Chapter 27
The First Total Diet Study in Fiji

William Aalbersberg

Introduction

The University of the South Pacific (USP) serves its 12 member countries of Solomon Islands, Vanuatu, Fiji, Marshall Islands, Tuvalu, Kiribati, Cook Islands, Tonga, Samoa, Nauru, Niue and Tokelau. The laboratory at its Institute of Applied Sciences (IAS) is one of the best equipped in this region. In 1986, the need for nutrient composition of locally produced and imported foods was identified as an analytical priority at a regional meeting and during the next decade, a food nutrient laboratory was developed at IAS and over 100 local foods were analyzed. These data were incorporated into an extensive Pacific Island Food Composition Table published in 1994. Follow-up workshops identified possible improvements in these tables and a Food and Agriculture Organization of the United Nations (FAO) technical cooperation project from 2002 to 2004 was funded by IAS to make these improvements, publish a second edition of the Pacific Island Food Composition Tables [1], and prepare for international accreditation of the nutrient laboratory. Support was also provided to further develop the food contaminant capability, especially heavy metals and pesticides, of the IAS laboratory. The IAS laboratory achieved international accreditation through *International Accreditation New Zealand* in 2004.

As Fiji has long developed annual national food balance sheets with FAO and through its National Food and Nutrition Centre conducts a national nutritional survey every 10 years that in 2004 included food consumption data, it was felt that it was possible to conduct a total diet study (TDS) for Fiji. In 2005, this became possible with support from the New Zealand Agency for International Development.

W. Aalbersberg, Ph.D. (✉)
Institute of Applied Science, University of the South Pacific, Laucala Bay Road, Suva, Fiji
e-mail: aalbersberg@usp.ac.fj

G.G. Moy and R.W. Vannoort (eds.), *Total Diet Studies*, DOI 10.1007/978-1-4419-7689-5_27,

Background

Indigenous Fijians, like most Pacific Islanders, have a traditional diet based on starchy staples, e.g. taro, cassava, sweet potatoes, yams, and breadfruit, combined with fish and edible greens, such as taro leaves, often cooked in coconut milk. Wild nuts and fruits supplement this basic diet. This diet, however, has been changing as people consume more easily prepared foods, such as rice, wheat, instant noodles and pulses. Thus an increasing amount of food is being imported. In Fiji there is also a significant population (36 %) of Indian origin, who have maintained typical food consumption patterns of rice, wheat, pulses, vegetables and milk products with some meat consumed by nonvegetarians.

The minimal industrial development in Fiji is localized to a few main urban centers. As a volcanic island, significant amounts of heavy metals, such as cadmium, occur naturally in the soil. Agriculture is mainly for subsistence reasons with little use of insecticides, but occasional use of herbicides for weed control. Commercial vegetable farmers do use pesticides and in some cases, it is suspected the required waiting period is not observed before marketing. The import of chlorinated pesticides, such as DDT, has been banned for some years.

For the first Fiji TDS, it was decided to include four heavy metals and pesticides already analyzed by the IAS laboratory (organochlorine and organophosphate screening methods). As a local issue, iron was also analyzed, as anemia is a major health problem in Fiji. It is recognized that there are additional contaminants, such as mycotoxins and ciguatoxins, which are likely to be present in a limited range of Fiji foods but potentially in high concentrations.

Approach

As New Zealand has a long history of conducting TDSs, the manager of these studies, Dr. Richard Vannoort, was engaged as a project adviser. Discussions were held with him as to the tasks to be undertaken, including protocols for:

- Selection of food groups and foods
- Sample collection
- Food handling and preparation
- Analyses

In addition, it was agreed that for some key foods, analyses would be carried out in an accredited New Zealand laboratory (Hill Laboratories) as well as the IAS laboratory, as a quality assurance measure. The lower detection limits in the New Zealand laboratory would also decrease the uncertainty in exposure estimates associated with assigning a default value, i.e. half of the limit of detection (LOD), to food group composites for samples in which no analyte was detected, often referred to as “non-detect”. For each step of the process, all key activities to be undertaken were detailed in a TDS protocol document to help ensure proscribed actions were followed.

