefits of consuming a diversity of coloured fruits and vegetables that are rich in phytochemicals such as anthocyanins and their related anthocyanidins (Ness & Powles 1997; Joshipura et al. 1999; Genkiger et al. 2004). Since processes leading to coronary heart diseases and cancers are developed and initiated many years before the diseases manifest themselves (Marco et al. 1997), it is important that educational campaigns are initiated to encourage young children to understand the health benefits of such rich sources of anthocyanins and other phytochemicals in helping to avoid and prevent the development of such diseases in the later stages of their lives.

Obviously, it is likely that there are other violet-reddish-purplish coloured foods remaining in the community or in the bush that are yet to be analysed. A call for further analysis of total anthocyanins, specific anthocyanins and anthocyanidins in traditional foods is warranted if anthocyanin-rich staples or diets are to be revived and promoted. The data gathered from this study may be a useful guide for further work using, for example, HPLC-MS to identify specific anthocyanins in Fijian local foods. Such information could result in greater appreciation of the value of traditional foods among the indigenous population. This could also lead to the development of programs designed to increase anthocyanin components in foods by plant breeders for agricultural produce that could help improve cultivar development, production practices, post-harvest storage and food processing.

**Conclusion**

The study has identified a number of traditional Fijian foods that have moderate levels of anthocyanins. The data generated from this study will be used as a guide for further work, for example, with HPLC-MS to identify specific anthocyanins in Fijian foods. Such information may encourage the indigenous population to appreciate the value of their traditional foods and to cultivate and consume them more regularly.

**Acknowledgements**

The corresponding author wishes to acknowledge the support and the assistance provided by the Chemistry Department of the University of the South Pacific and the Agronomy Department, Koronivia Research Station, Fiji Ministry of Agriculture. Appreciation is also gratefully extended to the staff of the PIRVic Food Chemistry Section at DPI-Werribee. One of us (JL) wishes to thank the Ministry of Fijian Affairs, Fiji, for financial support.

**References**


IDENTIFICATION OF MICRONUTRIENT-RICH LOCALLY GROWN FOODS IN THE FEDERATED STATES OF MICRONESIA, MARSHALL ISLANDS AND KIRIBATI

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Keywords: staple foods, nutrient-rich, health benefits, ethnography, Pacific Islands.

Abstract

Objective: Vitamin A deficiency, anaemia, and chronic diseases, including diabetes, heart disease, and cancers, are serious nutritionally-related health problems in the Federated States of Micronesia (FSM), Marshall Islands, and Kiribati. The purpose of this study was to identify locally grown acceptable foods rich in provitamin A carotenoids, vitamins, and minerals that could be promoted to alleviate these health problems.

Method: Ethnography was used to select foods and food cultivars for analysis and to understand factors of production, consumption, and acceptability. The DSM Yolk Colour Fan was used to estimate the edible flesh colouration. Samples were analysed for provitamin A and total carotenoids using HPLC and selected vitamins and minerals using HPLC and standard methods (vitamins and minerals) and a microbiological method (folate).

Results: The cultivars with greater yellow- and orange-coloured edible flesh had higher carotenoid levels. Many banana, giant swamp taro, breadfruit, and pandanus cultivars, and other staple foods, including apuch from FSM and te bero from Kiribati, were identified as rich in provitamin A carotenoids, meeting either half or all of the estimated daily vitamin A requirements. Some giant swamp taro cultivars were identified with high levels of zinc and other minerals, and the carotenoid-rich Karat banana had high levels of riboflavin and other vitamins. The fish liver samples of the species studied were all rich sources of retinol, but there were also great differences in the levels.
**Conclusion:** Many locally grown Pacific Island staple foods have been neglected but are rich in micronutrients, including provitamin A carotenoids, vitamins, and minerals. Such foods should be promoted for their role in alleviating micronutrient deficiencies and for possibly alleviating diabetes, heart disease, and certain cancers. Further work is needed in identifying other Pacific Island nutrient-rich locally grown foods. Ethnography should continue to be used in selecting locally grown foods for analysis, exploring social factors for reasons that these have been neglected, and for collecting information for planning promotion programs.

**Introduction**

The Federated States of Micronesia (FSM), Republic of the Marshall Islands, and Republic of Kiribati are three independent Micronesian countries located in the western Pacific. They are made up of many islands. Some of these islands are mountainous and some are atolls with harsh climates where only a few food crops can grow. A comparison of selected indicators for the three countries (ADB/FSM, 2004; ADB/Republic of the Marshall Islands; ADB/Republic of Kiribati, 2004) is as follows:

**Table 1: Comparison of population, infant mortality rate1 (IMR) and gross domestic product (GDP) in United States (US) dollars for three Micronesian countries.**

<table>
<thead>
<tr>
<th></th>
<th>Population</th>
<th>IMR</th>
<th>GDP (US$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FSM (comprises four states: Pohnpei, Chuuk, Yap, Kosrae)</td>
<td>108,000</td>
<td>40</td>
<td>2084</td>
</tr>
<tr>
<td>Republic of the Marshall Islands</td>
<td>50,900</td>
<td>37</td>
<td>1187</td>
</tr>
<tr>
<td>Republic of Kiribati</td>
<td>84,494</td>
<td>43</td>
<td>386</td>
</tr>
</tbody>
</table>

1 Number of deaths in a year of children less than 1 year old per 1000 live births.

Indigenous locally grown foods include taro, giant swamp taro, breadfruit, banana, pandanus, yam, other root crops, coconut, fish and seafood, meats, fruits and vegetables. However, these are increasingly being replaced by imported foods such as rice, flour products (bread, donuts, noodles), sweet and refined foods, and tinned fish and meat. At first glance, one might not think that such a dietary shift may be associated with vitamin A deficiency and other nutritionally-related diseases. However, all of the local staple foods (taro, breadfruit, banana, pandanus) contain at least some provitamin A carotenoids, but rice, the most common imported food, contains none.

The great shift from traditional foods to imported foods in all three countries has been followed by serious problems of nutrition-related diseases, including vitamin A deficiency and chronic diseases: diabetes, heart diseases and cancer (Government of the FSM, 1996; Government of Kiribati, 2002; Government of the Marshall Islands, 1996). Over half of the preschool children in all three countries have vitamin A deficiency, which is associated with increased vulnerability to infection and increased rates of morbidity and mortality as well as problems of eye health and vision (McLaren and Frigg, 2001). The important animal food sources of vitamin A (retinol) are egg, liver, milk and milk products, and some seafoods, and the important plant sources (provitamin A carotenoids) are orange/yellow fruits and vegetables and dark green leafy vegetables. Eggs, milk and milk products are not traditional foods on these islands; liver is only an occasional food; few orange/yellow-fleshed fruits and vegetables are available (the orange-fleshed papaya and mango were only introduced in the 1800s), and dark green leafy vegetables are often considered as foods for animals. Health
workers were puzzled as to what the traditional foods had been that protected the people from vitamin A deficiency in the past. Thus, the search was initiated to identify those varieties/cultivars of indigenous foods which could contribute to vitamin A status.

Diabetes is a particularly serious emerging health problem. As this problem is related to conveniences in lifestyles related to diet and physical exercise, it has been named as the “Disease of Convenience” in Micronesia (Hedson, 2004). There have been great lifestyle changes in the last 40 years, with a shift to motorised boats and cars and office work. A 1940s study showed that there was virtually no obesity and diabetes in FSM and the Marshalls at that time, whereas the problems now are of epidemic proportion. In FSM, for example, the rate of diabetes is 20% for FSM adults in the 45-55 year old age range, compared with 7% for United States adults in the same age range (Hedson, 2004).

Provitamin A carotenoids protect against vitamin A deficiency, whereas carotenoid-rich foods may help protect against diabetes, heart disease, and cancer. Another nutrient of importance in this project is riboflavin, for which there is now increasing evidence of a role in iron absorption and utilisation. The indigenous foods were also analysed for essential minerals, including zinc, which has a role in vitamin A metabolism and an important role in protecting against infection.

An important point that must be made is that there are many varieties and cultivars of the indigenous foods. In Pohnpei, FSM, alone, the names of 55 banana, 133 breadfruit, over 48 giant swamp taro, and over 40 pandanus varieties have been documented. The names of over 100 Marshallese pandanus and over 100 Kiribati pandanus have been documented. Most of these have not been analysed for nutrient content.

This present project developed from a PhD study in FSM where some banana and giant swamp taro cultivars were identified that have the highest carotenoid content in the world (Englberger, 2003). Also carotenoid-rich giant swamp taro, breadfruit, and pandanus cultivars were identified. These findings indicated that further work was needed to identify the nutrient-rich foods and varieties/cultivars of FSM and to extend the project to the Marshall Islands and Kiribati, where few of the local foods had ever been analysed.

The aims of the project were as follows:

- To identify foods and varieties/cultivars with high micronutrient content and acceptability;
- To build partnerships with the community, government and non-government agencies, laboratories and academic institutions;
- To gain insight on how to promote those foods for their health benefits.

**Methodology**

A multiple methodology approach was taken, including:

- Ethnography (key informant interviews, photography, informal focus group discussions, and literature review) to select the foods and document factors of production, consumption, and acceptability, also estimating the edible flesh colouration using the DSM Yolk Colour Fan (Vuilleumier, 1969).
- Sampling (composite samples), sample preparation (freezing and storing samples until they could be hand-carried frozen to the laboratory overseas as there are no laboratories in these countries), and sample transport (meeting quarantine requirements and getting samples to the laboratory as quickly as possible without thawing).
Analysis, using HPLC and standard methods for: provitamin A carotenoids (β- and α-carotene, β-cryptoxanthin), other carotenoids with demonstrated health benefits (lutein, xanthin, and lycopene), vitamins (retinol, riboflavin, niacin, α-tocopherol, folate†), and minerals (zinc, iron, calcium, and others).

Federated States of Micronesia
An inter-agency approach: Island Food Community of Pohnpei, Pohnpei State Agriculture of Economic Affairs, Pohnpei Department of Health, and the College of Micronesia-FSM.
Focusing on: banana, giant swamp taro, breadfruit, pandanus, other foods (apuch, fish liver).
Samples collected: from all four FSM states from 1998 to 2004.

Republic of the Marshall Islands
Focusing on: pandanus and some other atoll foods.
Samples collected: from Majuro Atoll during 2003.

Republic of Kiribati
An inter-agency approach: Ministry of Environment, Lands, and Agricultural Development, Ministry of Health and Medical Services, AMAK Women’s Group.
Focusing on: pandanus and some other atoll foods.
Samples collected: from Tarawa Atoll during 2003 and 2004.

Results
Banana
Of 26 cultivars, 18 had significant carotenoid levels, meeting half or all of the estimated daily vitamin A requirements (WHO/FAO, 2002) for a non-pregnant, non-lactating woman, within normal daily consumption patterns. For β-carotene, the most important of the provitamin A carotenoids, the levels ranged from 30 to 8508 µg per 100 g of edible portion. In our previous study we found that there are five distinct colours of edible flesh of banana (white, cream, yellow, yellow/orange, and orange) and that the carotenoid levels increased with increasing intensity of colouration. This study confirmed that colouration of edible banana flesh is a good indicator of carotenoid content.

One Karat sample was delivered to the laboratory by hand as a fresh unfrozen sample, thus avoiding the risk for repeated thawing and refreezing during transport, which may lead to carotenoid destruction. The β-carotene content of this Karat sample was 2230 µg/100 g, or four times the mean level of previous analyses and 100 times the β-carotene content of the common Cavendish banana (21 µg/100 g) (Holden et al. 1999). This finding also indicates that the carotenoid content of the frozen samples analysed previously may be less than that of a fresh sample.

Karat has a unique effect in turning the urine bright yellow after it is consumed. The high carotenoid content of Karat would not be expected to contribute to the urine colouration as carotenoids are digested in the intestine. Riboflavin, on the other hand, is quickly excreted in the urine. Thus, efforts were made to have Karat analysed for this vitamin. Strikingly high levels of riboflavin and uncharacterised flavonoids were found in Karat by two laboratories. The first laboratory (DSM Nutritional Products, Kaiseraugst, Switzerland), after finding a high
level (11.35 mg riboflavin/100 g), analysed the Karat sample a second time, using a different methodology and finding a lower riboflavin level (0.47 mg/100 g). The second laboratory, Anresco, California, US, found 14.30 mg riboflavin/100 g in the Karat. Using the lower level, one Karat banana (200 g) would still provide almost the entire WHO/FAO Recommended Nutrient Intake (RNI) for a non-lactating, non-pregnant woman (1.1 mg/day) (WHO/FAO, 2002). The Karat sample also contained significant levels of niacin and α-tocopherol.

Other banana cultivars analysed in this study included Utimwas (7200 µg β-carotene/100 g), Utiak (1197 µg β-carotene/100 g), and Utin Pihsi (38 µg β-carotene/100 g). It is clear that the Utimwas and Utiak contain higher β-carotene levels than Utin Pihsi. However, mineral analyses were also conducted. Utin Pihsi had 101 mg calcium/100 g; Utiak had only 48 mg calcium/100 g, showing that Utin Pihsi may be an important calcium source (note that milk contains 125 mg calcium/100 g).

**Giant swamp taro**

In FSM, 15 of 17 cultivars analysed contained significant levels of provitamin A carotenoids, meeting half or all of estimated daily vitamin A requirements for a non-pregnant, non-lactating women, within normal consumption patterns (WHO/FAO, 2002). These levels ranged from 50 to 4486 µg β-carotene/100 g. One carotenoid-rich cultivar was also identified in Kiribati. After the giant swamp taro is cooked, there are sometimes colour differences, although it is very difficult to identify the cultivar after cooking. Cultivars are generally identified by the stem colour, presence of thorns on the stem, leaf shape, and corm colour and texture.

A study was also made of mineral levels in one group of giant swamp taro samples. A comparison of five cultivars of giant swamp taro showed the following:

**Table 2: Comparison of five Pohnpei giant swamp taro cultivars for zinc, iron, and calcium content analysed by the University of Adelaide laboratory.**

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Zinc (mg/100 g)</th>
<th>Iron (mg/100 g)</th>
<th>Calcium (mg/100 g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mwahng Tekatek Weitahta</td>
<td>63.0</td>
<td>1.4</td>
<td>260</td>
</tr>
<tr>
<td>Mwahng en Wel</td>
<td>36.0</td>
<td>3.2</td>
<td>1440</td>
</tr>
<tr>
<td>Lahsekir</td>
<td>16.1</td>
<td>1.4</td>
<td>310</td>
</tr>
<tr>
<td>Mwahng en Meir</td>
<td>10.8</td>
<td>2.2</td>
<td>540</td>
</tr>
<tr>
<td>Mwahng Pwiliet</td>
<td>8.4</td>
<td>3.6</td>
<td>620</td>
</tr>
<tr>
<td>Spinach (from the PIFCT *)</td>
<td>0.5</td>
<td>2.6</td>
<td>154</td>
</tr>
<tr>
<td>Adult female RNI in mg/day *</td>
<td>9.8-3.0</td>
<td>59-20</td>
<td>1000</td>
</tr>
</tbody>
</table>


Samples of FSM giant swamp taro (two varieties, Fanal and Simihden) were analysed for zinc and phytate at another laboratory (Howard University, 2003). The low phytate-zinc molar ratios of the samples indicated that phytate would not hamper bioavailability (Fanal: 1.8; Simihden: 0.4)

**Pandanus**

In FSM 11 of 13 cultivars analysed had significant levels of provitamin A carotenoids (from 19 to 393 µg β-carotene/100 g, thus meeting half or all of the estimated daily vitamin A requirements for a non-pregnant, non-lactating woman. In the Marshall Islands 10 of 13 cultivars analysed had significant levels (ranging from 21 to 902 µg β-carotene/100 g), showing excellent agreement between laboratories. In Kiribati, seven of nine cultivars
analysed had significant levels (ranging from 62 to 19,086 µg β-carotene/100 g), showing considerable inter-laboratory differences.

A comparison of the pandanus keys for colour differences did show that carotenoid levels were generally higher in the more deeply orange-coloured keys (the individual pandanus fruit). However, colour differences were sometimes subtle and thus it would be difficult to use the colour of pandanus as an indicator of carotenoid content.

Other foods

The apuch fruit, a delicacy in Chuuk, FSM, and the te bero starchy berry from Kiribati were also identified as carotenoid-rich. As far as the authors are aware, this is the first time that either of these foods has been analysed for carotenoids.

Liver is known as a rich source of vitamin A (retinol) and fish liver is a delicacy in Micronesia. However, there were no data found in food composition tables for any species of fish liver. Three different types of fish liver were analysed for retinol, showing considerable differences between the different fish species. The results were: yellowfin tuna with 204,012 µg retinol, skipjack tuna with 50,169 µg retinol, and parrotfish with 8,623 µg retinol.

Conclusion

In brief, we conclude that:

- There is a wealth of potentially micronutrient-rich foods in Micronesia, most not yet assessed.
- A systematic investigation using an ethnographic approach for identifying nutrient-rich foods and for understanding food practices and beliefs is critical.
- Many cultivars of traditional Micronesian foods are rich sources of carotenoids (including provitamin A and other carotenoids), vitamins, and minerals.
- Thus, they offer potential for alleviating vitamin A deficiency and micronutrient deficiencies in Micronesia, and there is growing evidence of the role of these deficiencies in the development of chronic disease.
- Yellow colouration may be used as an indicator for carotenoid-rich banana cultivars and some other foods.
- Certain foods (and cultivars) are rare, whereas others may be available but not widely used.
- This approach may be relevant for other Pacific Island countries with similar foods.

Acknowledgements

Key informants, farmers, local markets.

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Kiribati Ministry of Environment, Lands and Agricultural Development, Ministry of Health and Medical Services, AMAK Women’s Group.

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Sight and Life, Secretariat of the Pacific Community (SPC), SPC Pacific German Regional Forestry Project, Australian and New Zealand Governments, Institute of Applied Sciences/University of the South Pacific, DSM Nutritional Products, University of Adelaide, University of Hawaii, Anresco Laboratory, Howard University, University of Queensland, University of Sydney.

Special thanks to Amy Levendusky and Luciano Mathias for some wonderful photographs and to Dr. Martin Frigg for his continual support!

References


NOTE: Three papers have been recently written on the new findings on Pohnpei bananas and Kiribati and Marshall Islands pandanus. Two of these are now in press (see below) and a third is presently under review.