Methodology

The general approach taken was to divide all foods consumed into 11 groups, e.g. grains, root crops, oils, vegetables, etc. Meats were further divided into poultry and red meat. The most commonly eaten components of each group were collected and either analyzed separately, if they were thought to be a major dietary contributor, or made into a food group composite sample, which was analyzed to represent the level of the chemicals of interest in that food group. A list of food groups and component foods is given in Table 27.1. The chemical concentration of each group was determined from the laboratory and then multiplied by the estimated weekly consumption to give the weekly exposure of the chemical of interest in that food group. These group results were then summed to give the total weekly exposure.

In addition to the four heavy metals and iron, thirteen organochlorine and five organophosphate pesticides that could be detected by general screening methods were also included. Atomic absorption spectroscopy was used for metal determination and gas chromatography for pesticides at IAS, and inductively coupled plasma mass spectrometry for metals in the New Zealand laboratory.

Fiji annually prepares a Food Balance Sheet for submission to FAO. For commercial crops and fish, annual production data are collected as well as imports and exports. From this, the amount of the food consumed (after subtracting wastage) can be estimated for the year which, divided by 365 days and the population of Fiji, gives the per capita daily consumption. Unfortunately, noncommercial crops are not included. In 2004, Fiji had also completed a major National Nutritional Survey in which a large sample population was asked the frequency of consumption of a wide selection of foods. This provided the approximate number of times in a week a certain item was consumed but the amount still needed to be estimated. Average serving sizes are fairly well established but it was not clear if a frequency meant a full portion or less (for instance, adding milk to tea as opposed to a glass of milk). Another problem was estimating the composition of mixed foods. For some foods, data from main Fiji producers were obtained. Estimates were made using both Food Balance Sheet and National Nutrition Survey data. In some cases, like root crop consumption, the two methods gave similar results but for other foods less so. In general Food Balance Sheet data were more useful.

Foods in the Fiji TDS were purchased from retail outlets. In general several samples of a given food were collected and composited to allow for individual variation. For locally grown foods (called regional foods) collections were made in both Suva (eastern side of main island) and Lautoka (western side of main island) in the winter and summer seasons. The seasonal (warm and cool season) collections of regional foods were analyzed as a composite of the Suva and Lautoka collection but separate reserve samples were kept so that regional differences could be assessed. A sampling and analysis plan was developed and documented. All foods were brought to the laboratory and prepared ready for consumption before analysis.

For economic reasons, considerable compositing of samples was undertaken. For each food a composite was made incorporating equal amounts of all collections of that food. Where a food group was suspected to have a small amount of analyte,

Table 27.1 Food groups included in the Fiji total diet study

G	*Grains*	
	1	Grains, wheat flour
	2	Grains, rice
N	*Nuts*	
	3	Peanuts
	4	Ivi nuts
M	*Poultry and meats*	
	5	Poultry, chicken whole
	6	Poultry, eggs
	7	Meat, corned beef and mutton
	8	Meat, beef cuts
S	*Seafood*	
	9	Fish, tinned mackerel
	10	Fish, tinned tuna
	11	Fish, reef fish
	12	Fish, shellfish
B	*Beverages*	
	13	Beverage, beer
	14	Beverage, bottled water
	15	Beverage, tap water
	16	Beverage, well water
	17	Beverage, tank water
	18	Beverage, kava
O	*Oil*	
	19	Oil, soya bean
	20	Oil, canola
	21	Oil, ghee
	22	Oil, coconut cream
D	*Dairy products*	
	23	Dairy products, milk
	24	Dairy products, butter
	25	Dairy products, ice cream
R	*Root crops*	
	26	Roots, taro (dalo)
	27	Roots, cassava
F	*Fruits*	
	28	Fruits, pawpaw
	29	Fruits, bananas
	30	Fruits, pineapples
L	*Legumes*	
	31	Legumes, beans
	32	Legumes, split peas
V	*Vegetables*	
	33	Vegetables, taro leaves
	34	Vegetables, cabbages
	35	Vegetables, bhaji (Amaranth sp.)

a "group composite" was made by combining equal amounts of the individual food composites from that group.

Depending on the level of consumption and the expected contaminant concentration, some foods were analyzed individually, or the component foods of a given food group were composited before analysis. Key samples were sent to Hill Laboratories in New Zealand for heavy metal analysis and the results compared with those obtained by the IAS laboratory at the University of the South Pacific.

In the Fiji TDS, a large number of samples had contaminant levels below the limit of detection. For calculation purposes, the pragmatic practice is to use half the detection level as the "average" likely value for such samples in determining mean concentrations for use in subsequent exposure estimates. With more advanced analytical equipment available in Hill Laboratories, detection levels were sometimes one tenth of those at the IAS so more accurate calculations could be made for such "non-detect" samples. Calculations using the Hill data and USP data were in good agreement. The presence of "non-detects" suggests that besides the use of 50 % of the detection level in calculations, a range should also be given with the lower end of the range assuming the level is zero and the upper bound using the detection level itself.

Results

Exposures are normally expressed on a per body weight (bw) basis which for an adult in Fiji has been taken as 75 kg. The summary of the results is given below in Tables 27.2 and 27.3. Results are also expressed as percentage of the PTWI (Provisional Tolerable Weekly Intake) for heavy metals established by the World Health Organization (WHO), namely 25 μg/kg bw for lead [2], 7 μg/kg bw for cadmium [3] and 1.6 μg/kg bw for methylmercury [4] and 4 μg/kg bw for inorganic mercury [5]. For inorganic arsenic, WHO established a BMDL 0.5 (Benchmark Dose Lower Confidence Limit) for a 0.5 % increased incidence of lung cancer was determined from epidemiological studies to be 3.0 μg/kg bw/day (3–7 μg/kg bw/day based on the range of estimated total dietary exposure) [5]. A range of assumptions were used to estimate the total dietary exposure to inorganic arsenic from drinking water and food. However, for organoarsenic, which is the predominant form in marine products, WHO has noted that intakes of about 50 μg/kg bw/week did not appear to cause any health effects in populations so exposed. For iron, the situation is complex given the low and variable bioavailability of iron and the special needs of premenopausal and pregnant women. Recommended Dietary Allowances range from 8 mg/day for men, 18 mg/day for women of childbearing age and up to 27 mg/day for pregnant women [6].

Only one food had detectable levels of pesticides and so calculations were not done on pesticide intakes.

Table 27.4 compares the results obtained for samples collected in the summer and winter months.

Table 27.2 Dietary exposure to heavy metals and iron and comparison with corresponding health reference values

	Health reference value (HRV)	Fiji lab	% HRV	NZ lab	% HRV
Arsenic (total) (μg/kg bw/week)	50	45.6 (40.4–50.9)	91 % (81–102 %)	56.8 (56.5–57.7)	114 % (113–115 %)
Cadmium	7	1.17 (1.01–1.35)	17 % (14–19 %)	1.15 (1.13–1.17)	16 % (16–17 %)
Mercury (total)	5	1.25 (0.02–1.88)	25 % (12–38 %)	0.85 (0.57–1.15)	17 % (11–23 %)
Lead	25	3.2 (0.93–5.5)	13 % (4–22 %)	1.9 (1.6–2.0)	8 % (7–8 %)
Iron (mg/week)	56–350	135	NA	–	–

Table 27.3 Heavy metals and iron in the food groups in warm season (mg/kg)

		As	Cd	Hg	Pb	Fe
Grains (G1)	Fiji	0.112 (0.094–0.130)	0.015	0.011 (0–0.022)	0.032 (0–0.064)	17.29
	NZ	0.063 (0.057-0.120)	0.013	0.007 (0–0.014)	0.010 (0.004–0.016)	–
Nuts (G2)	Fiji	0.0015 (0–0.003)	0.0034 (0.003–0.0035)	0.0005 (0–0.001)	0.0015 (0–0.0030)	11.40
	NZ	0.0004 (0.0002–0.0004)	0.0031 (0.003–0.0032)	0.0003 (0–0.0006)	0.0001 (0.00004–0.0001)	–
Meat (poultry) ($G3_a$)	Fiji	0.0196	0.0008 (0–0.0016)	0.0033 (0–0.0066)	0.0049 (0–0.0098)	4.60
	NZ	0.024	0.0002	0.0008	0.003	–
Meat (red) ($G3_b$)	Fiji	0.0055 (0–0.011)	0.0009 (0–0.0018)	0.0037 (0–0.0074)	0.0055 (0–0.011)	11.62
	NZ	0.0030	0.0013	0.0004 (0–0.0008)	0.0030	–
Seafood (G4)	Fiji	2.898	0.0103 (0.010–0.0143)	0.0462	0.031 (0.021–0.041)	17.41
	NZ	4.018	0.0204	0.0417	0.0145	–
Beverages (G5)	Fiji	0.307 (0–0.614)	0.0328	0.0031 (0–0.0062)	0.0862 (0.0442–0.128)	39.64
	NZ	0.103	0.0327	0.0041 (0–0.0810)	0.0724	–
Oils (G6)	Fiji	0.0169 (0–0.0338)	0.0028 (0–0.0056)	0.0056 (0–0.0112)	0.0169 (0–0.0338)	3.54
	NZ	0.0056 (0–0.0112)	0.0012 (0–0.0025)	0.0056 (0–0.0112)	0.0056 (0–0.0112)	–