ENSURING QUALITY AND INTEGRITY OF ANALYTICAL DATA ON FOODS: AN OVERVIEW

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Keywords: laboratory, sample, accuracy, methodology, report

Abstract

Integrity of analytical data for food samples has to be maintained to ensure that correct and accurate information is provided to the client by the analytical laboratory. When choosing a laboratory to carry out analytical work the laboratory has to meet several key criteria. These criteria are integral to quality, accuracy and integrity of the analytical data. The importance of receiving accurate and quality data is critical for nutritionists who have to make decisions that would affect human and animal health. The choice of laboratory, analytical methodology, integrity of the sample and analytical report are critical.

Introduction

A contract laboratory has to be operating to an internationally recognised laboratory standard. The standard defines the parameters that the laboratory has to comply with in order to achieve accreditation by regulatory authorities or comply with customer expectations. The laboratory is then audited on a regular basis by either the regulatory authority or their appointed auditors and customers, according to:

- Unique identification of samples.
- Maintenance of customer confidentiality.
- Sample treatment upon arrival at the laboratory (storage, homogenisation etc)
- Choice of test method.
- Laboratory staff training.
- Equipment used for analysis.
- Validation status of chosen method.
- Participation in inter-laboratory comparisons (both national and international laboratories).
- Reporting of results.

The integrity of the sample registration and unique identification should be linked to the analytical method and rigorous quality control processes immediately upon arrival of samples at the laboratory.

Discussion

The use of a Laboratory Information Management System (LIMS) is a key part of the process to ensure the integrity of the analytical data. The LIMS is usually an electronic database in which the information about the incoming samples is recorded. The samples are assigned unique identifiers and these identifiers link the sample to the customer, sample matrix, tests to carried out, report type required, specifications for the product and other relevant information (special handling or reporting requirements as specified by the customer). The linking of the
sample to the customer, customer specifications, information about the product and customer’s contact information by the LIMS should be secure to maintain confidentiality. This is usually achieved by limiting access to the LIMS by non-laboratory staff and by use of access levels. The programmers of the LIMS software put in security features to prevent inadvertent or blatant misuse of the information by unauthorised people.

The samples have to be treated according to matrix type and special instructions supplied by the customer. If the sample has special storage conditions then the laboratory has to comply with these before and after testing has commenced and a record of the storage conditions maintained. The laboratory inspects the sample (packaging, temperature of sample, etc) when received and information recorded. If there are any problems with a sample at time of receipt then the submitter of the sample is contacted and informed of the problem and instructions on whether to carry on testing or not are asked for. All of these processes and decisions have to be documented and traceable.

The correct choice of methods is necessary before proceeding with testing. The method has to be applicable to the sample type. Method validation requirements are to be considered before commencing with the testing. The use of the data usually dictates the type of validation required. The method validation demonstrates the capability, relevance and limitations of the method. The validation should be carried out to satisfy both in-house and external (various regulatory bodies, United States Food and drug administration, New Zealand Food Safety Authority, New Zealand Ministry of Health’s Medsafe-GMP and customer’s) requirements. Validation protocols used should be based on guidelines such as International Organisation for Standardisation’s and International Electrotechnical Commission’s standard, General requirements for the Competence of Testing and Calibration Laboratories ISO/IEC17025, current Good Manufacturing Practices (cGMP), United States Pharmacopoeia, AOAC, International Committee on harmonisation (ICH) guidelines etc. The method validations help determine and verify the performance parameters of the method: linearity, repeatability, single lab reproducibility, multi-lab reproducibility, ruggedness, recovery, limits of detection and quantitation, specificity, matrix effects and uncertainty of measure. Once this information is evaluated the method can then be assessed for its fitness for generating data. Can the method be used to produce data required by regulatory authorities? Is the method only good enough to provide data for “information only”?

Audits must be conducted on a regular basis, whereby customers and regulatory bodies audit the analytical laboratory. The laboratory should also have internal audits. The schedule and scope of the internal audits are determined by the laboratory management team, usually the quality manager, laboratory manager and technical manager. The schedule and scope of the internal audits should be useful and effective in monitoring and maintaining compliance to the quality system. Audit scopes, both external and internal, should be comprehensive and should cover systems, sample registration, methods, equipment, security, Safety health and Environment (SH&E) and technical competence of staff and management.

Staff training both in method techniques and background (fitness for purpose, reason for testing, science behind the test, troubleshooting of methods and equipment, regulatory requirements, quality controls) should be carried out when staff first commence employment and refresher training carried out regularly for both existing and new staff.

Special consideration should also be given to the instrumentation that is used to produce results. Each instrument has to be installed and used correctly in accordance with the manufacturer’s specification. The instrument must have undergone performance checks as well to determine that the instrument is capable of performing the operations for which it was purchased. During the instrument commissioning process the following are usually carried
out: installation qualification (IQ), operational qualification (OQ) and performance qualification (PQ).

The elements involved in IQ are checks that the instrument has been installed correctly. The environmental conditions are assessed. Checks on the power supply, temperature, lighting levels, bench strength and placement and other checks are made. Tests are carried out on the instrument that would indicate if there are any detrimental effects. For Photo Diode Array detectors that are used in High Performance Liquid Chromatographs, (CFR editor – use of caps here?) temperature stability checks are made. Changes in the environmental temperature show a shift in the baseline of the chromatograph. As a second example, if an analytical balance, recording weights to four decimal places, is placed on a bench that vibrates when people walk by it will not give an accurate reading. The instrument will fail the IQ and would have to be situated on a vibration-free bench.

Operational Qualification (OQ) refers to checks and tests carried out on the instrument to verify that it complies with the manufacturer’s specifications. The tests carried out in the factory to ascertain that the equipment is functioning correctly are carried out at the installation site to ensure that instrument is still performing to the original specifications to which it was designed and built.

The person assessing IQ and OQ has to have a through understanding of the mechanical, electrical and software parts of the instrument. The IQ and OQ are usually carried out by a factory trained and certified engineer.

Performance Qualification (PQ) has to be carried out on the instrument before acceptance for routine use. The PQ is usually carried out by the relevant laboratory staff, usually competent senior staff who have had prior experience with the technique or have been trained on the instrument. The instrument is tested to ensure that is able to perform the task that it was bought for.

Conclusion

In order to maintain the integrity and quality of analytical data the correct operational choices have to be made prior to commencing analysis. Firstly the reasons behind the analysis have to be understood. Once the reason for the testing or use of the data has been determined, then the choice of laboratory, analytical method, acceptable result format, quality system and accreditation needs can be determined. The laboratory has to be accredited by an internationally recognised accreditation body: International accreditation in New Zealand, NATA in Australia, UKAS in the United Kingdom. The chosen laboratory has to have a robust and secure LIMS. The registration of the samples into the LIMS is on of the most important part of the analytical process. The information put into the LIMS determines the choice of method, data format, links the sample to the product specifications, includes special instructions (if any), and links the sample to the customer. The chosen laboratory should be able to help the customer go over their requirements and to assist them in refining these requirements. The analytical methods have to be validated, peer reviewed and accredited by the relevant accreditation body.
Abstract
Sampling protocols are considered a major determinant of the quality of food composition data. In this paper, we discuss sampling methods in relation to the development of the New Zealand Food Composition Database (NZFCD).

Users of the NZFCD require representative values on the composition of foods. Well-designed sampling plans detailing sampling methods should provide database compilers with information that enables them to assess the representativeness of the samples being analysed. Variability data on the foods being analysed is important in determining representative samples. Multiple analyses of food samples would provide information on variability. However, due to financial constraints, the NZFCD primarily analyses foods derived from single (replicate) analysis of either an individual or multiple-variety composite sample.

An application of a statistical methodology in sampling protocols for the assessment of variability and sample quantity is discussed. To date we have identified two currently available sources of variability data. These are published data (international databases, and literature), and data supplied by food manufacturers. In future, a third source of variability data would result from successive re-analysis of key foods/nutrients. Using such variability data, a statistical method of assessing precision has been applied.

This may benefit the development of sampling protocols for other similarly resourced databases, and has the potential for assigning a data quality index score within the category of representative composite samples.

Introduction
Users of food composition data require high quality data, and are therefore reliant on compilers of food composition databases to use appropriate sampling methods in determining nutrient values. It has been acknowledged that the method of sampling is a major determinant of data quality (Greenfield & Southgate 2003). The development of a sampling plan often involves compromises between cost/time/quality, thus requiring independent judgements from food to food and nutrient to nutrient on how best to maintain a satisfactory level of quality whilst balancing these other constraints. Current sampling plans for the New Zealand Food Composition Database (NZFCD) are developed based on flexible protocols that have been developed in the context of intuitive judgement, experience, and local expertise. Sampling protocols are designed to meet internationally recognised principles and guidelines that have been shown to lead to quality data, thereby meeting users’ needs and expectations. In this paper, the term ‘sampling’ describes activities involved in the selection and collection of items of food defined in relation to the number, size and nature of the material being analysed.

All foods are biological materials and show natural variations in composition. This initial food variability still exists with composite samples and further variability may be introduced by the sampling process. Therefore, sampling is associated with varying sources and degrees of
error. A question often asked about composite samples with one estimate of the mean is ‘How representative is that one value of the true nutrient value?’ Statistical methods can assist in making such assessments, and those routinely used in food composition sampling work include determinations of the mean, standard deviation (SD), coefficient of variation (CoV) and precision (r). The use of statistical mathematics provides a framework to assess various aspects of a sampling plan. However, even traditional techniques should be evaluated to determine their appropriateness when applied to food composition data (Holden 1995).

Recent developments in the use of key foods (Haytowitz 2002) and data quality indicators (DQI) (Holden 2002) raise further questions for compilers. Are these approaches beneficial to the database? Can these approaches be incorporated into sampling protocols? Each of these approaches has a core attribute beneficial to sampling protocols, e.g. the key foods method allows for the selection of foods for analysis to be based on those foods that provide important amounts of nutrients of public health significance to the diet. Data quality indicators provide users with a confidence value on which to assess the quality of the values for a food.

Food data routinely entered into the NZFCD come from single (replicate) analysis of individual or multiple-variety composite samples, e.g. an individual sample may be a composite of various apples of the same cultivar, and a multiple-variety composite may be formed from many different commercial brands or variants within a brand. In determining which foods should be composited, the number of individual samples required, and the overall appropriateness of the proposed composite sample, it is preferable to base assessments on the foods in question. For example, to calculate the number of food samples needed, information is required on the variability of the composition of the foods being sampled. If no information is available, a judgement call based on experience or expediency may be required. The majority of sampling plans developed for the NZFCD are based on analysing a generic multiple-variety composite sample, which may reflect n brands and n variants used to make the composite. Often, market share information is used to identify which brands and variants should be included in the composite sample. Apart from other necessary considerations, i.e. regional sampling, distribution patterns, population demographics, etc, a composite i.e. brands of a similar food are assessed to ensure that it is sufficiently representative of the food’s population. This assessment includes recording label data and reviewing differences between products for declared nutrients to ensure that these differences are within suggested tolerances. For example, a composite sample can be made from two or more samples if the differences between the declared values on the labels for the nutrients vary by less than the required tolerance. Current use and reliance on manufacturers’ food composition data is well established, and as New Zealand and Australian manufacturers make efforts to comply with the Food Standards Code (Food Standards Australia New Zealand, 2005) the provision of manufacturers’ analytical data to assist in the database’s development has increased. These data assist food composition database compilers in a number of ways. However, as the food standard code allows for the calculation and/or borrowing of values, it is essential to view manufacturers’ data with caution. It is important that compilers ensure that the compositing of samples does not affect the ability of a database food record to represent the intended population.

We have further developed these steps by applying statistical methods to sampling protocols, primarily for identifying and using indicative variability data, and quantifying the required sample size. Composite sampling plan development based on published, label and key foods data, and data quality is discussed. The aim of implementing these steps is to develop better sampling protocols based on recognised guidelines within the context of the quality/time/cost considerations placed upon the NZFCD.
Methods
The current sampling protocol comprises a series of steps to ensure representative samples are being analysed. Not all steps can be considered of equal importance, however, and only three pertinent to the NZFCD are presented here. They are:

Formulate appropriate composite samples.
Calculate sample amount.
For sampling plan steps 1 and 2 above, qualitatively determine a DQI score.

To determine whether a proposed single or multiple-variety composite sample is suitable for analysis and the number of items that should be sampled from the population, the protocol includes the following steps:

- Estimate the probable mean value for nutrients of interest to be analysed in the food.
- Identify a source of likely variability data, appropriate to the probable mean value for the food. Variability is expressed as SD, by which both the mean and SD can be weighted in foods for which the production/market share information percentages are known.
- Determine the CoV (SD x100/Mean). The CoV may also be derived from the weighted SD and Mean.
- Compare the CoV to previously developed tolerance values. A tolerance value is an intuitively appropriate figure used by compilers to quantitatively identify nutrients with very large variances around the probable mean. Reference tolerance values currently exist only for certain nutrients, i.e. protein, fats, carbohydrates. These are as follows:
  - CoV up to 50% when the mean nutrient value is less than 5 g/100 g
  - CoV up to 20% when the mean nutrient value is >5 g/100 g or less than 10 g/100 g
  - CoV up to 10% if the mean nutrient value is more than 10 g per 100 g.

If at this point the CoV for a given nutrient is outside these levels, remedial action is required. Primarily this is achieved by further stratifying the food population, which will result in the removal of certain varieties with unusual proportions of nutrients or ingredients, i.e. high or low fat varieties in the population. Foods that are of ‘budget’ or ‘premium’ quality may also need to be treated similarly. Other nutrients will be assessed as to the level of variability that is acceptable. The CoV serves as a check to ensure the composite does not give a potentially misleading result for the nutrients of interest and/or the food as a whole.

Using the CoV for each nutrient, perform a precision test by applying a similar statistical sampling methodology to that reported by Parpinel et al. (2000) in which sample sizes, i.e. number of individual items from the population, are determined by a statistical equation. This equation has been adapted from others as it applies to representative sampling selections (Cochran 1977: Holden 1995).

Determine the average of the precision score values for all nutrients considered. This average score provides an overall score for the food item being sampled. In the future, this average score can be assigned as a Data Quality Indicator (DQI) score, which will likely form part of the DQI scoring for the category of Representative Sample. In addition, setting a goal to only sample foods that achieve a certain level, i.e. a DQI of 70-100, is then possible. This latter step indicates that the final composite samples are representative, and that sample numbers have been determined in a quantitative manner.
Source of variability data

Producing representative composites and determining an appropriate number of samples requires the use of variability data. We have identified two currently available sources for the NZFCD: published and industry label data. As a third source in the future, appropriate variability data could be identified from the analysis of key foods in the NZFCD.

Precision test

Table 1 shows the number of food samples required for a given level of precision, based on food composition variability (CoV). With increasing variability of the nutrient of interest, and for greater precision of the estimate, the number of samples increases. This table becomes a reference table within the sampling protocol.

Table 1: Precision test reference table.

Examples of sample size calculations for food items with varying coefficients of variation and for different levels of precision. The level of significance = 0.05.

<table>
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<tr>
<th>CoV</th>
<th>5%</th>
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<td>14</td>
<td>11</td>
<td>9</td>
</tr>
<tr>
<td>80</td>
<td>983</td>
<td>246</td>
<td>109</td>
<td>61</td>
<td>39</td>
<td>27</td>
<td>20</td>
<td>15</td>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>85</td>
<td>1110</td>
<td>278</td>
<td>123</td>
<td>69</td>
<td>44</td>
<td>31</td>
<td>23</td>
<td>17</td>
<td>14</td>
<td>11</td>
</tr>
<tr>
<td>90</td>
<td>1245</td>
<td>311</td>
<td>138</td>
<td>78</td>
<td>50</td>
<td>35</td>
<td>25</td>
<td>19</td>
<td>15</td>
<td>12</td>
</tr>
<tr>
<td>95</td>
<td>1387</td>
<td>347</td>
<td>154</td>
<td>87</td>
<td>55</td>
<td>39</td>
<td>28</td>
<td>22</td>
<td>17</td>
<td>14</td>
</tr>
<tr>
<td>100</td>
<td>1537</td>
<td>384</td>
<td>171</td>
<td>96</td>
<td>61</td>
<td>43</td>
<td>31</td>
<td>24</td>
<td>19</td>
<td>15</td>
</tr>
</tbody>
</table>

CoV = Coefficient of variation.
R  = precision of the estimate.
Adapted from: Parpinel, M.; Gnagnarella, P.; and Salvini, S. 2000.

DQI assignment

Once the precision test to determine the number of samples required for a suitable composite has been determined, the average precision test score (average of r) is calculated, from which the DQI scoring for Average Precision Score is derived. Table 2 illustrates how an average score corresponds to a DQI score. The table then becomes a reference table within the sampling protocol. Equally, the DQI score presented here is for the food as a whole. However, individual DQI scores for each nutrient considered can also be determined.
Table 2: Data quality indicators reference table.

<table>
<thead>
<tr>
<th>Data Quality Indicators scoring</th>
<th>Average Precision</th>
<th>DQI score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Score</td>
<td></td>
</tr>
<tr>
<td>$r \leq 5%$</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>$r \leq 10%$</td>
<td></td>
<td>90</td>
</tr>
<tr>
<td>$r \leq 15%$</td>
<td></td>
<td>80</td>
</tr>
<tr>
<td>$r \leq 20%$</td>
<td></td>
<td>70</td>
</tr>
<tr>
<td>$r \leq 25%$</td>
<td></td>
<td>60</td>
</tr>
<tr>
<td>$r \leq 30%$</td>
<td></td>
<td>50</td>
</tr>
<tr>
<td>$r \leq 35%$</td>
<td></td>
<td>40</td>
</tr>
<tr>
<td>$r \leq 40%$</td>
<td></td>
<td>30</td>
</tr>
<tr>
<td>$r \leq 45%$</td>
<td></td>
<td>20</td>
</tr>
<tr>
<td>$r \leq 50%$</td>
<td></td>
<td>10</td>
</tr>
</tbody>
</table>

Discussion

Correct sampling is a major determinant of data quality, and therefore the goal is to develop a robust sampling protocol based on internationally recognised standards. However, framing such protocols within the context of the compilers’ unique set of time, cost and quality considerations requires an intuitive (local) approach. Database developers who cannot analyse many samples will need to pay more attention to certain aspects of their sampling protocols. The NZFCD’s current sampling protocol incorporates steps from more ideal sampling protocols as a means of remaining focused on the overall need to provide quality data. However, we have avoided adding steps that offer no additional benefit and may even detract from quality by using up more of a compiler’s time, for example. The development of many cooking retention or yield values to assist in the determination of values in a similar yet unrelated food/sample, can be viewed as a similar beneficial application.