(continued)

Table 27.3 (continued)

		As	Cd	Hg	Pb	Fe
Dairy products (G7)	Fiji	0.006 (0–0.012)	0.001 (0–0.002)	0.0020 (0–0.004)	0.006 (0–0.012)	0.087
	NZ	0.0002 (0–0.0004)	0.0001 (0–0.0002)	0.0002 (0–0.0004)	0.0002 (0–0.0004)	–
Root crops (G8)	Fiji	0.0299 (0–0.0598)	0.0050 (0–0.01)	0.0099 (0–0.0198)	0.0298 (0–0.0596)	7.996
	NZ	0.0102 (0–0.0204)	0.0100	0.0020 (0–0.004)	0.0163	–
Fruits (G9)	Fiji	0.004 (0–0.008)	0.007 (0–0.0014)	0.0013 (0–0.0026)	0.004	0.79
	NZ	0.0003 (0–0.0006)	0.0002 (0–0.0004)	0.0003 (0–0.0006)	0.002	–
Legumes (G10)	Fiji	0.004 (0–0.008)	0.0007 (0–0.0014)	0.0010 (0–0.002)	0.004	2.027
	NZ	0.0003 (0–0.0006)	0.0004	0.0003 (0–0.0006)	0.002	–
Vegetables (G11)	Fiji	0.018 (0–0.036)	0.0144	0.0060 (0–0.012)	0.018 (0–0.036)	18.97
	NZ	0.0312	0.0035	0.0012 (0–0.0024)	0.0048	–
TOTAL	Fiji	3.4224 (3.0296–3.8152)	0.0941 (0.0755–0.1028)	0.0936 (0.0425–0.141)	0.2398 (0.0732–0.4062)	135.37
	NZ	4.2592 (4.2372–4.3309)	0.0861 (0.0845–0.0878)	0.0639 (0.0462–0.0860)	0.1339 (0.1224–0.1461)	–

Discussion

In general, the heavy metal values were about 20 % of PTWI. For arsenic, only total arsenic was determined and these values were close to the PTWI for inorganic arsenic, the more toxic form of arsenic. However, a majority of arsenic exposure came from seafood, which contains mainly organic forms of arsenic, which is less toxic.

Comparison of the results from samples analyzed in New Zealand and Fiji showed results in almost all cases to be within expected uncertainties. Values for arsenic in the New Zealand samples showed a bias to slightly higher values. As expected, with lower detection levels, the average dietary exposure values and range were lower for mercury and lead, which had a large number of "non-detects" in the Fiji laboratory. For total mercury, the Fiji range was 12–38 % of the PTWI, while the New Zealand laboratory results produced a range of 11–23 % of PTWI. For lead, the Fiji range was 4–22 %. The much lower LOD for lead obtained by the New

Table 27.4 Comparison of results in warm and cool seasons (mg/kg)

	Arsenic	Cadmium	Mercury	Lead	Iron
Meat (Fiji lab, cool season)	0.0125	0.0012	0.0022	0.0045	11.36
Meat (Fiji lab, warm season)	0.0055	0.0009	0.0037	0.0055	11.62
Seafood (Fiji lab, cool season)	2.4512	0.0083	0.1374	0.0297	16.00
(Fiji lab, warm season)	2.898	0.0103	0.0462	0.031	17.41
Beverages (Fiji lab, cool season)	0.0211	0.0232	0.0043	0.0442	37.27
Fiji lab, warm season	0.0307	0.0328	0.0031	0.0862	39.64
NZ lab, cool season	0.0201	0.0499	0.0043	0.0261	–
NZ lab, warm season	0.0103	0.0327	0.0041	0.0724	–
Root Crops (Fiji lab, cool season)	0.0299	0.0043	0.01	0.0299	10.56
Fiji lab, warm season	0.0299	0.0050	0.01	0.0298	8.00
NZ lab, cool season	0.0060	0.0086	0.002	0.0189	–
NZ lab, warm season	0.0102	0.0100	0.002	0.0163	–
Fruits (Fiji lab, cool season)	0.004	0.0007	0.0013	0.004	0.735
Fiji lab, warm season	0.004	0.0007	0.0013	0.004	0.79
NZ lab, cool season	0.0008	0.0002	0.0003	0.0003	–
NZ lab, warm season	0.0003	0.0002	0.0003	0.0002	–
Legumes (Fiji lab, cool season	0.0003	0.0007	0.001	0.004	3.315
Fiji Lab, warm season	0.004	0.0007	0.001	0.004	2.207
NZ lab, cool season	0.0003	0.002	0.0003	0.0003	–
NZ lab, warm season	0.0003	0.0004	0.0003	0.0024	–
Vegetables (Fiji lab, cool season)	0.018	0.011	0.006	0.018	17.64
Fiji lab, warm season	0.018	0.0144	0.0016	0.018	18.97
NZ Lab, cool season	0.0096	0.004	0.001	0.0008	–
NZ lab, warm season	0.0312	0.0035	0.0012	0.0048	–

Zealand laboratory dramatically reduced the uncertainty in the mean concentration calculations, and therefore the exposure estimates, so that the exposures had a much lower and a smaller range (7–8 % of PTWI). For iron daily intake amounts were within the broad range of recommended daily intake.

The most challenging part of the process was determination of weekly exposures. Data were available from national Food Balance Sheets and a national survey of food frequency consumption. These were fairly accurate and in good agreement for imported foods and major crops. The consumption of "wild foods", which may be a significant part of a rural diet when the food is in season, was likely not captured. It will be useful to have data from a 24-h recall survey in which serving size has also been estimated. This study has been done, but the data are still being analyzed.

Conclusions and Recommendations

The successful conduct of Fiji TDS was a major accomplishment. It confirmed preliminary data that exposure to heavy metals and pesticides is not a population-wide health concern. However, some commonly used pesticides were not tested and there are some vegetables on which these are used. The steering committee for the project has recommended for the future that chemicals of known health effects in Fiji, such as ciguatoxins, should be measured. The study of mycotoxins, which are likely to thrive in Fiji's hot, humid conditions, is another group of contaminants to be considered.

The absence of significant differences in samples collected from different parts of the island and during the wet and dry seasons suggests that the costs of these added collections are not justified for an island the size of Fiji. These resources might be spent on looking at foods important to different age groups, especially infant weaning foods. The availability of food consumption for different age groups, sexes and ethnicity would also allow for disaggregated analysis by these groups.

These data can also be put to use for other purposes. When the issue of possible calcium deficiency in Fiji diets arose, food consumption data were combined with calcium concentration estimates for each food group based on local food composition tables to get a rough estimate of total calcium intake, which was less than 50 % of recommended values.

Another possible extension of the TDS would be to include other island countries of similar climate and geography. The food contaminant data could be used in concert with local food consumption information to estimate weekly heavy metal exposures. Perhaps a few key local foods might be analyzed to help confirm the assumption that these will not vary too much from island to island. Another similarity is that the increasing amount of food is being imported, usually from the same source country.

References

1. Dignan C, Burlingame B, Kumar S, Aalbersberg W (2004) The Pacific Islands food composition tables, 2nd edn. Food and Agriculture Organization of the United Nations, Rome
2. FAO/WHO (1999) Fifty-third meeting of the Joint FAO/WHO Expert Committee on Food Additives. Technical Report Series 896, World Health Organization
3. FAO/WHO (2005) Sixty-fourth meeting of the Joint FAO/WHO Expert Committee on Food Additives. Technical Report Series 930, World Health Organization
4. FAO/WHO (2003) Sixty-first meeting of the Joint FAO/WHO Expert Committee on Food Additives. Technical Report Series 922, World Health Organization
5. FAO/WHO (2010) Seventy-Second meeting of the Joint FAO/WHO Expert Committee on Food Additives. Technical Report Series 959, World Health Organization
6. Food and Nutrition Board, Institute of Medicine, National Academy of Sciences (2001) Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc. Report available at www.nap.edu