The generation of a DQI (via a precision score) is seen as a key requirement for supporting data quality, and has been built into the currently developed protocol. The development of data quality indicators for the NZFCD is only in its early stages. However, as protocols change, we have found it beneficial to make allowances for asking and answering questions related to data quality for the foods/nutrients being analysed. The current DQI for the reported aspects of the sampling protocol will be weighted appropriately within the algorithm of combined DQIs. At present, the DQI provides a quantifiable goal, i.e. 70-100 DQI for these aspects.

There are general rules on which to base the sample quantity in the absence of variability data, i.e. “a sample of primary produce or prepared food may consist of at least 10 items, each a separate purchase or collection, since large variations in composition can be expected” (Greenfield & Southgate 2003). However, a determination of sample amount based on indicative variability data is more likely to provide a better estimate of the mean for nutrients of interest.

Literature/published data

Published variability data have been identified from the literature and in overseas databases, and contain a substantial amount of variability data owing to the multiple analysis sampling protocols employed. These data are useful for primary foods for which no detailed research has been conducted in New Zealand and/or for pilot studies to ascertain nutritional variability.
in the food (see Table 3, Published data, for an example of the use of this data to determine variability estimates and sample numbers). Depending on the nutrient data available in the reference record, nutrients classified as providing first, second or third quartile intake levels could form the basis of an assessment to determine the probable composite mean, SD, precision scores and DQI.

The use of overseas published and manufacturers’ data is an application of an indirect methodology in the development of the database. In other words there is a trade-off between less direct cost and less data certainty. The question of relevance does arise, and requires an increased level of scrutiny and judgement as to appropriate use of the data. This may be especially so with extrapolating data as described here.

**Table 3: Literature/published data.**

<table>
<thead>
<tr>
<th>Most nutrients with variability data</th>
<th>Protein</th>
<th>Fat</th>
<th>TDF</th>
<th>Calcium</th>
<th>Iron</th>
<th>Mg</th>
<th>K</th>
<th>Copper</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>g/100g</td>
<td>g/100g</td>
<td>g/100g</td>
<td>mg/100g</td>
<td>mg/100g</td>
<td>mg/100g</td>
<td>mg/100g</td>
<td>mg/100g</td>
</tr>
<tr>
<td>Banana, raw</td>
<td>Mean</td>
<td>1.09</td>
<td>0.33</td>
<td>2.6</td>
<td>5</td>
<td>0.26</td>
<td>27</td>
<td>358</td>
</tr>
<tr>
<td>Source USDA NDB No: 09040</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Musa X paradisiaca</td>
<td>SD*</td>
<td>0.076</td>
<td>0.29</td>
<td>0.46</td>
<td>0.31</td>
<td>0.006</td>
<td>3.186</td>
<td>12.82</td>
</tr>
<tr>
<td>CoV</td>
<td>6.97</td>
<td>87.88</td>
<td>17.69</td>
<td>6.20</td>
<td>2.31</td>
<td>11.80</td>
<td>3.58</td>
<td>89.74</td>
</tr>
<tr>
<td>% Precision score</td>
<td>5</td>
<td>45</td>
<td>10</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>45</td>
</tr>
<tr>
<td>No of samples</td>
<td>15</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ave precision score</td>
<td>18.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DQI score</td>
<td>70</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Only key food nutrient variability data</th>
<th>TDF</th>
<th>Mg</th>
<th>K</th>
<th>Copper</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>g/100g</td>
<td>mg/100g</td>
<td>mg/100g</td>
<td>mg/100g</td>
</tr>
<tr>
<td>Banana, raw</td>
<td>Mean</td>
<td>2.6</td>
<td>27</td>
<td>358</td>
</tr>
<tr>
<td>Source USDA NDB No: 09040</td>
<td>SD*</td>
<td>0.46</td>
<td>3.186</td>
<td>12.82</td>
</tr>
<tr>
<td>Musa X paradisiaca</td>
<td>CoV</td>
<td>17.69</td>
<td>11.80</td>
<td>3.58</td>
</tr>
<tr>
<td>% Precision score</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>30</td>
</tr>
<tr>
<td>No of samples</td>
<td>35</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ave precision score</td>
<td>11.3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DQI score</td>
<td>80</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Calculated from SEM

Data sourced from http://www.nal.usda.gov/fnic/foodcomp/ SR17 data files

**Label/industry data**

Manufacturers’ label data has also been identified as a source of variability data, and is used to determine a CoV for given nutrients (predominantly those required by labelling regulations). Generally, manufacturers should provide analytical reports to confirm the label values used or be asked to comment on whether values are calculated or analytical. Table 4 illustrates the use of such data to again determine 1) is the composite appropriate? 2) sample numbers. In the sampling protocol the label data are presented as a mean for each label value, i.e. kJ, protein, fat, saturated fat, total carbohydrate, total sugars, sodium and any other nutrients declared for all brands. If market share data are obtained, the mean values are weighted according to the market share. Mean, SD, COV and precision scores are thus determined.

How good are manufacturers’ label data? Experience suggests that most (leading market share brands) of the processed foods have label data based on analytical data. Alternatively, larger companies have sufficient resources to maintain their own recipe calculation tools, which may provide more accurately calculated values. Schakel et al. (1997) reported that the calculated values for macronutrients were more similar to analytical values than were those for micronutrients. Hence, the macronutrient values on labels may be reasonably accurate i.e. 10% variation. Further investigation of the accuracy of label data regulated under the
Food Standards Code would help to establish how much confidence can be placed in label data in this region.

**Table 4: Industry/label data.**

<table>
<thead>
<tr>
<th>Brand</th>
<th>Market share</th>
<th>Protein kJ/100g</th>
<th>Fat g/100g</th>
<th>Sat fat g/100g</th>
<th>CHO g/100g</th>
<th>Sugar g/100g</th>
<th>Na mg/100g</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>41</td>
<td>600</td>
<td>6.3</td>
<td>7.5</td>
<td>5.2</td>
<td>12.3</td>
<td>1.6</td>
</tr>
<tr>
<td>Y</td>
<td>46</td>
<td>680</td>
<td>7.2</td>
<td>6.4</td>
<td>5</td>
<td>18.9</td>
<td>1.6</td>
</tr>
<tr>
<td>Z</td>
<td>14</td>
<td>785</td>
<td>6</td>
<td>10</td>
<td>5.2</td>
<td>18.4</td>
<td>3.6</td>
</tr>
</tbody>
</table>

|                  | Weighted contribution Brand X | 244.40 | 2.57 | 3.06 | 2.12 | 5.01 | 0.65 | 101.83 |
|                  | Weighted contribution Brand Y | 309.81 | 3.28 | 2.92 | 2.28 | 8.61 | 0.73 | 132.12 |
|                  | Weighted contribution Brand Z | 107.60 | 0.82 | 1.37 | 0.71 | 2.52 | 0.49 | 50.71  |
|                  | MS weighted mean              | 661.81 | 6.67 | 7.34 | 5.11 | 16.14 | 1.87 | 284.67 |
|                  | Weighted SD                   | 61.54  | 0.50 | 1.18 | 0.10 | 3.19 | 0.69 | 38.74  |
|                  | CoV                           | 9.30   | 7.43 | 16.02| 1.95 | 19.76| 36.70 | 13.61  |
|                  | % Precision score             | 5      | 5    | 10   | 5    | 10   | 20    | 5      |
|                  | No of samples                 | 15     |      |      |      |      |       |        |
| Ave precision score |                          | 8.57   |      |      |      |      |       |        |
| DQI score         |                              | 90     |      |      |      |      |       |        |

**Key foods data**

This approach draws upon successive re-analysis of key foods, which provides a basis for variability data (see Table 5 – Key foods, for an example).

Key foods also provide indications on key nutrients, i.e. those that provide first, second and third quartile intakes of nutrients. Only nutrients of such importance should form the basis of determining the probable composite mean, SD, precision scores and DQI. The variability of other nutrients is of less importance.
### Table 5: Key foods data.

<table>
<thead>
<tr>
<th>FOOD IDENTIFIER</th>
<th>SHORT_NAME</th>
<th>CSM PORTION</th>
<th>Energy (kJ)</th>
<th>Protein (g/100g)</th>
<th>Starch (g/100g)</th>
<th>Fibre (g/100g)</th>
<th>Sodium (mg/100g)</th>
<th>K (mg/100g)</th>
<th>Iron (mg/100g)</th>
<th>B1 (mg/100g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A95</td>
<td>Bread, pita, white (2003)</td>
<td>1 large pocket</td>
<td>1060</td>
<td>9</td>
<td>41.8</td>
<td>1.65</td>
<td>665</td>
<td>164</td>
<td>1.59</td>
<td>0.22</td>
</tr>
<tr>
<td>A95</td>
<td>Bread, pita, white (2000)</td>
<td>1 large pocket</td>
<td>864</td>
<td>7</td>
<td>43.6</td>
<td>2.26</td>
<td>550</td>
<td>134</td>
<td>1.25</td>
<td>0.12</td>
</tr>
<tr>
<td>A95</td>
<td>Bread, pita, white (1997)</td>
<td>1 large pocket (average)</td>
<td>971.67</td>
<td>8.67</td>
<td>41.47</td>
<td>2.44</td>
<td>552.33</td>
<td>141.00</td>
<td>1.58</td>
<td>0.17</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SD (STDEV)</td>
<td>99.42</td>
<td>1.53</td>
<td>2.32</td>
<td>0.89</td>
<td>111.52</td>
<td>20.42</td>
<td>0.33</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CoV (STDEV/ x 100/average)</td>
<td>10.23</td>
<td>17.63</td>
<td>5.59</td>
<td>36.45</td>
<td>20.19</td>
<td>14.48</td>
<td>20.58</td>
<td>29.04</td>
</tr>
<tr>
<td></td>
<td></td>
<td>% precision score</td>
<td>5</td>
<td>10</td>
<td>5</td>
<td>15</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No of samples</td>
<td>22</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Ave precision score 11.10  
DQI score 80

The identification of key foods for food composition research in the NZFCD is still in early development. As the NZFCD has a good representation of the majority of foods in the New Zealand market, the adoption of a key foods approach as reported by Haytowitz et al. (2002) is a natural progression in the database’s development. Given the relative importance of key foods to the diet, actual analytical variability data would be very useful. However, even with the more frequent re-analysis of key foods, i.e. every 2-3 years, this variation can be ascribed in the case of a primary food, such as milk, as capturing important variability data. These data can then be used to determine representative sampling and sample size in primary foods such as milk, fresh produce etc. Other variations in processed foods may only reflect changes in manufacturing practices or ingredients. Hence, the variability data derived may be of little practical use.

### Statistical methods

Statistical methods provide a framework and point of reference for food selection, variability and a quantitative assessment of these and other aspects of the sampling plan. The principal assumptions of this approach in assessing sample representativeness are that variability data have been derived from foods with a normal distribution of nutrients and that the published variability data are in fact applicable. The mean of the industry/label data reflects the absolute unweighted values. However, weighting the mean by market share increases the likelihood that a greater percentage of users will find the data to be more representative of actual values consumed by a population. When market share is used to determine the composite proportions, a weighted SD is used. The use of an unweighted SD would overestimate the true variability in the composite sample. However, care needs to be taken that such statistical inferences are valid, and the use of statistical tools to create a framework for supporting compilers’ decisions is an area for further work. The use of variability data from various sources raises questions about their accuracy or reliability. Unfortunately we do not know exactly and some assumptions must be made. Manufacturers’ label data in New Zealand and Australia, for example, are required to provide representative ‘average’ values, but of course may be prone to varying degrees of inaccuracy. However, such values can support more representative analysis of foods. The applications presented here are an attempt to illustrate
that such a resource can be incorporated into a sampling protocol with appropriate judgement.

Conclusion
The methods described are steps towards developing more robust sampling protocols for NZFCD based on established guidelines and using available resources, which may be applicable to compilers in other countries. They also illustrate that food composition database compilers can use additional resources to assist in what is a daunting task, the determination of representative food composition data.

References
Food Standards Australia New Zealand 2005: Food Standards Code, located at www.foodstandards.gov.au
AGRIQUALITY FOOD PROFICIENCY PROGRAMMES IN NEW ZEALAND

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AgriQuality Proficiency Programmes, AgriQuality, Hamilton, New Zealand.

Keywords: Food, proficiency programmes, ILAC (International Laboratory Accreditation Co-Operation) Guide 13, Z Score, Youden Diagram, repeatability, reproducibility, risks and market requirements, interlaboratory comparisons, quality control.

Abstract

This paper describes food laboratory proficiency programmes in New Zealand and some other parts of the Asia-Pacific region. These programmes include microbiology and chemical tests on meat, water, dairy, wine and “other” food and beverage matrices. Many of these programmes are accredited to ILAC (International Laboratory Accreditation Co-Operation) Guide 13 by the International Accreditation of New Zealand scheme (IANZ), the National Association of Testing Laboratories Australia (NATA) and some are recognized by the New Zealand Food Safety Association (NZFSA), International Accreditation of New Zealand (IANZ), and National Association of Testing Laboratories Australia (NATA). NZFSA assures United States Department of Agriculture and the European Community of food safety and microbiology measures for the export of New Zealand foods to the United States of America. The AgriQuality Proficiency Programme serves over 300 laboratories, and other less frequent programmes analyse “within-the-round” using common proficiency measures (e.g. Z score and Youden Diagram).

Food proficiency rounds are designed to suit ongoing quality control including “uncertainty of measurement” per repeatability r, bias, collective reproducibility R, “individual reproducibility” R and include graphs with various presentations for participants to use the full range of statistical process control techniques. Design has taken account of food aspects: “risks and market requirements”, “analyte instability”, and “result method dependence”. Microbiology trials have further improved organism selection, media, and storage over time so that reduction in “sample variation” has allowed a clear determination of “laboratory variation”. These treatments, and especially the microbiology treatments, have been very successful and can provide assurance for laboratories dealing with foods and nutritional products. The above proficiency programmes have been used for the past 10 years in monitoring the technical performance and quality control functions of testing laboratories in the Asia Pacific Oceania regions.

Introduction

The economy of New Zealand is very dependent on the export of food products. For the $31 billion dollars of overseas trade, 45% is attributed to the sale of dairy, meat, fruit, and fish products (NZ Official Year Book 2002). At the forefront of supporting this export drive are the New Zealand food laboratories responsible for testing, quality control and ensuring the food products meet international health import standards and specifications. One of the tools used to control the quality of laboratory results is known as interlaboratory comparison programmes (ILCP). ILCP are often used as a benchmark for checking the integrity and reliability of laboratory results. In this paper we briefly describe a proficiency programme that has been in successful operation in the food industries since 1980.
AgriQuality, a New Zealand national organisation, runs a number of Proficiency Programmes from its offices in Hamilton (Twomey & Leong 1980; Dykes & Leong 1985). Three current programmes are discussed in this paper.

**Discussion**

**New Zealand Meat Industry Laboratory Approval Scheme (LAS)**

The New Zealand Food Safety Authority (NZFSA) has used this programme to monitor the performance of over 40 meat laboratories. The AgriQuality programme is accredited to ISO Guide 43, ILAC Guide 13 and was the first laboratory to gain this status in New Zealand. The LAS programme is used to support the export of meat products to the USA and other countries and the programme operates on a monthly basis for microbiology and chemistry testing. Specifically, the programme looks at microbiology testing in potable water, food microbiology, pathogen testing, meat microbiology and meat chemistry. The programme coordinator follows up on all bias and repeatability alerts raised in the programme. As a result, this is one of AgriQuality’s highly successful programmes in New Zealand and it is linked directly to market access issues.

**Food, Meat, Water Pathogen Programme**

The Food, Meat, Water Pathogen Programme is also a monthly programme used by many food companies and testing laboratories outside of the mandatory Laboratory Approval Scheme. The programme has over 80 participants in New Zealand, Australia and Asia Pacific Regions. The pathogen (Listeria, Salmonella, Campylobacter, *Escherichia coli* O157) scheme is of particular interest as it detects whether a laboratory can identify pathogens in food products. This programme is one of our more popular programmes in recent years because of increasing concerns about food safety issues in New Zealand and other parts of the world.

**Wine Programme**

The wine programme has great potential as the range of tests keeps increasing over the years. The range of tests in the programme includes titratable acidity, sulfur dioxide, residual sugars, minerals and pH. Results of the programme are used by winemakers in their manufacturing process and quality control. It shows that science and arts can go hand in hand with good winemaking. All the major wine companies in NZ use AgriQuality ILCP.

**The LAS Proficiency Programme Statistics**

The principal statistics used in present ILCP are based on the “Z” Score system and have been adapted by AgriQuality over the years (Viggers et al. 1993). The programme uses the median as a “true result”. Three key parameters are used: repeatability, reproducibility and bias. A sample of the result form is shown in Figure 1.

Bias is represented as the standardised difference of a laboratory’s result compared with results from other participating laboratories over time. Thus the standardised difference $= (your	ext{ result} - median)/limit$. The limit is sometimes known as the Industry Agreed Limit which has been set in advance for the individual test. Bias is linked to accuracy. It measures the variance between your result with the median or the “true result” over a period of time. Note: “Your” is the participant’s results in this instance.

Repeatability is a measure of precision, for an analyst or within a laboratory, of procedures carried out at the same time under the same conditions.

Reproducibility is also a measure of precision and the ability of a laboratory to link its results to other laboratories in a proficiency programme at different times and different conditions.
Performance is based on “good”, “ok” or “alert”. These are based on limits which is a numeric value multiplied by a limit (usually a standard deviation). Robustness is how well the data stand up to less than perfect conditions (e.g. number of participants and test variables). This is the reason AgriQuality opts for a desired minimum of eight laboratories for ensuring robustness of data.

The key requirement in understanding statistics for proficiency programmes is to know what the result means. Are the data valid and are they robust?

**Proficiency Samples Quality Control**

Food proficiency programmes are designed to be used as a laboratory quality control tool and to assess the “uncertainty of measurement”, “repeatability (r)”, bias, collective and individual reproducibility (R). In order to ensure the samples are suitable for the programme, they are subjected to rigorous stability and homogeneity trials. AgriQuality has carried out stability trials for microbiology freeze-dried samples for over 2 years and statistical data have shown that they have been stable over this time under normal storage conditions.

In terms of homogeneity testing, every batch of microbiology samples is validated for the types of micro-organisms present and multiple samples are tested to ensure they pass the rigorous statistical evaluation.

These steps are essential because the programme wants to pick up real differences in testing capabilities rather than sample variation.

**Using Proficiency Performance for Quality Control**

One of the key issues for using proficiency programmes for quality control (QC) purpose is to identify bias. However to accurately determine the bias, the data must consider “repeatability” and “reproducibility” with consideration of the “uncertainty of measurement” of the test. To ignore any of these parameters is a mistake, as food testing has many high risk factors with tight specifications. Another key parameter for QC is the charting of performance over time. This gives a trend analysis, which is important for management purposes. In some instances, warning limits have been ignored to the detriment of testing capability. The graphic description of these trends needs to be simple, as some of the users of the programmes are not statisticians and do not have good knowledge of test methods. In some instances, reports are linked to individual methods so as to enhance interpretation of data by managers.

Manufacturers of specialty foods and ingredients rely on food laboratories for process quality control and batch acceptance. They are concerned about laboratory results that are “unstable” due to different test methods giving different results (as seen in many microbiology testing), analyte instability (e.g. vitamins) and uncertainties due to sampling. The importance of sample stability has been mentioned in this paper. Combining timely QC reporting and using a reliable proficiency programme with stable samples are the key ingredients of food proficiency programmes for the Australasia/Pacific region.

**Conclusions**

Food proficiency programmes in New Zealand have been developed for over 20 years. Simple statistics are an essential ingredient for a good ILCP. Nowadays the programmes have good, timely follow-up, which is in line with management policies of ISO 17025.

QC of proficiency samples is important as it ensures that laboratory alerts, when raised, are genuine and are due to actual “poor performance” of the laboratory.
Food proficiency programmes data should consider the “repeatability” and “reproducibility” of the test so that poor performance by the laboratory is treated fairly, with due considerations given to the “uncertainty of measurement” of the test.

Trend analysis of ILCP data and the use of simple graphs make the programme more effective as a tool for managers.

The use of stable samples and a holistic approach to proficiency programme management will assist immensely in quality control in food manufacturing.

References


ISO 17025, 1999: General requirements for the competence of testing and calibration laboratories.
Figure 1: Report example.
TECHNICIAN TRAINING IN THE LABORATORY

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Keywords: laboratory training, assessment, health and safety, courses.

Abstract

In the modern analytical laboratory, a technician needs good qualifications and/or experience, good communication skills, good customer relations, good teamwork, and the right attitude. These are the key attributes considered when selecting staff and, once appointed, the technician must be adequately trained for the work they are expected to undertake. Without training and assessment of a person's skills it is unreasonable to expect or allow a technician to carry out analytical work within the laboratory.

This training should cover all aspects of the laboratory's operation. It starts with the induction that the person receives when starting a new job and needs to cover personnel management systems as well as laboratory systems for efficient sample handling. The technician needs to know who to ask should things be unclear or help is required, and there is also a need to be familiar with the range of apparatus and equipment that may be used. The technician needs to know where methods, records and other relevant documentation can be found. The technician also needs to be familiar with the laboratory's safety, health, and environmental policies and procedures. It is only after such general training that detailed training on specific analytical methods can commence.

Introduction

All technicians will need training in the laboratory. It is important that such instruction matches the existing level of skill and experience of the trainee. It is only by building on current knowledge that training can be effective. For example, if the training is at too low a level then the trainee can lose interest and fail to benefit as much as expected. Conversely, if the level is too high then the trainee could get discouraged and fail to benefit from the training. It is vital that during training the trainee understands the material being taught. Without understanding, it becomes more difficult to appreciate pitfalls that may occur during analysis and the technician becomes little more than a robot carrying out analytical tasks repetitively without the ability to critically examine the process that is occurring.

We live in a continually changing world where scientific developments, technology, environmental, safety, nutritional regulations and requirements for overseas market access are evolving ever more rapidly. New legislation, technological refinements and the impact of electronics require a continuous process of re-training of laboratory technicians and staff.

Training is essential for the benefit of both laboratory and its personnel, and vital for the laboratory to function as it must. Without training a laboratory technician may feel a lack of reward or challenge. To have a sense of achievement, a person needs a good understanding of the tasks required and the ability to recognise a job well done. Training in the laboratory can cover a wide variety of different aspects: statistics, instrumental techniques such as high performance liquid chromatography (HPLC) and gas liquid chromatography (GLC), good laboratory practice, maintaining a safe and healthy working environment, equipment maintenance, chemicals and their purity, reagent preparation, aseptic handling techniques,
disinfection and sterilisation, teamwork and communications, and quality control. The laboratory can encompass a wide range of different technologies and disciplines.

Methodology
Training in laboratory techniques and procedures can take many forms. It can be on-the-job training where the new appointee learns from peers and supervisors; training can also be formal training at a university or technical institute; it may consist of attending specialist courses on a number of areas in which the technician needs to be proficient; it may be self-paced, often with questions and answers to verify that basic facts have been understood before developing these further. Whatever method of training is used, it is vital that this includes an element of assessment. This is required for two reasons: firstly, to verify the training has accomplished the desired outcome; secondly, to ensure that the trainee is following the instruction and not getting out of his/her depth.

Laboratory work is manipulative, involves many hazardous reagents, and often requires the use of specialised equipment. It is therefore very helpful if the training includes a significant portion of practical sessions. Without being able to build on the understanding of the theoretical aspects of the training, the ability and quality of the analyst could be seriously compromised. It is also necessary to ensure that valuable equipment is adequately maintained and used correctly, as most laboratories cannot afford equipment downtime.

Training at AgriQuality
AgriQuality has laboratory facilities in Melbourne, which include a seed laboratory, a GMO and allergen laboratory, a food laboratory and a proficiency programme provider. In New Zealand there is a residues and environmental laboratory specialising in residue analysis for food and environmental samples, and food forensics. The AgriQuality laboratory at Lynfield in Auckland specialises in food and environmental analysis. It has a technical staff of over 100 people and covers a number of different disciplines, using a variety of techniques. The laboratory has a microbiology section which carries out tests for pathogens and general microbiology of a wide variety of foods. The microbiology laboratory trains staff at meat works in the correct procedures for aseptic sampling and carries out regular reviews on the techniques used within the works. Staff members have given training in the establishment and training of laboratory technicians in the analysis of microbiological techniques and methods.

The chemistry section’s scope of analyses includes the analysis of proximates, vitamins, minerals and natural toxins. The chemistry team has carried out training in the proximate analysis within the dairy industry, including training on the various components in milk, products manufactured and their analysis. This has included training in the analysis for fat, protein, moisture, ash, lactose, peroxide value, and free fatty acids. The chemistry team has also conducted courses in heavy metal and pesticide analyses in external customer laboratories.

One example of this was training staff from other laboratories in the analysis of foods for pesticide residues. This training covered both the theory and practical sessions on the pesticide analysis. The scope of the training included instrumentation, extraction clean-up and concentration, separation and detection, identification and quantification, gas chromatography-mass spectrometry (GCMS) quality assurance, rounding significant figures and units, and uncertainty of measurement.

The training was focused at a level that would be most useful and beneficial to the trainee. It covered equipment and apparatus that the trainee would be likely to use within his or her own laboratory. For example, for the analysis of pesticides, our laboratory uses much semi-
automated equipment such as accelerated solvent extraction (ASE), gel permeation chromatographic clean-up (GPC), automated sample concentration and miniature column clean-up. Such equipment may be unattainable to the trainee, therefore emphasis needed to be placed on traditional methods using basic equipment such as blenders, separating funnels and rotary evaporators. The training also drew heavily on reference material from the pesticide methods of the USFDA with additional material from instrument suppliers such as Agilent, Shimadzu, Perkin Elmer and Varian. From the Lynfield laboratory, materials were used on systems and methods of analysis. Thus the trainee was able to get an appreciation of the wide range of reference material available. This is vital, as they would be required to be able to analyse samples and solve the various problems that arise from time to time when performing routine analysis.

The training also had over 200 questions and model answers for review of each section. This was vital to ensure understanding of the preceding sections before proceeding to the next section of the training.

The laboratory’s training has included extensive practical sessions, as these are essential for laboratory personnel to gain familiarisation with the techniques required and are necessary to help solve problems should they arise during routine analysis. This training has included the use of our laboratory’s equipment and has allowed hands-on experience in performing many of the routine parts of equipment maintenance and pesticide analysis.

Training courses can be tailored to the requirements of the laboratory and have included week-long sessions and more extensive 6-week training periods. The use of short courses for topics such as pesticide analysis serve more as an introduction to give an appreciation of the equipment, principles of analysis and techniques involved. These shorter courses have included limited practical sessions, while longer courses have included far more practical sessions on both the equipment and the various procedures for pesticide analysis. Such courses have included basic techniques and hands-on experience to enable staff to gain confidence and improve the ability to meet the demands of the modern laboratory.

Without training and assessment of a person’s skills it is unreasonable to expect or allow a technician to carry out analytical work within the laboratory.
KEYNOTE ADDRESS

FOOD CONTAMINANT STUDIES IN THE PACIFIC AND IMPLICATIONS FOR THE OCEANIA REGION

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University of the South Pacific, Suva, Fiji

Keywords: persistent organic pollutants, mercury, cadmium, arsenic, cyanide.

Abstract
Chemical contaminants in food are a focus of much interest to ensure health is not damaged. Increasingly, the levels of nutrients and contaminants in food have become a trade issue as countries seek to promote and protect the health of their citizens. The World Trade Organisation has adapted international standards for allowed levels of food contamination as acceptable barriers to trade.

Given the important role of food for both health and trade, and the lack of much knowledge about what is in the food we eat in the Pacific, the Institute of Applied Sciences (IAS), a section of the University of the South Pacific, has operated a Food Unit since 1985 to study these matters. It originally developed skills in food nutrient analysis, and since 2002 has expanded its expertise to include food contaminants. These contaminants have included chemicals in breast milk, mercury in fish, cadmium in taro, arsenic in water and cyanide in cassava.

Introduction
Two major chemical contaminant classes in food are pesticides and heavy metals. These are usually identified with heavy industrial and agricultural activity and so it had been assumed that such food contamination might not be a problem in the islands of the Pacific. However, evidence of inappropriate use of pesticides, and problems in their transport and stability that allow them to build up in places even where they are not used, has led to concerns about their presence even on remote islands. An increasing proportion of people's diets consists of imported foods that are unlikely to be checked for contamination when imported (which raises the issue of dumping contaminated products). The arsenic contamination of many wells in Bangladesh alerted people to the fact that heavy metals can become concentrated in the soil, especially in volcanic soils.

Given the success of the IAS laboratory in nutrient analysis, the Food and Agriculture Organisation of the United Nations has supported a project to further develop food analyses at IAS and in five Pacific countries. Under the project the IAS quality system has also undergone scrutiny for possible international accreditation. Food contaminant analyses are also being developed.

Results and discussion
Breast milk study
The enhanced ability of the IAS laboratory to perform pesticide and heavy metal analyses, which is being developed under the FAO project, has been used in some small projects. These are beginning to give people in Fiji a better idea of the levels of some of these contaminants in the food they eat.
The Global Environment Monitoring System (GEMS)-Food project, a collaboration between WHO and FAO, has periodically monitored the levels of pesticides and other persistent organic pollutants (POPs) in breast milk.

The need to lessen the amount of POPs in the environment was highlighted by the recent signing of the Stockholm Convention, in which countries agreed to stop the use and production of POPs. Some POPs, such as DDT, are pesticides whose use has been phased out in most countries, including all Pacific countries. Others, such as dioxins, are by-products of industrial processes and burning. They are also formed naturally. Their presence in the environment can be lessened by actions such as less rubbish burning and more efficient burning of fossil fuels. Most of these chemicals (more than 90%) enter the human body from the food we eat, mainly through the fat of meat and large fish. In 2002 IAS, working with the National Food and Nutrition Centre, collected breast milk samples to be analysed for POPs by an internationally accredited German laboratory.

The results are shown in Table 1. Samples were donated from 10 women in the urban Suva area and 10 from the more rural Nausori area to see if there were significant differences, but there were not. Breast milk samples were monitored because they give an idea of the long-term intake of people from all sources. Half of the dioxins in a person's fat are still there 7½ years later. The levels that can cause health effects are very low. For dioxins the units are 1 toxic equivalent of dioxins in 10^6 units of fat. Most POPs are thought to be endocrine disrupters; they affect the function of sex hormones in the body. Some POPs, such as dioxins, are also known to cause cancer.

Table 1: Fiji breast milk contaminants (μg/kg fat for pesticides, ng/kg fat for TEQ).

<table>
<thead>
<tr>
<th></th>
<th>Nausori</th>
<th>Suva</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dioxins/furans (TEQ)</td>
<td>3.51</td>
<td>3.17</td>
</tr>
<tr>
<td>PCB flat (TEQ)</td>
<td>1.80</td>
<td>1.70</td>
</tr>
<tr>
<td>Total TEQ</td>
<td>5.31</td>
<td>4.87</td>
</tr>
<tr>
<td>PCB (sum)</td>
<td>15.7</td>
<td>18.5</td>
</tr>
<tr>
<td>DDT (sum)</td>
<td>1.08</td>
<td>1.37</td>
</tr>
<tr>
<td>Dieldrin</td>
<td>0.005</td>
<td>0.003</td>
</tr>
<tr>
<td>Endrin</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Heptachlor</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Chlordane (sum)</td>
<td>0.003</td>
<td>0.003</td>
</tr>
<tr>
<td>Toxaphene (sum)</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>HCH (sum)</td>
<td>0.012</td>
<td>0.013</td>
</tr>
<tr>
<td>Mirex</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>HCB</td>
<td>0.004</td>
<td>0.004</td>
</tr>
</tbody>
</table>

TEQ toxic equivalents, PCB polychlorinated biphenyls, HCB hexachlorobenzene, HCH hexachlorocyclohexanes (e.g. lindane).

The World Health Organization has conducted studies of POPs in milk in 1988, 1993 and 2002. The 2002 study was the first time Fiji had taken part. Country by country comparison of toxic equivalents of dioxins, furans and similar-acting polychlorinated biphenyls is shown in Table 2 (WHO 2004).
Table 2: Dioxin-like chemicals in breast milk (2002) (TEQ (pg/g fat)).

<table>
<thead>
<tr>
<th>Country</th>
<th>TEQ (pg/g fat)</th>
<th>Country</th>
<th>TEQ (pg/g fat)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fiji</td>
<td>5.1</td>
<td>USA</td>
<td>11.5</td>
</tr>
<tr>
<td>Philippines</td>
<td>6.3</td>
<td>China</td>
<td>12.9</td>
</tr>
<tr>
<td>Brazil</td>
<td>6.8</td>
<td>Croatia</td>
<td>13.5</td>
</tr>
<tr>
<td>Australia</td>
<td>8.4</td>
<td>Finland</td>
<td>15.1</td>
</tr>
<tr>
<td>Hungary</td>
<td>9.7</td>
<td>Norway</td>
<td>15.1</td>
</tr>
<tr>
<td>Bulgaria</td>
<td>10.1</td>
<td>Romania</td>
<td>17.3</td>
</tr>
<tr>
<td>New Zealand</td>
<td>10.3</td>
<td>Sweden</td>
<td>18.9</td>
</tr>
<tr>
<td>Ireland</td>
<td>10.8</td>
<td>Spain</td>
<td>21.8</td>
</tr>
</tbody>
</table>

Many of these levels in European countries are considered by WHO to be "unsafe". The Fiji breast milk level of dioxins equates roughly to an intake of 0.2 pg TEQ/kg/day. Recommended tolerable intake is 1 pg/kg/day (B. Graham, pers. comm.). Levels have been reduced in most places since 1988 and hopefully will continue to do so under the aegis of the Stockholm Convention. Pacific countries which have signed the convention are currently developing national implementation plans to develop strategies to lower production and use of POPs. Although levels in Fiji are low, they are still significant, and our increasing dependence on imported foods can also mean a threat of higher POPs ingestion.

Although breast milk is an ideal material to monitor, the presence of poisonous chemicals in it creates a problem in risk communication. The chance of any health risks from POPs in Fiji at these levels is less than one in a million whereas not breast feeding is known to contribute to many serious health problems. Poisonous chemicals are present everywhere in our food and water. We can only try to make their levels as low as possible.

Mercury in fish

Mercury (Hg) and its compounds pose a significant threat to human health, particularly to pregnant women and their foetuses. Mercury is a toxin to the central nervous system and can readily cross the placental barrier. Previous studies in other locations have shown dangerously high mercury levels in certain types of seafoods, particularly large predatory fish. Data on mercury levels in fish and other seafoods from the Pacific Islands are scarce.

This lack of data is especially worrisome as fish form the basis of the diet of many Pacific Islanders and the tuna industry is economically important to Pacific countries. Therefore a project, supported by WHO, was undertaken to study the mercury level in Pacific fish.

The total Hg levels in several of the large predatory fish species (marlin, swordfish, sunfish and shark) exceeded the WHO/FAO limit of 0.5 μg/g (1.0 μg/g for predatory fish). Other types of fish steaks, smaller reef fish, shellfish, canned tuna and mackerel had average levels well below the regulatory limit. Fish steaks of swordfish, marlin and walu showed a positive correlation in mercury levels with the size of steaks (Kumar et al. 2004).

Although only a few analyses were conducted on some fish species, it is clear that health risks exist, particularly to pregnant women, from consuming relatively small quantities (1-2 portions per week) of a number of the larger fish species, such as shark, marlin, swordfish, sunfish, large albacore tuna (canned and fresh), bigeye tuna, sailfish and walu. For the marlin, swordfish, shark and sunfish the calculated safe level of consumption for pregnant women is less than 1 portion size/week and for bigeye tuna it is about 1 portion per week (FAO/WHO 1991). Frequent consumption of more than the recommended amount of these fish by pregnant women and women of childbearing age could be harmful to the developing foetus. More data on Hg levels in the larger species of fish and on human body mercury levels are needed to better assess the health risk. It must be remembered that seafoods
make an important nutritional contribution to the diet in Pacific Island countries and limited diet options are available to outer island dwellers. It should be noted that the reef fish (except barracuda) and shellfish normally consumed by Fijian people in rural/outer island areas have very low levels of mercury and calculations indicate that they can be consumed almost without limit. More emphasis should be placed on public education in order to protect human health in regards to mercury intake, particularly for pregnant women in areas where large predatory fish species are consumed. In Fiji such fish are being sold cheaply as a by-catch of the tuna industry in urban settlements.

Table 3: Hg levels (range and average) in different fresh fish and shellfish from the Fiji Islands, with length and weight data where available.

<table>
<thead>
<tr>
<th>Seafood sample</th>
<th>N</th>
<th>Average length (cm)</th>
<th>Average weight (kg)</th>
<th>Hg range (μg/g)</th>
<th>Hg mean (μg/g) ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Albacore tuna</td>
<td>31</td>
<td>72.7</td>
<td>21.3</td>
<td>0.03 - 1.01</td>
<td>0.34 ± 0.22</td>
</tr>
<tr>
<td>Yellow fin tuna</td>
<td>24</td>
<td>71.3</td>
<td>15.2</td>
<td>&lt;0.02 - 0.40</td>
<td>0.11 ± 0.11</td>
</tr>
<tr>
<td>Skipjack tuna</td>
<td>12</td>
<td>45.7</td>
<td>2.4</td>
<td>&lt;0.02 - 0.16</td>
<td>0.06 ± 0.04</td>
</tr>
<tr>
<td>Bigeye tuna</td>
<td>3</td>
<td>103.3</td>
<td>28.3</td>
<td>0.28 - 0.80</td>
<td>0.53 ± 0.21</td>
</tr>
<tr>
<td>Marlin</td>
<td>5</td>
<td>167.6</td>
<td>67.4</td>
<td>0.45 - 5.60</td>
<td>1.76 ± 1.94</td>
</tr>
<tr>
<td>Reef fish</td>
<td>5</td>
<td>17.2</td>
<td>0.09</td>
<td>&lt;0.02 - 0.04</td>
<td>0.04 ± 0.01</td>
</tr>
<tr>
<td>Barracuda</td>
<td>4</td>
<td>61.25</td>
<td>1.32</td>
<td>0.18 - 0.38</td>
<td>0.26 ± 0.07</td>
</tr>
<tr>
<td>Mussels</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>&lt;0.02 - 0.04</td>
<td>0.03 ± 0.01</td>
</tr>
<tr>
<td>Shellfish</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>&lt;0.02 - 0.05</td>
<td>0.03 ± 0.01</td>
</tr>
<tr>
<td>Crab meat</td>
<td>3</td>
<td>13.3</td>
<td>-</td>
<td>0.03 - 0.07</td>
<td>0.05 ± 0.02</td>
</tr>
</tbody>
</table>

Note: N = number of samples, SD = standard deviation.

Table 4: Hg levels (range and average) in canned fish sold in the Fiji Islands.

<table>
<thead>
<tr>
<th>Canned fish type</th>
<th>N</th>
<th>Hg range (μg/g)</th>
<th>Hg mean (μg/g) ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canned albacore</td>
<td>6</td>
<td>0.16 - 0.27</td>
<td>0.20 ± 0.03</td>
</tr>
<tr>
<td>Canned skipjack</td>
<td>9</td>
<td>0.016 - 0.11</td>
<td>0.08 ± 0.02</td>
</tr>
<tr>
<td>Canned tuna in oil</td>
<td>3</td>
<td>0.05 - 0.16</td>
<td>0.09 ± 0.05</td>
</tr>
<tr>
<td>Canned mackerel</td>
<td>6</td>
<td>0.18 - 0.22</td>
<td>0.21 ± 0.01</td>
</tr>
<tr>
<td>Canned salmon style mackerel</td>
<td>6</td>
<td>0.17 - 0.29</td>
<td>0.23 ± 0.05</td>
</tr>
</tbody>
</table>

Note: N = number of samples, SD = standard deviation.

Table 5: Hg levels (range and average) in fish steaks from the Fiji Islands.

<table>
<thead>
<tr>
<th>Steak type</th>
<th>N</th>
<th>Diameter of steak (cm)</th>
<th>Hg range (μg/g)</th>
<th>Hg mean (μg/g) ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marlin</td>
<td>19</td>
<td>19.1</td>
<td>&lt;0.02 - 1.01</td>
<td>0.47 ± 0.31</td>
</tr>
<tr>
<td>Sunfish</td>
<td>5</td>
<td>23.6</td>
<td>0.67 - 0.78</td>
<td>0.72 ± 0.07*</td>
</tr>
<tr>
<td>Walu</td>
<td>17</td>
<td>12.5</td>
<td>&lt;0.02 - 0.87</td>
<td>0.23 ± 0.21</td>
</tr>
<tr>
<td>Swordfish</td>
<td>5</td>
<td>23.4</td>
<td>0.99 - 2.81</td>
<td>1.81 ± 0.82*</td>
</tr>
<tr>
<td>Shark</td>
<td>7</td>
<td>14.1</td>
<td>0.57 - 0.85</td>
<td>0.78 ± 0.09*</td>
</tr>
<tr>
<td>Wahoo</td>
<td>4</td>
<td>13.5</td>
<td>0.05 - 0.12</td>
<td>0.08 ± 0.03</td>
</tr>
<tr>
<td>Mahi Mahi</td>
<td>3</td>
<td>21.3</td>
<td>0.05 - 0.11</td>
<td>0.08 ± 0.02</td>
</tr>
<tr>
<td>Sailfish</td>
<td>2</td>
<td>23.5</td>
<td>0.32 - 0.34</td>
<td>0.33 ± 0.01</td>
</tr>
<tr>
<td>Kalia-Blacksnapper</td>
<td>2</td>
<td>23.0</td>
<td>0.17 - 0.34</td>
<td>0.26 ± 0.09</td>
</tr>
<tr>
<td>Skipjack</td>
<td>5</td>
<td>14.6</td>
<td>0.11 - 0.19</td>
<td>0.15 ± 0.03</td>
</tr>
</tbody>
</table>
Cadmium in taro

Shipments of taro (Colocasia esculenta) to Australia in 2003 were analysed by Australian Quarantine and found to have levels of cadmium in excess of Codex guidelines of 0.1 mg/kg. This threatened a multimillion-dollar export market. Fiji agricultural authorities asked USP to assist in investigating the problem and WHO agreed to fund this as part of its risk assessment initiative.

Samples of taro, soil and fertiliser from the export farmers were analysed along with 40 taro root samples taken randomly from the Suva market. The analyses did not detect any levels above 0.1 mg/kg in taro samples or unusual levels in fertilisers or soils on taro farms.

**Table 6: Cadmium in taro, Fiji.**

<table>
<thead>
<tr>
<th>Sample type</th>
<th>Number of samples</th>
<th>Range of values (mg/kg wet wt.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taro root</td>
<td>100</td>
<td>0.005 – 0.031</td>
</tr>
<tr>
<td>Fertiliser</td>
<td>25</td>
<td>0.23 – 0.51</td>
</tr>
<tr>
<td>Soils</td>
<td>25</td>
<td>0.07 – 0.25</td>
</tr>
</tbody>
</table>

Arsenic in water

The Bangladesh experience of high levels of arsenic in drinking water from wells has highlighted the high natural levels of heavy metals that may exist in some sediments. In the older, volcanic Pacific islands this could also be an issue, as shown by the high level of mercury in certain fish species. Drinking-water sources throughout Fiji were tested, including city supplies and rural streams and boreholes. Samples were also taken around the Vatukoula gold mine where mineralised arsenic may get activated.

The total arsenic levels were mostly below the detection limit (Table 7). All the samples were below WHO guidelines of 10 μg/L for arsenic, suggesting no contamination from arsenic by either anthropogenic or natural sources. However, raised levels of arsenic were found in the samples taken downstream from the Nasivi river intake, where there is a creek carrying discharge from the tailings pond of the Emperor gold mine. The river below the pumping station is not used regularly for drinking, but people bathing there have reported sores on their bodies and it is likely that the river is used for drinking water. People should be advised not to drink that river water.

**Table 7: Arsenic in water, Fiji.**

<table>
<thead>
<tr>
<th>Sample type</th>
<th>Number of samples</th>
<th>Range of values (μg/L Hg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drinking water</td>
<td>45</td>
<td>&lt;0.5 – 0.7</td>
</tr>
<tr>
<td>Nasivi River (upstream of mine)</td>
<td>3</td>
<td>&lt;0.5 – 1.0</td>
</tr>
<tr>
<td>Nasivi River (downstream of mine)</td>
<td>13</td>
<td>29 – 110</td>
</tr>
<tr>
<td>Tailings dam</td>
<td>4</td>
<td>1208 – 6950</td>
</tr>
<tr>
<td>Creek outlet</td>
<td>4</td>
<td>208 – 1194</td>
</tr>
</tbody>
</table>

Cyanide in cassava

Cyanide occurs naturally in cassava (and other crops) as a glucoside. This is thought to be a natural defence against pests. Cyanide, of course, is a potent poison and its presence in food crops has drawn attention. Cassava has often been classed as “sweet” (low in cyanide) or “bitter” (high in cyanide) even though these correlations do not always hold. Concentrations in
Cassava range from roughly 10 to 1000 mg/kg raw cassava. Pacific cultivars are usually classed as “sweet”, even though during droughts Tonga reports that they might taste bitter.

The health effects of the cyanide content of cassava are not simple to predict. Total cyanide removal by processing is variable. Simple boiling, which removes 50-60% of the cyanide, is sufficient in the Pacific for low cyanide cultivars, whereas in Africa there are average higher levels of cyanide and so the traditional processing involves a complex process of grating, fermentation, and frying (Aalbersberg & Limalevu 1991). The fate of the remaining cyanogenic glycoside during digestion is not well known; that is, how much is released as cyanide into the body.

Cyanide in the body is mainly detoxified by reaction with sulphur-containing amino acids, but the resulting thiocyanide blocks iodine uptake by the thyroid gland. Thus, neurological disorders and lack of mental and physical development are the hallmarks of chronic intake of cassava high in cyanide. More acute effects, even death, can occur if this is combined with improper food processing and malnourishment (lack of the sulphur-containing amino acids, Bradbury & Holloway 1988).

In this somewhat murky scientific situation, New Zealand regulators decided to “protect” their consumers from cassava poisoning by calculating a worst-case scenario in which all the cyanide in the cyanogenic glycoside of raw cassava ended up as cyanide in the body. With a safety factor, this yielded a figure of 50 mg/kg as the safe limit for cyanide in cassava. Using the data of Bradbury from the 1980s, all Pacific cassava cultivars fell below this level, so it was felt that this regulatory level would create no barrier to the considerable trade of cassava from Pacific Island countries to New Zealand (Bradbury & Holloway 1988).

Unfortunately, the published research by Aalbersberg, showing that most cultivars in Fiji contained more than 50 mg/kg and suggesting that the Bradbury samples were likely to have been compromised during their journeys to his laboratory in Australia (Aalbersberg & Limalevu 1991), seems not have been consulted. Differences could also be caused by differences in analytical procedures.

Since then, Tonga samples have also been analysed and all mature cultivars are above 50 mg/kg.

Table 8: Cyanide in cassava, Fiji and Tonga (mg/kg).

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Aalbersberg</th>
<th>Bradbury</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cassava varieties from Fiji</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Katafaga</td>
<td>26</td>
<td>ND</td>
</tr>
<tr>
<td>Kaseleka</td>
<td>62</td>
<td>ND</td>
</tr>
<tr>
<td>Aikavitu</td>
<td>42</td>
<td>ND</td>
</tr>
<tr>
<td>Manioke</td>
<td>19</td>
<td>ND</td>
</tr>
<tr>
<td>Belesilika</td>
<td>61</td>
<td>ND</td>
</tr>
<tr>
<td>Yabia Damu</td>
<td>101</td>
<td>ND</td>
</tr>
<tr>
<td>Yabia Vula</td>
<td>93</td>
<td>ND</td>
</tr>
<tr>
<td>Sokobale</td>
<td>36</td>
<td>26.9</td>
</tr>
<tr>
<td>Vulatolu</td>
<td>70</td>
<td>31.5</td>
</tr>
<tr>
<td>Coci</td>
<td>55</td>
<td>ND</td>
</tr>
<tr>
<td>Merelesita 2</td>
<td>90</td>
<td>ND</td>
</tr>
<tr>
<td>Merelesita</td>
<td>14</td>
<td>ND</td>
</tr>
<tr>
<td>Vula tolu 2</td>
<td>21</td>
<td>ND</td>
</tr>
<tr>
<td>Noumea</td>
<td>38</td>
<td>ND</td>
</tr>
<tr>
<td>Navolau</td>
<td>107</td>
<td>24.1</td>
</tr>
<tr>
<td>Beqa</td>
<td>121</td>
<td>34.0</td>
</tr>
<tr>
<td>New Guinea</td>
<td>80</td>
<td>23.6</td>
</tr>
</tbody>
</table>
Cassava varieties from Tonga

(July 2004 – USP Laboratory)

<table>
<thead>
<tr>
<th>Variety</th>
<th>&lt;10 month</th>
<th>&gt;14 months</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tano’a Hahake</td>
<td>211</td>
<td></td>
</tr>
<tr>
<td>Tano’a Hihifo</td>
<td></td>
<td>153</td>
</tr>
<tr>
<td>Lepa, Hihifo</td>
<td></td>
<td>164</td>
</tr>
<tr>
<td>Silika, Hahake</td>
<td>110</td>
<td></td>
</tr>
<tr>
<td>Silika, Hihifo</td>
<td></td>
<td>159</td>
</tr>
<tr>
<td>Mataki’eu, Hahake</td>
<td>91</td>
<td></td>
</tr>
<tr>
<td>Mataki’eu, Hihifo</td>
<td></td>
<td>128</td>
</tr>
<tr>
<td>Engeenga nonou, Hahake</td>
<td>81</td>
<td></td>
</tr>
<tr>
<td>Engeenga nonou, Hihifo</td>
<td></td>
<td>111</td>
</tr>
<tr>
<td>Engeenga fo’ou, Hahake</td>
<td>40*</td>
<td></td>
</tr>
<tr>
<td>Engeenga loloa, Hahake</td>
<td>126</td>
<td></td>
</tr>
<tr>
<td>Fisi (Sokobaru), Hihifo</td>
<td></td>
<td>150</td>
</tr>
</tbody>
</table>

*<6 months of age

Conclusions

These analyses have proved to be useful in assessing the risks of food contaminants in Fiji. The examples of cadmium in taro and cyanide in cassava suggest the need for a closer relationship between the IAS laboratory and regulatory authorities in New Zealand and Australia. Since all are members of OCEANIAFOODS this may be a platform for fuller and more efficient communication, perhaps through an OCEANIAFOODS Listserv.

References


A NOVEL APPROACH FOR PRESENTING FOOD COMPOSITION DATA IN THE FEDERATED STATES OF MICRONESIA, MARSHALL ISLANDS, AND KIRIBATI

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Keywords: health promotion, carotenoid-rich foods, resource development, community project, Pacific Islands.

Abstract

Objective: In order to effectively communicate food composition data the right kind of promotional materials and messages are needed. This project developed a set of materials in order to promote locally grown carotenoid-rich foods and alleviate vitamin A deficiency, anaemia, and chronic diseases (diabetes, heart disease, and certain cancers). The project included the Federated States of Micronesia, Marshall Islands, and Kiribati.

Method: Ethnography, including key informant interviews, informal focus group discussions, photography, and observation, were used to select foods of potential carotenoid content and to understand factors of production, consumption, and acceptability. Photographic materials were developed to show visual differences between the white-fleshed (or lighter-coloured) cultivars of low carotenoid content and the yellow- and orange-fleshed cultivars of high carotenoid content, focusing on banana, giant swamp taro, breadfruit, and pandanus. The content of the most important of the provitamin A carotenoids, \(\beta\)-carotene, expressed per 100 g edible portion, was presented under the photo of the edible flesh of each cultivar. One page presented the message that rice contains no carotenoid at all. Another page presented the health benefits of yellow-fleshed cultivars.

Results: Great interest was shown in the materials by people in a broad range of professions and backgrounds, some requesting a fuller explanation of technical terms, such as \(\beta\)-carotene. On the whole, respondents could see that the deep yellow- or orange-fleshed
cultivars had the higher carotenoid content, while some were interested simply in seeing photographs of their own traditional foods presented in an attractive form or were interested in learning the cultivar names.

**Conclusion:** This novel approach to presenting carotenoid data was effective in communicating health messages in Micronesia.

**Recommendation:** This approach for communicating food composition data could be used in further Micronesian programs and possibly elsewhere to present nutrient content data and promote locally grown foods.

**Introduction**

Many varieties of staple foods, including banana, breadfruit, giant swamp taro, and pandanus were recently identified as carotenoid-rich (Englberger et al. 2003a,b,c) as part of a PhD project (Englberger 2003) in the Federated States of Micronesia (FSM), which is made up of four states: Pohnpei, Kosrae, Chuuk, and Yap. Since then, carotenoid-rich pandanus varieties and other atoll island staple foods have been identified in the Republic of the Marshall Islands and Republic of Kiribati (Englberger et al. 2006a,b.) Other work has shown that some of these foods are also rich in other nutrients (i.e. retinol in liver of different fish species, riboflavin in Karat banana and zinc and iron in giant swamp taro varieties). As there are serious problems of nutrition-related diseases (including vitamin A deficiency, diabetes, heart disease, cancer) in these countries, it is important to be able to communicate about the findings in an effective way.

Further collection and analysis of varieties of these foods showed that yellow colouration is a good indicator of carotenoid content. This led to the “Yellow Varieties Message” and the development of this novel approach for presenting food composition data to the community. Provitamin A carotenoids protect against vitamin A deficiency, a serious problem in all three countries. Carotenoid-rich foods may help protect against diabetes, heart disease, and certain cancers, which are also serious health problems in all three countries. Thus, the same foods could be promoted for multiple health benefits.

The past experience of the 15-year regional UNICEF-supported Family Food Production and Nutrition project (from 1986 to 2001) showed that the approach of promoting green leafy vegetables for dietary improvement and alleviating micronutrient deficiency was less successful in these three countries, due to the low acceptability of these vegetables. In all three countries, green leafy vegetables have only been considered as food for animals (Barker 1996; Schoeffel et al. 1991; Englberger 2003).

**Methodology**

Ethnography (key informant interviews, informal focus group discussions, observation, literature review, and photography) and a participatory approach were used to collect factors of production, consumption, and acceptability and to plan how to most effectively communicate the new findings of food composition on the locally grown indigenous foods in FSM, the Marshall Islands, and Kiribati. Identifying the acceptable nutrient-rich foods to promote was the first step needed for the project.

An inter-agency approach was taken, collaborating with many governmental and non-governmental agencies (including the private sector, regional and international agencies, academic institutions, and the media) mainly in Pohnpei State, FSM, but also in Kosrae State, FSM, Marshall Islands, and Kiribati.
Results and discussion

Using photographs comparing white-fleshed and yellow/orange-fleshed varieties of bananas, it was found that people in the community were often very interested in the differences in carotenoid content. Although people were not familiar with some of the terms, such as carotenoids, they could see that the yellow/orange-fleshed varieties had the higher carotenoid levels and thus could contribute more to nutritional status in the body.

This work led to the “Yellow Varieties Message,” presenting communities with scientific data on their own varieties in a simple visual method. ß-carotene is the most important provitamin A carotenoid and is present in foods in greater levels than other provitamin A carotenoids. Thus, the food composition data on carotenoids could be simplified by presenting only that of the ß-carotene content.¹

A mixture of methods was used to present the “Yellow Varieties Message” to the community including the following:

- Posters, booklets, brochures, and newsletters
- Workshops, conferences, agricultural fair
- Presentations on the radio, via newspaper, or by email
- Training in small-scale food processing, new recipes
- Collecting and conserving rare varieties
- Providing planting materials of rare banana varieties to commercial growers and other community members.

Approaches taken

A strategy was developed using a participatory approach with many agencies and several other approaches:

- Shifting from one group of staple foods (white-fleshed) to another group of staple foods (yellow/orange-fleshed), most of which were common in the past.
- Including the “Yellow Varieties Message” into a variety of print materials and promotional activities: this included cards, booklets, posters, brochures, newsletters, media releases, World Food Day, agricultural work, research.
- Using memories and cultural values to promote rare varieties: older people fondly recalled memories of their childhood when they saw photos of the rare banana varieties and this became a way of promoting these valuable foods.
- Evaluating the print materials and promotional activities: these were informally evaluated through discussions, collections of comments, and revisions of the materials over a 2-year period. A more formal evaluation is presently being planned with assistance from the Secretariat of the Pacific Community Lifestyle Health Section.

¹ Other provitamin A carotenoids include α-carotene and ß-cryptoxanthin. Carotenoids with demonstrated health benefits but no vitamin A activity include lutein, zeaxanthin, and lycopene. The Micronesian foods were analysed for all these carotenoids. The total carotenoid results were made available to all interested but were not included in teaching tools.
Forming a new non-governmental organisation, the Island Food Community of Pohnpei (IFCP), which would focus on the identification and promotion of nutrient-rich island foods, such as yellow-fleshed varieties.

The promotional campaign was based on these factors:
- In the past many community members were familiar with many varieties.
- Presently there is an increasing loss of traditional knowledge.
- Elder community members are concerned and are asking for help in this area.

The differences in colouration and carotenoid content of the varieties were striking. A photograph of different banana varieties, peeled to show the colouration differences, was used as a teaching tool, presenting the ß-carotene content alongside the peeled banana. For example, the white-fleshed Utin Menihle contained 30 µg ß-carotene/100 g and the Taiwang, Mangat, Karat, and Utimwas contained 662, 4799, 2230 and 6360 µg ß-carotene/100 g respectively. However, health workers were reminded to point out that the message was not to discourage eating white-fleshed varieties, as even Utin Menihle contains some carotenoids... and rice contains none! A separate page in the Vitamin A-rich cards was prepared to point out that fact.

People of a broad range of professions and backgrounds showed interest in the materials. Some asked about the technical terms, such as ß-carotene, and health workers explained them. Others were mainly interested in the photographs, seeing their own traditional foods presented in an attractive form, and some were interested in learning the cultivar names. Some of the print materials developed using the “Yellow Varieties Message” were:
- Pohnpei Vitamin A-rich Foods cards
- Kosrae Vitamin A-rich Foods cards
- Marshall Islands Vitamin A-rich Foods cards
- Kiribati Vitamin A-rich Foods cards
- Kiribati Pandanus poster
- Pohnpei Bananas booklet (Englberger and Lorens, 2004)
- Pohnpei Bananas (Uht Kan en Pohnpei) Carotenoid-rich Varieties poster
- Island Food Community of Pohnpei brochure
- Island Food Community of Pohnpei Food Trends Newsletter
- Pohnpei Bananas Calendar 2005
- Mwoakilloa Pandanus Calendar 2005.

One main message repeated throughout the materials was as follows (in English):

“Grow and eat yellow and orange-fleshed varieties in order to help prevent diabetes, heart disease, certain cancers, vitamin A deficiency, and anaemia.”

Workshops, meetings, classes, conference, and Food Fair

One series of workshops was an inter-agency workshop led by the Headstart Early Childhood Education agency with nine workshops held in Pohnpei from 19 January to 5 February 2004. In that series of workshops in centres throughout the island, there were 257 Headstart parents as participants and 14 facilitators of five agencies. The “Yellow Varieties Message” was presented, and there was much interest, also for the Taiwang banana. This tasty banana
is not rare, but it is not often consumed as people presently consider it as a lowly banana, as it is so easily grown.

During the workshop, it was also revealed that some people believed that it causes worms. People were informed about the rich carotenoid content and health benefits of this banana, and also that a banana would not cause worms as long as it is kept hygienically. After attending the workshop, many participants informed different facilitators that they had started eating the banana. Another set of impressive workshops were those in Kosrae, using an inter-agency approach teaching about the “Yellow Varieties Message” and discussing those varieties, as well as cooking demonstrations using fish liver with vegetables.

Farmers’ meetings were another way to present the “Yellow Varieties Message.” The Rare Bananas Project was organised to purchase planting materials (suckers) of Karat and other rare carotenoid-rich varieties from those having them and to distribute to those who wanted them, focusing on commercial farmers. Over 900 suckers were re-distributed and it is hoped that this project will lead to an increased availability of carotenoid-rich banana varieties in the local markets.

The Youth to Youth program, sponsored by the Conservation Society of Pohnpei (CSP) is a project raising awareness about rare Pohnpei banana varieties among primary schoolchildren. This is an initiative of IFCP and CSP and is carried out by working as a team with sixth grade classes of primary schoolchildren. Cooking classes and recipe development are an important part of the project. Recipes for Karat and Taiwang Bread and a Taiwang Pancake recipe were developed, which were incorporated into various materials, including the IFCP brochure and the Pohnpei Bananas booklet.

The Island Food Community of Pohnpei’s first conference was held December 13, 2005, along with the keynote speaker talking of the role of island foods in Pohnpei culture. Young children were involved to perform in skits, talking about island foods, which created much fun and interest.

The Pohnpei World Food Day/Food Fair in 2004 selected a theme based on the “Yellow Varieties Message.” It was: “Grow and eat yellow varieties for health and wealth.” First-place prizes for yellow varieties were higher than first-place prizes for white-fleshed varieties of banana and giant swamp taro. Farmers noticed this and there was much discussion about it, as the agriculture extension agents in contact with the farmers later pointed out. The event drew over 500 people and featured on the front page of the local newspaper. It was filmed as a 40-minute documentary of the event and was shown several times on the local television channel.

**Print material for raising awareness**

The Vitamin A-rich Food Cards have raised much interest and have been prepared both in laminated form for mounting on walls and in book form for inter-personal teaching. A similar format was followed for the sets for Pohnpei, Kosrae, Marshall Islands, and Kiribati, presenting the photographs comparing the yellow varieties for their edible flesh colour differences and carotenoid content. Each set presented the information that rice, the imported food which has become a common part of the diet, contains no carotenoids. Each group then worked out the translation of the English message as to the health benefits of the yellow varieties through a participatory effort.

“Pohnpei Bananas (Uht Kan en Pohnpei: Carotenoid-rich Varieties)” poster has also become very popular. This poster communicates the “Yellow Varieties Message” by presenting photographs of bunches of only the orange- and yellow-fleshed banana varieties, along with information on carotenoid content, with all varieties ranked according to carotenoid content.
levels. The poster captured much attention at the 31 March 2005, Pohnpei Cultural Day event.

The Kiribati Pandanus poster presents the “Yellow Varieties Message” by focusing on pandanus varieties and two forms of preserved pandanus that have been analysed for carotenoid content. Again the poster was organised so that those varieties with a higher carotenoid content were placed at the top of the poster.

Newspaper articles communicating the “Yellow Varieties Message” were prepared as an ongoing effort. From 2003 to April 2005 over 25 articles were published in the Kaselehlie Press. Another media project in preparation is that of a documentary that on the vitamin A program in Pohnpei, which is supported by Sight and Life, and will also present the “Yellow Varieties Message.” Also car bumper stickers proclaiming “Exclusive Breastfeeding is Best” were produced in order to promote the wonderful natural resource of breastmilk.

Press releases were provided to regional and international agencies, which raised an international awareness on the high carotenoid content of Karat and other Pohnpei banana varieties. A presentation was made at the First International Banana Congress meeting in Penang, Malaysia, as coordinated by the International Network for the Improvement of Bananas and Plantain (INIBAP). The science writer for INIBAP prepared a press release on Karat at the time of the Congress, and an article was then published in the New Scientist, after which articles came out in newspapers and magazines around the world, including the Hindustani Times in India and Die Welt in Germany.

The development of a Karat postal stamp for FSM was another major effort, as supported by the FSM Philatelic Bureau. A commemorative issue will be made for World Food Day in October 2005.

Reaching the leaders and media was a part of the project. Governor Johnny P. David of Pohnpei State was an active promoter, as he agreed to pose for the camera eating Taiwang banana and to be interviewed for a newspaper article. He pointed out that despite the low status of Taiwang (it is used to feed pigs), it was his favorite banana for taste, and he encouraged people to eat it for its health benefits.

Documentation and conservation of primary food crops

A banana documentation consultancy was conducted by a leading expert, who classified 39 Pohnpei banana varieties by their international classification (Daniells 2004). The documentation of rare varieties is an on-going project, recording data on the primary identifying characteristics. The colouration of edible flesh (white, cream, yellow, yellow/orange, or orange) is one of the major pieces of information collected.

Over 30 banana varieties were planted in a Banana Genebank at the Pilot Farm in Pohnpei, for conservation, research, and as a nursery for planting material. The “Yellow Varieties Message” is incorporated in this genebank because there is also a collection of the yellow-fleshed varieties.

Giant swamp taro was another major focus. In collaboration with a University of the South Pacific student who was doing his Master’s degree research project on the documentation of characteristics of giant swamp taro, further data were collected. Local experts were employed to continue documenting the names and characteristics of the many varieties. A collection of over 30 giant swamp taro varieties was planted in the Giant Swamp Taro Genebank in Pohnpei. Mwoakilloa, an outer atoll of Pohnpei State, was visited in order to collect planting material for the giant swamp taro and pandanus collections on the main island of Pohnpei (the largest pandanus genebank in the world is in Kiribati).
Small-scale food processing and food product development

One of the major attractions of imported foods has been their convenience. Thus, the Island Food Community of Pohnpei put a priority on working on small-scale food processing. A consultancy was held in Pohnpei in October 2004, which was very popular, with over 100 participants attending. The challenge remains to develop food products from local island foods and to bring these into the commercial market.

A community project in Madolenihmw, Pohnpei

A new activity for IFCP is the Documentation of Traditional Pohnpei Food Systems, as a collaborative effort with the Centre of Indigenous Peoples’ Nutrition and Environment (CINE), based at McGill University, Canada. Pohnpei was selected as the 12th case study of the global health project, among other countries such as India, Japan, Peru, Columbia, Nigeria, Thailand, and Canada (Kuhnlein et al. 2005). The Mand community in the Madolenihmw municipality of Pohnpei was selected to participate in this project. There are two phases of this project: Phase 1 involves the documentation of the food system, collecting information on the foods available, their nutrient content, acceptability, prices, dietary intake, and other information relevant to a food promotion intervention. Phase 2 then includes the promotion of those foods identified as the most nutrient-rich and likely to contribute to an improvement of the health status. Phase 1 was carried out from May to August 2005, whereas Phase 2 was planned for a 2-year period and was initiated in September 2005.

Conclusions and challenges

This novel approach to presenting carotenoid data was effective in communicating health messages in Micronesia. Some of the challenges include:

- Competing with imported foods that are convenient and low-cost
- Developing simple effective teaching materials
- Acquiring staff, office and facilities (for IFCP)
- Acquiring community input
- Identifying appropriate training for the staff and community
- Maintaining activities initiated
- Creating close partnerships with many agencies
- Identifying funding sources.

A major question has been whether there has been any impact of the local foods promotion program so far. Due to lack of resources for monitoring production and consumption of local foods, there are few data. However, it is known that Karat (banana) was not sold in the markets prior to the 1999 campaign, whereas following the campaign it did appear in Pohnpei markets. Sales of Karat have slowly but steadily been increasing since that time, indicating that this approach is having an impact, but needs further input. Similarly, Taiwang was not sold in the markets prior to the campaign in 2003, but since then it has started to be sold in several markets. In August 2007, data will be collected on the dietary intake and other baseline health indicator data (i.e. fasting blood sugar) of the random sample of participants in the Mand Study. These data will be compared with the baseline data collected in 2005. In this way the project will be evaluated for its success in improving behavioural patterns, dietary intake, and health outcomes in the community of Mand.
Acknowledgements

Agencies and individuals are acknowledged from all three countries: Federated States of Micronesia, Marshall Islands, and Kiribati.

References


Phenolic phytochemicals are abundant micronutrients in our diet. Evidence of their role in the prevention of several degenerative diseases is emerging and has been attributed to their ability to act as antioxidants. However, the health benefits depend on their biological activity, interactions that they may have with each other and with other food components and their bioavailability.

Objective: To employ cell based assays to assess possible health benefits of phytochemicals and fruit extracts containing them.

Methods: Anti-inflammatory activity was measured by the inhibition of production of an inflammatory mediator, tumour necrosis factor-α (TNF-α) from a macrophage cell line (Garcia-Alonso et al. 2004). Protection of cells from oxidative stress induced damage was measured by inhibition of DNA damage and programmed cell death (apoptosis) (Vermes et al. 1995) and used to detect possible synergies between phytochemicals. For bioavailability studies monolayers of CaCo-2 colon carcinoma cells were used (Boyer et al. 2004).

Results: Anti-inflammatory activity was demonstrated in apple extracts by the inhibition of TNF-α production by 47-86%. Combinations of phytochemicals found in apple extracts (e.g. caffeic acid and catechin) acted synergistically to decrease stress-induced apoptosis, suggesting that any nutrient benefit derived may be a reflection of the mix of these compounds present in a particular food or even in the whole meal. *In vitro* bioavailability studies showed that there was low uptake of the phytochemical quercitin into CaCo-2 cells and passage through the cell monolayer to the other side.

Conclusion: It is important to consider the potential interactions and synergies as well as the composition of phenolic phytochemicals in food and their bioavailability when considering their health benefits.

References

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OVERVIEW OF FAT AND FATTY ACID ANALYSIS OF FOODS

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Keywords: Gravimetric methods, gas chromatography, conversion factor, food composition database.

Abstract

Objective: To review and compare methods used in fat and fatty acid analysis of foods and put forward recommendations for future work.

Methods: The methods commonly used in analytical laboratories to measure the level of fat in foods are briefly reviewed to highlight differences in the various gravimetric methods used for different food matrices (Greenfield & Southgate 2003). Fatty acid analysis by gas chromatography is briefly reviewed (Zamora & Hidalgo 2004) followed by a description of the fatty acid conversion factors commonly used when entering fatty acid profiles into food composition databases (McCance & Widdowson 1998). The American Nutrition Labeling and Education Act of 1990 defined fat as the sum of the levels of fatty acids expressed as triglycerides (Carpenter et al. 1993).

Results: Using a gravimetric method for fat determination can result in the incomplete extraction of fat fractions and extraction of non-fat fractions. In addition, the use of fatty acid conversion factors can cause problems resulting in either an overestimation or underestimation of the level of fatty acids. The combination of the disadvantages of gravimetric methods of fat determination and problems associated with the use of conversion factors can thus result in slightly misleading results being entered in food composition databases. However, the use of an internal standard minimizes the disadvantages of gravimetric fat determination methods and reduces the number of assumptions required when using fatty acid conversion factors.

Conclusion/Recommendation: Using an internal standard minimizes the disadvantages of using gravimetric fat determination methods and conversion factors and provides a more accurate reflection of the true fatty acid profile and fat level in food samples.

Introduction

Accurate estimates of the fat content of foods are important in monitoring human health (Anon. 2005, Kris-Etherton et al. 2004). There is therefore a need for accurate, well-defined fat and fatty acid data in food composition databases. There are a number of well established methods for determining fat levels in foods (Carpenter et al. 1993). This paper is not a comprehensive review of the methodology used to measure fat and fatty acid levels in foods, but is based on a summary of several comprehensive reviews (Carpenter et al. 1993, Greenfield & Southgate 2003, Zamora & Hidalgo 2004) and a limited literature survey of supplementary material where necessary. This paper gives an overview of the differences between the various methods, highlighting some of the difficulties encountered with each when applied to particular food matrices.

Fat analysis is briefly discussed as an introduction to the fatty acid conversion factors used by compilers of food composition databases. These factors are required to convert the proportion...
of each fatty acid detected by gas chromatographic analysis to grams of each fatty acid per 100 grams of food. Problems with the use of these factors are outlined.

The use of an internal standard during analysis provides a way of correcting for losses that occur during analysis of fatty acids (Palmquist & Jenkins 2003). It also provides a mechanism for summing the proportion of individual fatty acids to get an independent measure of fat. This approach is mandated by USA food labeling regulations (Carpenter et al. 1993), thus avoiding the potential pitfalls associated with gravimetric methods of fat analysis and the use of fatty acid conversion factors.

**Methodology and discussion**

**Gravimetric fat determination**

Classical methods for measuring the fat level in food typically involved the extraction of fat from a sample by soaking the finely ground sample in an organic solvent. The solvent was then evaporated and the weight of extracted material was defined as the amount of fat in the sample. Typical solvents used to extract lipids include anhydrous diethyl ether, petroleum ether, chloroform methanol mixtures and tetrachloroethylene (Carpenter et al. 1993). All these solvents extract triglycerides, whereas ether extracts simple glycerides, e.g. mono-, di- and triglycerides. These various methodologies are labeled gravimetric methods and can be further subdivided into four general classes, i.e. the use of mixtures of polar solvents, ether extraction, acid hydrolysis, and alkaline pretreatment (Carpenter et al. 1993).

A commonly used method based on using a chloroform:methanol binary solvent mixture for the extraction of fat is the Folch method. This method is applicable to all foods and is the preferred method for performing fatty acid and sterol analysis of food samples (Carpenter et al. 1993, Zamora & Hildalgo 2004). It is also one of the standard methods used for the New Zealand Food Composition Database. Chloroform methanol extraction combines the tissue-penetrating capacity of alcohol with the fat-dissolving power of chloroform (Greenfield & Southgate 2003). Mixtures of more polar solvents (such as chloroform and methanol) extract neutral lipid classes but also extract the more polar lipid classes including phospholipids, sterols, terpenes, waxes, hydrocarbons and other non lipid material. It is generally agreed that in the Folch method (Carpenter et al. 1993, Zamora & Hildalgo 2004):

- total lipid is extracted more completely than other solvents and that the extract can be used for further lipid characterization (e.g. fatty acid analysis);
- cholesterol and sterols are not destroyed in the extraction process;
- the chance of changing the structure of any particular class of lipid is very low.

Because of these characteristics, the Folch method is the preferred method when extracts are being measured for fatty acids and sterols (e.g. cholesterol). The principal drawback of the Folch method is that the ratio of chloroform, methanol and water during extraction is critical for quantitative extraction of fat (Zamora & Hildalgo 2004).

Extraction of food samples using non-polar solvents such as diethyl ether or petroleum ether is also commonly used in food analysis (Greenfield & Southgate 2003, Carpenter et al. 1993). However the use of non-polar solvents restricts the application of these assays to low moisture foods. Depending on the food matrix, a non-polar solvent may not quantitatively extract polar lipids such as phospholipids and free fatty acids (Greenfield & Southgate 2003). In addition, the presence of water-soluble carbohydrates, certain sugars, glycerol, lactic acid and similar materials may interfere with the extraction (Carpenter et al. 1993). It has been reported in the literature that in ether extracts of forage leaves (Palmquist & Jenkins 2003),
40% of the weight of the ether extract is from non-lipid material such as galactose and chlorophyll. The Soxhlet assay is the most commonly used example of this class of extraction. Petroleum ether is often used as it is less flammable than diethyl ether and less likely to form peroxides. When using these types of assays, the analytical portions must be completely dry, and monosaccharides and disaccharides should be removed before the analysis. The extract cannot be used for subsequent fatty acid analysis (Greenfield & Southgate 2003).

Acid hydrolysis of portions of food samples is often used as a pre-treatment before ether or chloroform methanol extraction (Carpenter et al. 1993). This approach is applicable to all food types except dairy and products containing high levels of sugars (Greenfield & Southgate 2003). The acid hydrolysis of the sample assists in the extraction of fat by hydrolyzing protein and polysaccharides and disrupting cell walls. When acid hydrolysis is followed by either extraction method it results in the removal of fat such as neutral lipids from the sample, and also the extraction of non-fat material such as glycerol, low molecular weight carbohydrates (e.g. sugars and their derivatives), amino acids and urea salts. This is a serious problem in low fat products, resulting in higher fat values being reported. The use of acid during the initial stages of the analysis of samples by this method can result in some hydrolysis of lipids occurring. Thus, the extracts cannot be used for fatty acid studies.

Alkaline treatment of food samples is another approach, which is typically used for the analysis of dairy products including cheese. Two commonly used methods based on this approach are the Roese-Gottlieb and Mojonnier methods (Anon. 2002). Both involve the use of ammonium hydroxide to break the fat emulsion, neutralize acid and solubilise protein prior to extraction with ether. Both the Roese-Gottlieb and Mojonnier methods have been sanctioned by the International Dairy Federation for official use for the analysis of dairy samples (Greenfield & Southgate 2003). The Mojonnier method breaks emulsions by centrifugation and uses a mixture of diethyl and petroleum ether, whereas the Roese-Gottlieb method uses only petroleum ether. Both methods only extract neutral lipids so lower fat values may be obtained relative to the chloroform methanol (Folch) method if the food sample contains sizeable proportions of polar lipids. The latest supplement to the official analysis methods published by the American Organization of Analytical Chemists (AOAC) (Anon. 2002) states that the Roese-Gottlieb (AOAC official method 905.02) method was repealed in 2001, and the Mojonnier method was modified (AOAC official method 989.05).

As can be seen, each of the approaches used in the gravimetric measurement of fat in food samples has disadvantages for some sample types. For the majority of samples, the Folch is arguably the best method for fat determination (Carpenter et al. 1993), although it may be necessary to use other methods for specific food types, e.g. the Mojonnier method for dairy products. However, if fatty acid analysis is to be performed on a dairy sample, it is first necessary to carry out a Folch extraction to completely extract all the lipid classes to enable the fatty acid profile to be accurately measured. The choice of method used to measure the fat level in a particular food sample is often prescribed by regulation. If this is not the case, it is possible to follow the recommendations of organisations such as the AOAC (Carpenter et al. 1993, Zamora & Hildalgo 2004). However, considerable care is required when comparing results from different laboratories, particularly if different methods are used, as differences in methodology may have a marked effect on results.

**Fatty acid analysis**

Users of food composition databases are interested in both the level of fat in a food sample and also the level of different types of fatty acids, e.g. saturated, monounsaturated, or polyunsaturated. To produce this information, the levels of all the individual fatty acids are generally determined by performing gas chromatography, although HPLC methods have been
used (Zamora & Hidalgo 2004). HPLC analysis is particularly useful for characterizing the
different lipid classes present in a food sample. It is also capable of separating and
quantifying the different lipid classes, and resolving fatty acids with the same number of
double bonds that differ only in the position of the double bonds.

During the initial stages of fatty acid analysis by gas chromatography the fat extract is
hydrolyzed and the individual fatty acids converted to esters so that they are volatile enough
to be separated by gas chromatography. Generally, methyl esters are used, but butyl and
other esters have also been used (Zamora & Hidalgo 2004). Gas chromatography separates
the fatty acids on the basis of size, degree of unsaturation and also the isomerism of the
double bonds. In natural samples, fatty acids with even numbers of carbons and cis double
bonds are the most common form. However, odd numbered fatty acids can occur at low
levels, and trans isomers can also occur. Trans isomers are particularly important in highly
processed foods.

The end result of fatty acid analysis is a fatty acid profile in which the levels of individual fatty
acids are expressed relative to the total fatty acids measured in the food sample (i.e. gram of
fatty acid per 100 grams total fatty acids). Expressing the results in this way is not particularly
useful to users of nutrient data available in food composition databases.

**Fatty acid conversion factor**

For the results to be practically applicable, they must be converted into units of grams of fatty
acid per 100 g edible portion of the food. As can be seen from examining the chemical
structure of the lipid classes, i.e. triglycerides, phospholipids and glycolipids, fatty acids are
only part of the structure of the individual lipids. In the case of triglycerides, the structure is
composed of a glycerol backbone and three fatty acids linked via ester bonds. Gas
chromatography only measures the proportion of the fatty acids, not the level of glycerol.
Therefore, a means of converting these results to the proportion of fatty acids in each lipid
class is required. In food samples, the fatty acids invariably occur in more than one lipid class.
It is only for samples such as separable fat that close to 100% of the fatty acid occurs in one
class — in this case, triglyceride. For this reason, a number of fatty acid conversion factors
have been formulated. At present, 22 different factors have been derived with the highest
being 0.953 for separable fat (triglyceride) and the lowest 0.67 for wheat, barley and rye flour.
The seventh supplement to the fifth edition of McCance & Widdowson’s The Composition of
Foods (Anon. 1998) lists the 22 conversion factors in common use. Some of these factors
have been in use for almost 30 years (Weihrauch et al. 1977). Table 1 gives a worked
example of the derivation of the conversion factor for egg lipids.

**Table 1. Derivation of conversion factor for egg lipid.**

<table>
<thead>
<tr>
<th>Lipid fraction</th>
<th>Weight % of total lipid</th>
<th>Grams fatty acid/ grams lipid</th>
<th>Gram fatty acids/ grams total lipid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Triglyceride</td>
<td>65</td>
<td>0.956</td>
<td>0.62</td>
</tr>
<tr>
<td>Lecithin</td>
<td>25</td>
<td>0.708</td>
<td>0.17</td>
</tr>
<tr>
<td>Cephalin</td>
<td>6</td>
<td>0.756</td>
<td>0.04</td>
</tr>
<tr>
<td>Cholesterol</td>
<td>5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>0.83</strong></td>
</tr>
</tbody>
</table>

Adapted from Weihrauch et al. 1977.
While fatty acid conversion factors have been in use for some time, caution is needed in using them. The calculation of the conversion factor for egg lipids is relatively simple, but the approach assumes that:

- all sources of egg lipid have an identical distribution of lipid classes;
- all the lipid classes are extracted;
- non-lipid components are not extracted.

A similar set of assumptions is required for the calculation of each of the other 21 fatty acid conversion factors. For some fat assays and/or food samples, one of more of these assumptions could be invalid. In addition, some foods are a mixture of one or more food ingredients so a simple average of the relevant fatty acid conversion factors is not advisable. A more practical approach would be to calculate the weighted mean of the fatty acid conversion factor, or the weighted mean based on the proportion of fat from each ingredient relative to that of total fat in the food sample.

Converting the results of fatty acid analysis to the final results of grams of individual fatty acid per 100 grams of edible portion is a relatively simple exercise. It simply requires multiplication of the measured fat level of the food by the relevant fatty acid conversion factor; the resulting figure is then multiplied further by the proportion of the individual fatty acid measured in the fatty acid profile. However, this procedure is subject to a number of sources of error. If the method used to extract all the fat does not completely extract the entire lipid classes that exist in the food sample, the level of fatty acids reported are lower than the actual value. Similarly, if the method extracts all the lipid classes and also a proportion of non-lipid material, then the reported results for fatty acids are higher than the actual values. Finally, the choice of an inappropriate fatty acid conversion factor can also result in inaccurate fatty acid levels. It is possible to minimize the effect of these confounding factors when analyzing and processing the results for various food samples by ensuring that all lipid classes are extracted quantitatively and the extraction of non-lipid material is minimized. It is also possible to deduce whether interference in the measurement of fat levels in a sample was likely (e.g. high sugar levels in samples tested using ether extraction) by examining the levels of other proximate components (e.g. water, protein, and carbohydrates including sugars). If interference is suspected, the analysis should be repeated using a different methodology. Using these approaches, either individually or in combination, it is possible to minimize the effects of these confounding factors. However, it is not always possible to completely remove these effects for all samples without taking a slightly different approach.

The confounding factors for fatty acid analysis described above are often encountered in the analysis of components. A simple and effective solution is to add a known amount of an internal standard during the analysis and to express the final results in terms of the amount of the internal standard (Palmquist & Jenkins 2003). The advantage of this approach is that it is possible to correct for any losses of fatty acids during the analysis. This approach also removes the confounding effect of non-lipid material being extracted with the fat during the analysis. Finally, there is no need to decide which conversion factor should be used.

The choice of the appropriate internal standard for use in fatty acid analysis is critical to the success of this approach. The ideal internal standard should have the following attributes (Palmquist & Jenkins 2003):

- Pure and able to be added in known amounts to samples;
- Of a similar structure to the components being tested;
- Cheap and readily available commercially.
If the internal standard does not have a similar structure to the components being tested it will be subject to a different level of loss during the analysis, thus defeating the purpose of adding it to the sample. Since the large majority of fatty acids from biological samples typically have even numbers of carbons (due to the method of biosynthesis), the common approach is to use odd-numbered fatty acids as internal standards. A number of fatty acids have been used as internal standards ranging from 11 carbon straight-chain fatty acids in AOAC official method 999.06 (Anon. 2002) through to 23 carbon straight-chain fatty acids (Wang et al. 2000).

To further negate the effect of confounding factors when reporting levels of fatty acids in food samples, USA food labeling regulations state all fatty acids in food in the form of triglycerides. Thus, individual fatty acid levels are reported as triglyceride equivalents (Carpenter et al. 1993). The level of fat in a food sample is then simply the sum of the levels of all the detected fatty acids. It should be noted, however, that the assumption that fatty acids in foods always occur in the form of triglycerides might not be valid for all food samples, e.g. lean meat samples contain sizeable amounts of phospholipids and plant material contains sizeable amounts of glycolipids. However, this assumption is likely to be substantially correct as it has been reported that triglycerides account for 98% of the total fatty acids in commonly consumed foods (Zamora & Hidalgo 2004).

It is possible that the use of internal standards to measure the level of fat in foods and to determine fatty acid profiles will be required by regulatory agencies in other countries for routine use in food nutrition labelling (Greenfield, pers. comm.). It is noteworthy that the majority of fatty acid data in the USA food composition database (Holden, pers. comm.) has not been determined using this approach, despite this being the required approach for nutrition labels and despite some users of the food composition database using the data to formulate food labels.

**Conclusion and recommendation**

Gravimetric methods of fat determination may either underestimate or overestimate fat levels in some food samples. Therefore, care is needed when examining the results of nutrient analyses. While indications of the possible accuracy of fat determination can sometimes be deduced from the level of other proximate components, absolute confidence in the results of gravimetric fat determination methods is not always possible. The use of fatty acid conversion factors to compile fatty acid profile data using fat levels determined by gravimetric methods may also result in misleading data being listed in food composition databases. While it is possible to minimise these errors, it is impossible to completely eliminate them. The use of an internal standard during fatty acid determination minimises the difficulties associated with gravimetric fat determination and the use of fatty acid conversion factors. Although in some cases this approach can result in slight errors for food samples where the principal or major lipid class is not a triglyceride, this effect can be mitigated. The internal standard method can therefore provide a more accurate estimate of the true fatty acid content of foods.

**References**


EFFECT OF LIPID EXTRACTION METHOD ON TOTAL FAT DETERMINATION

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Keywords: Lipid recovery, tissue type, hoki flesh.

Introduction

There are a variety of methods currently used for the determination of total lipid content of foods. Although these methods use different solvent systems and apparatus, most investigators assume that these methods extract the lipid component from foods to an equal degree. Two commonly used techniques are Bligh and Dyer (1959) and Folch (1957). The effects that these two methods have on the total lipid recovery from the flesh and liver tissues of hoki fish (Macruronus novaezelandiae) were analysed and compared.

Method

Fresh tissues were minced in differing proportions of chloroform and methanol as specified in the original publications. The homogenates were filtered, the solvents partitioned, and the lipid extract recovered from the non-polar phase by rotary evaporation. The lipid yield was determined gravimetrically. Extractions were carried out in triplicate.

Results

There was no significant difference between the two methods for total lipid yield from the hoki flesh (Figure 1): Bligh and Dyer (2.0 ± 0.2%), and Folch (2.1 ± 0.1%). However, for recovery of the lipid fraction from hoki liver (Figure 2), the Bligh and Dyer method produced a significantly lower yield than the Folch method (62.5 ± 3.2% and 74.1 ± 2.4% respectively).

Figure 1: Oil yield from hoki flesh.  
Figure 2: Oil yield from hoki liver.
Discussion
Despite both methods using chloroform and methanol for lipid solubilisation and extraction, the two techniques produced significantly different results for total lipid recovery from high-fat tissue samples. The polarity, volume, or order of addition of the solvent systems may have affected the amount of different lipid fractions recovered from the tissue.

Conclusion
It appears that one extraction method is not suitable for all tissue types. Further investigations are being carried out on the effect of lipid extraction methods on lipid classes and fatty acid profile, of high- and low-fat tissues.

Recommendation
It is important to specify the method of lipid extraction used when profiling lipid recovery from tissues. The use of Folch’s method is recommended for high-fat fish tissue due to the higher lipid recovery relative to that from Bligh and Dyer. However, as the method of Bligh and Dyer extracts equally as well as Folch for lean fish tissues but requires a lower volume of solvents, the Bligh and Dyer method is recommended for tissue samples considered to be low-fat.

References
TRANS FATTY ACIDS IN AUSTRALIAN AND NEW ZEALAND FOODS WITH SPECIAL REFERENCE TO NUTRITIONAL LABELLING

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Keywords: hydrogenation, isomers, cardiovascular disease, food regulation, food industry.

Abstract

Trans fatty acids (TFA) are found in various levels in a wide range of food products. This paper reports typical levels found in an analysis of over 500 food samples. Considering the data and their physiological significance outlined in various studies it is suggested that TFA level be included in the FSANZ mandatory requirements of nutritional labelling.

Food prepared in partially hydrogenated vegetable oils or shortening such as commercially baked products and fast foods are most likely to contain high levels of TFA. Some of the unsaturated fatty acids ingested by ruminants are partially hydrogenated by enteric bacteria. In consequence, milk fat, dairy products and beef and mutton fat also contain cis and trans isomers of fatty acids. Trans fatty acids are also formed during heating and frying of oils at high temperature. Small amounts of TFA are also present in poultry and pork fat, derived from feeds.

The health hazards of saturated fatty acids in products such as lard, palm oil, and butter are well recognised. Therefore, manufacturers started to use less saturated/unsaturated vegetable oils for food production. As liquid vegetable oils are not stable to heat and can go rancid easily, scientists began to hydrogenate liquid oils so that they can withstand food production processes better and provide better flavour and shelf life. This in turn led to concerns about the TFA content of these hydrogenated products.

Labelling of TFA became mandatory in Canada in January 2003. The US Food & Drug Administration published a final rule, which will take effect in January 2006. Such labelling in Australia and New Zealand is not mandatory unless a special nutritional claim is made to the related area.

Introduction

Trans fatty acids (TFA) are unsaturated fatty acids that have at least one double bond in the trans configuration. Most of the unsaturated sites in natural fats and oils from animal and plant origin are in cis form. Cis and trans isomers are geometric isomers that differ only in the position of atoms relative to a specific plane.

![Figure 1: Carbon bond in saturated, cis-unsaturated, and trans-unsaturated fatty acids.](image-url)
The health hazards of saturated fatty acids are well recognised. Therefore, manufacturers started to use less saturated/unsaturated vegetable oils in their food production. As liquid vegetable oils are not stable to heat and go rancid easily, industry began to hydrogenate the oil to withstand food production processes and provide better flavour and shelf life. As a result of this hydrogenation, TFA are produced. Other sources of TFA include deodorisation of vegetable/fish oil (an essential step in refinement), heating and frying of oils at high temperature, TFA derived from feeds in poultry and pork fat, and bacterial transformation of unsaturated fatty acids in ruminants (e.g. milk and dairy products, beef and mutton).

Hydrogenation produces up to 50% TFA in total fat in partially hydrogenated vegetable oil (PHVO), whereas refining vegetable or fish oil produces ~3% TFA of total fat (Fritsche & Steinhart 1997). Ruminant fat generally contains 1 to 8% TFA of total fat (Wolff et al. 1998). C18:1 TFA represent over 80% and 90% of total trans in ruminant fats and PHVO respectively (Wolff & Precht 2002). C18:1 11t (vaccenic acid) accounts for 30 to 50% of total TFA in ruminants compared with C18:1 9t (elaidic acid) 20 to 30% and C18:1 11t 10 to 20% of total TFA in PHVO (EFSA 2004).

Conjugated linolenic acid (CLA) represents 0.5 to 2% of fatty acids in meat and dairy products (Lin et al. 1995). CLA has one cis and one trans double bond separated by a single bond. CLA has anti-carcinogenic and other beneficial physiological effects such as reduction of body fat, improved immune response etc. (EFSA 2004). C18:2 9c, 11t is the major (70 to 80%) CLA isomer in meat and dairy products (Angel 2004).

**Physiological significance of trans MUFA (c18:1)**

In most of the human intervention studies, trans monounsaturated fatty acid (MUFA) especially C18:1 from PHVO, were evaluated. One of the first controlled human intervention studies that specifically examined the effects of trans MUFA from PHVO on serum lipoprotein profile was that of Mensink & Katan (1990). The study concluded that trans MUFA significantly raised the LDL cholesterol or “bad” cholesterol (LDL-C) and lowered HDL cholesterol or “good” cholesterol (HDL-C) as compared with an iso-energetic amount of oleic acid. Despite the clear results, this study was criticised as the amount of trans MUFA employed (11% total energy) by far exceeded habitual intakes. However, Mensink et al. (2003b) estimated that increasing the intake of trans MUFA with 1% of energy at the expense of carbohydrates significantly increased serum LDL-C, while HDL-C did not change significantly. Mauger et al. (2003) found that trans MUFA decreased LDL particle size. Small dense LDL is positively related with the risk of cardiovascular disease (CVD) (Kraus 2001).

Under isoenergetic conditions, the effects of trans MUFA on fasting triacylglycerol (TAG) concentrations are similar to those of a mixture of carbohydrates (Mensink et al. 2003), while other fatty acids lower fasting TAG levels. An increased concentration of fasting TAG is positively associated with the risk of cardiovascular disease (Hokanson & Austin 1996).

A diet high in TFA may also pose a higher risk of type 2 diabetes and various other disorders, although in July 2004 the European Food Safety Authority report (EFSA 2004) on the effect on human health of the consumption of TFA concluded that “Epidemiological evidence for a possible relationship of TFA intake with cancer, type 2 diabetes or allergy is weak or inconsistent.”

**Methodology**

Samples were received at AgriQuality, Auckland Laboratory from various New Zealand and Australian customers. They were analysed as per the customer request. The analysis was done by GLC-FID using a BPX 70 capillary column (AOCS 2003).
Results and discussion

A total of 20 samples each of butter and cheese tested for TFA levels were found to have had 5.4 ± 0.1% m/m and 0.4 ± 0.1% m/m, respectively, on sample basis. Of 52 samples of milk powders tested, 71% had <0.1% m/m and the remaining 39% had 1.4 ± 0.4% m/m on a sample basis. Most of the powders tested are either premixes or formulations and are most likely defatted and blended. However these results are in agreement with most of the published results on TFA in dairy products (Wolff et al. 1998).

Of 16 meat (beef and mutton) samples tested for TFA, 56% had 6.3 ± 0.9% m/m and the remaining 44% had slightly higher TFA levels of 10.3 ± 1.6% m/m calculated on a total fat basis. A major source of this TFA could be ruminant bacterial conversion of unsaturated fatty acids in the rumen. Fifty-six percent of 34 fish samples tested recorded <0.1% m/m and the remaining 44% had 3.5 ± 2.9% m/m on total fat basis.

A total of 218 vegetable oil or PHVO samples were tested for TFA levels. Seventy-one percent of the samples recorded <0.1% m/m, whereas the remaining 29% of the samples had TFA levels ranging from 0.4% m/m to 29.7% m/m. The samples with higher TFA levels were more solid in physical appearance, which may be an indication of degree of hydrogenation.

Table 1: TFA levels in a total of 218 oil / PHVO samples tested.

<table>
<thead>
<tr>
<th>Number of oil / PHVO samples tested for TFA</th>
<th>Percentage of the total number of samples</th>
<th>TFA levels (% m/m)</th>
<th>Mean ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>159</td>
<td>71</td>
<td>&lt;0.1</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>5</td>
<td>0.4 ± 0.1</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>4</td>
<td>1.3 ± 0.4</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>3</td>
<td>3.4 ± 0.7</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>10</td>
<td>4.9 ± 0.5</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>4</td>
<td>8.9 ± 2.5</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>3</td>
<td>29.7 ± 2.0</td>
<td></td>
</tr>
</tbody>
</table>

Of 138 prepared food samples analysed for TFA, 86% had <0.1% m/m and the remaining 14% have had from 0.2% m/m to 9.9% m/m calculated on a sample basis (Table 2). The samples are ready to eat and are similar to those available in Australia and New Zealand markets.

Table 2: TFA levels (on sample basis) in a total of 139 food samples tested.

<table>
<thead>
<tr>
<th>Number of food samples tested for TFA</th>
<th>Percentage of the total number of samples</th>
<th>TFA levels (% m/m)</th>
<th>Mean ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>119</td>
<td>86</td>
<td>&lt;0.1</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>9</td>
<td>0.2 ± 0.1</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>4</td>
<td>0.4 ± 0.2</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>9.9</td>
<td></td>
</tr>
</tbody>
</table>

Conclusion

The combined result of metabolic and epidemiological studies strongly support an adverse effect of TFA on the risk of coronary heart disease (EFSA 2004). Few studies have shown that the dual effect of TFA (increasing LDL-C and decreasing HDL-C) is greater than that caused by saturated fatty acids (Mensink & Katan 1990). This is especially significant in New Zealand, where four out of every ten deaths are caused by CVD, of which coronary heart
disease (CHD) accounts for more than 23% (Ministry of Health, New Zealand FAQ Release 2004).

A diet high in TFA may also pose a high risk of type-2 diabetes, cancer and allergy, although epidemiological evidence for this is weak or inconsistent (EFSA 2004).

In the present study, 24% of oil or PHVO samples had from 1% to 30% of TFA and 13% of prepared food samples had 0.2 to 0.4% TFA calculated on a sample basis. In all the samples analysed the major components of TFA were C18:1 9t, C18:1 11t, C18:2t and C16:1t. The C18:1 9t and C18:1 11t are the major components in PHVO and dairy products (Wolff & Precht 2002). The samples are tested to meet specific customer requirements under current labelling regulations: heart foundation tick, specific claim with respect to TFA, cholesterol, mono- or polyunsaturated fatty acids, omega fatty acids, or to meet importing countries requirements or overseas market access requirements on TFA. Hence the samples analysed may not be representative of either PHVO or food products in the Australian or New Zealand market. Moreover, TFA is present and has been reported in many studies in fast foods and deep-fried items (IFST 2004). Most of these products are outside the labelling regulation.

Saturated fat content is mandatory as per current FSANZ labelling regulation, thereby providing an incentive to manufacturers to increase the TFA while decreasing the saturated fatty acids (SFA) level. Most baked goods and fried fast foods are still made in PHVO and are high in TFA. It is unlikely that this situation will change without strong FSANZ regulation. TFA labelling will allow consumers to choose a more beneficial diet and help them to place individual food selection within the context of their total diet. This is especially useful to consumers who select certain foods because they contain “low” or “reduced” levels of SFA and are likely to assume that the product does not contain other components that may adversely affect LDL-C. Consumer knowledge about TFA compared with SFA is low. Labelling could bring more awareness and consumer education of its potential health effects.

TFA levels can be reduced from the food supply by changes in processing, consumer education and behavioural modification. Behavioural changes include mainly eating more unprocessed foods, fruits and vegetables. New technologies for TFA-free and low-SFA products for food processing developed in European markets have been and could provide a feasible solution (Katan 1995). Reduction of TFA can be achieved by modifying the process of hydrogenation and raising the melting point by interesterification. Complete hydrogenation of a small portion of the oil, which provides a matrix for the unhydrogenated greater part, results in the desired physical properties with much lower TFA.

Labelling of TFA became mandatory in Canada in January 2003. The US FDA published a final rule, which will take effect on January 2006. The European Union and other countries have gone a long way towards implementing similar regulations. It may be suggested that TFA labelling should be a mandatory requirement in Australia and New Zealand.

Acknowledgements

We would like to thank AgriQuality management and staff, especially the Chemistry Team, for their support and suggestions for this work.

References


EFSA Journal 2004: European Food Safety Authority Journal 81: 1-49. Food Standards
Australia and New Zealand 1.2.8 (Nutrition).


CLOSING REMARKS

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At this, the conclusion of the 7th OCEANIAFOODS conference I would like to thank you all for participating in this meeting. I hope you have found this conference informative and beneficial for your food composition work and I look forward to seeing you all at future Oceaniafoods meetings.

My appreciation goes to our speakers for their insights into their research work. Without any doubt, they have enlightened us and maintained our concentration.

I would particularly like to express my gratitude to Professor Heather Greenfield from the University of NSW, for providing leadership in the challenging role of chairing the scientific review committee. She ensured all abstracts were reviewed professionally and on time. Her job’s not finished yet; Professor Greenfield has graciously agreed to play a key role in the preparation of conference Proceedings for publication.

I would like to acknowledge my food composition team at Crop & Food Research for their support and patience. Special thanks go to Jo Skinner who has been a great support in organising this conference.

Finally, I would like to thank all our sponsors for their generous support. Also, I wish to acknowledge the generous support of the Ministry of Health for funding two fellowship grants so students could present their research work.

To conclude, for those who are staying I wish you well and those of you returning home tonight and tomorrow have a safe journey.
# REPORT ON THE RECOMMENDATIONS AND RESOLUTIONS FROM THE 6th OCEANIAFOODS CONFERENCE

<table>
<thead>
<tr>
<th>Recommendation/resolution</th>
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<tbody>
<tr>
<td>Administration</td>
<td></td>
<td></td>
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<tr>
<td>1 New Zealand will be appointed as Convener of OCEANIAFOODS until the 7th OCEANIAFOODS Conference.</td>
<td>Convener</td>
<td>Completed</td>
</tr>
<tr>
<td>2 The OCEANIAFOODS conference will be held in New Zealand in 2004.</td>
<td>Convener</td>
<td>Meeting held in Wellington, New Zealand in April 2005</td>
</tr>
<tr>
<td>3 Articles in the proceedings of the 6th OCEANIAFOODS Conference will be submitted to CAB Abstracts and reviews and to appropriate newsletters. Authors to provide abstracts of their presentations to Judy Cunningham, the Convener of the 6th Conference.</td>
<td>Judy Cunningham, authors</td>
<td>-</td>
</tr>
<tr>
<td>4 The Proceedings of the 6th Conference will be submitted to the Journal of Food Composition and Analysis for review as a book review along with précis of the proceedings. Authors to provide full text versions of their presentations in a format suitable for publication.</td>
<td>Judy Cunningham, authors</td>
<td>It hasn’t happened and there is no capacity in the foreseeable future to do it.</td>
</tr>
<tr>
<td>5 FAO to elaborate its existing OCEANIAFOODS webpage and link it to appropriate sites of member countries and of the Secretariat of the Pacific Community. Members to provide information on appropriate links to Barbara Burlingame.</td>
<td>Barbara Burlingame, all members</td>
<td>Ongoing</td>
</tr>
<tr>
<td>6 OCEANIAFOODS members should subscribe to the INFOODS list serve via the FAO website, and should advise INFOODS of relevant publications and activities.</td>
<td>All members</td>
<td>Ongoing</td>
</tr>
<tr>
<td>7 FAO to investigate holding a postgraduate three-week course in food composition in the Oceania region, possibly in 2003.</td>
<td>FAO</td>
<td>Heather Greenfield and Bill Aalbersberg have agreed to investigate this in association with the next meeting, to be hosted by South Pacific.</td>
</tr>
<tr>
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<tr>
<td><strong>Technical issues</strong></td>
<td></td>
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<tr>
<td>8 Information on forthcoming meetings and on sources of expertise for food analysis and training should be referred to INFOODS for inclusion on the INFOODS website. This information should also be shared directly among OCEANIAFOODS members</td>
<td>All members to share relevant information as appropriate. Jayashree Arcot to assist with holding relevant information</td>
<td>Information about the forthcoming meeting was conveyed to INFOODS for inclusion on the INFOODS website. This information was also shared directly among OCEANIAFOODS members.</td>
</tr>
<tr>
<td>9 OCEANIAFOODS laboratories developing new analyses are encouraged to facilitate testing of these methods by other laboratories</td>
<td></td>
<td>Ongoing</td>
</tr>
<tr>
<td>10 In-house standards, and any listings of available reference materials should be shared among the three analysis programs and ASEANFOODS for analysis and comparison. The AOAC Technical Committee on reference materials is doing relevant work in this area. (Further to this resolution, Dr Scheelings has subsequently requested delegates to provide information to him on reference materials used in their laboratories).</td>
<td></td>
<td>No progress</td>
</tr>
<tr>
<td>11 OCEANIAFOODS members should explore a common description for indicators of quality for food composition data.</td>
<td></td>
<td>New Zealand has developed a set of quality indicators and will start using as a part of their new database management system.</td>
</tr>
<tr>
<td><strong>Food composition table issues</strong></td>
<td></td>
<td></td>
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<tr>
<td>12 The Secretariat of the pacific Community should coordinate a study of the current use of the Pacific Island Food Composition Tables (PIFCT) in the pacific and an analysis of future needs in this area, and to seek funding for a regional follow-up to the 1994 launch of PIFCTs.</td>
<td></td>
<td>Done</td>
</tr>
<tr>
<td>13 The second edition of the PIFCTS should be prepared and include a review of niacin values.</td>
<td></td>
<td>Done</td>
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<tr>
<td>14 OCEANIAFOODS members should explore effective ways to make existing food composition data more accessible to the general public (e.g. bar graphs by nutrient in relation to certain diseases).</td>
<td></td>
<td>No progress</td>
</tr>
<tr>
<td>15 OCEANIAFOODS recognises the importance of education about the use of food composition tables, for example to assist with labelling of packages food.</td>
<td></td>
<td>Ongoing</td>
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<tr>
<td>16 OCEANIAFOODS recognises the wide variety of cultivars of traditional Pacific Island food crops, including fruits, root crops and starchy staples, and the wide variation that is found in important nutrients. This should be reflected in food composition tables (e.g. by reference of edible flesh to degree of orange/yellow coloration) and in education programs.</td>
<td></td>
<td>Ongoing</td>
</tr>
<tr>
<td>17 OCEANIAFOODS members should investigate the possibility and necessary harmonisation of combining the three major OCEANIAFOODS food tables and software, recognising that work in this area has already taken place between the PIFCTs and New Zealand tables.</td>
<td></td>
<td>This recommendation needs to be reworded: “OCEANIAFOODS members should investigate opportunities to harmonise aspects of the three major OCEANIAFOODS food tables and software, recognising that work in this area has already taken place between the PIFCTs and New Zealand tables.”</td>
</tr>
<tr>
<td>18 All food composition-related publications by OCEANIAFOODS members should be shared with other appropriate OCEANIAFOODS members.</td>
<td></td>
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**General resolutions**

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<td>19 OCEANIAFOODS recognises the University of the South Pacific (USP) laboratory as regional centre of excellence for Pacific Island food composition analysis and strongly recommends continued support for it from FAO and other development partners in its continued analysis of priority Pacific foods and, further, to assist other Pacific Island countries to set up and undertake food composition analysis.</td>
<td></td>
<td>Done</td>
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</tbody>
</table>
20 OCEANIAFOODS supports ongoing efforts to facilitate the involvement of the University of Technology in Papua New Guinea in food composition activities, including participation in future OCEANIAFOODS meetings.

21 New Zealand and Australia, wherever possible, will continue to facilitate the provision of assistance for food composition analysis to Pacific Island countries.

22 OCEANIAFOODS strongly supports the continuation of the beneficial collaboration with ASEANFOODS.

23 OCEANIAFOODS members should continue to explore collaboration with the University of Hawaii and with other groups in the Pacific region.

24 OCEANIAFOODS recognises that many traditional Pacific Island food crops are important culturally and are important sources of key nutrients. Promotion/production of these foods should be supported in preference to imported products.

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<td>20 OCEANIAFOODS supports ongoing efforts to facilitate the involvement of the University of Technology in Papua New Guinea in food composition activities, including participation in future OCEANIAFOODS meetings.</td>
<td></td>
<td>No progress</td>
</tr>
<tr>
<td>21 New Zealand and Australia, wherever possible, will continue to facilitate the provision of assistance for food composition analysis to Pacific Island countries.</td>
<td></td>
<td>Reworded to clarify “laboratories in Australia and New Zealand are encouraged to facilitate provision of assistance etc”. FSANZ and CFR are certainly not in a position to do anything in this regard. However, there has been good proactive assistance with UNSW for folate analysis and also QHSS to some degree, less with NZ.</td>
</tr>
<tr>
<td>22 OCEANIAFOODS strongly supports the continuation of the beneficial collaboration with ASEANFOODS.</td>
<td></td>
<td>New Zealand has been participating in the interlaboratory trials initiated by Prapasari in Thailand.</td>
</tr>
<tr>
<td>23 OCEANIAFOODS members should continue to explore collaboration with the University of Hawaii and with other groups in the Pacific region.</td>
<td></td>
<td>Dr Suzanne Murphy attended the 7th OCEANIAFOODS meeting. Bill Aalbersberg visited University of Hawaii. A number of collaborative initiatives were developed with Suzanne’s staff but not funded yet. Bill and Lois presented their work in session on the ‘Unique Foods of the Pacific at the US Nutrient Databank Conference held in September 2006 in Hawaii.</td>
</tr>
<tr>
<td>24 OCEANIAFOODS recognises that many traditional Pacific Island food crops are important culturally and are important sources of key nutrients. Promotion/production of these foods should be supported in preference to imported products.</td>
<td></td>
<td>Upon reviewing this recommendation, we feel it is really outside our remit because it covers issues associated with trade, development, environment.</td>
</tr>
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<tr>
<td>25 OCEANIAFOODS should liaise with UN agencies and regional organisations to encourage the consideration of food composition in relevant national projects and programs in the pacific region, such as supply of agricultural statistics to FAO, food balance sheets, agriculture research and extension, nutrition programs and food legislation.</td>
<td>No progress</td>
<td></td>
</tr>
<tr>
<td>26 Members of OCEANIAFOODS should be supported in efforts to attend the 5th International Food Data Systems meeting to be held in Washington DC in 2003 in conjunction with the National Nutrient Databank Conference.</td>
<td>Done</td>
<td></td>
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<tr>
<td>27 FAO should facilitate provision of relevant Codex documents to OCEANIAFOODS members.</td>
<td>No progress</td>
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</tr>
<tr>
<td>28 OCEANIAFOODS appreciates the attendance of UN agencies at this meeting and strongly supports their continued involvement in OCEANIAFOODS.</td>
<td>Ongoing</td>
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This list only includes the names of those participants who have agreed to name disclosure, and was current at the time of printing.
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This list only includes the names of those participants who have agreed to name disclosure, and was current at the time of printing.
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