THE COMPOSITION OF SOME NEW GUINEA FOODS

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ABSTRACT

The nitrogen, fat, ash, fibre, water and gross energy contents of 87 raw and cooked Papua New Guinean highland and coastal foods were analysed. Carbohydrate was obtained by difference and the available energy was calculated using appropriate factors. Information on the edible portion, average serving or portion size and the ratio of available to gross energy contents of these and other foods is presented.

The results confirm the low protein and energy contents of sweet potato and taro, the staple food stuffs. Considerable variations were found within and between the different varieties of the staples, owing to variations in water content probably caused by different methods of food preparation.

INTRODUCTION

An important factor in the accuracy of dietary surveys in all parts of the world is the accuracy of available information on composition of local food stuffs. Where a staple crop assumes a considerable role in the diet, as in Papua New Guinea, it becomes of greater importance to obtain precise information on its composition. As part of a lengthy nutritional survey carried out in two localities in Papua New Guinea, 104 samples of 87 raw and cooked foods were collected, dried and analysed for nitrogen, fat, ash, crude fibre and gross energy content. These analyses have been used to calculate the nutrient and energy contents of the diets of subjects we have studied (Norgan *et al.* 1974; Ferro-Luzzi *et al.* 1975) and may be useful in other areas of Melanesia, S.E. Asia and the tropics. Some analyses of uncooked foodstuffs from these areas have been published (Hipsley and Clements 1950; Massal and Barrau 1956; Peters 1958; Platt 1962; and Bailey 1968) but the available information is not extensive, particularly for coastal areas of Papua New Guinea. Further information on the composition of the common foodstuffs, on the many varieties of the staple and on the effect of different methods of preparation is required.

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METHODS

Area of study

The samples were collected in the Lufa area of the Eastern Highlands District and in the Kaul villages of Kar Kar Island, off the northern coast of Papua New Guinea. Details of these places and of the nutrition study carried out have been published (Norgan *et al.* 1974). Sweet potato *(Ipomoea batatas)* was the staple foodstuff in Lufa although yams *(Dioscorea* spp.*)* and bananas (*Musa* spp.) were common in the diet. In Kaul, taros (*Colocasia* and *Xanthosoma* spp.) were the staple although at some times of the year breadfruit (*Artocarpus altilis*) was the most important dietary item. Bananas were also plentiful. Particular attention was paid to the collection and analysis of different varieties of the staple foods and of the other common foodstuffs. This explains why large numbers of sweet potatoes and taros were analysed.

Collection and drying of samples

Representative samples were collected at meal times from foods prepared for family consumption. Whole items, e.g. one tuber, were taken to avoid variations in composition in different parts of a food. The sample sizes were 400-600 g for roots and tubers, 150 g for green leaves and 200-300 g for the remainder. With larger items, such as breadfruit, longitudinal sections were made and sampled. The samples were allowed to cool to eating temperature before weighing. Some samples collected at a distance from the field laboratory were weighed cool but any condensate was retained with the sample. The samples were transferred to weighed porcelain evaporating basins and dried to constant weight in a vacuum oven at 60°C. Some samples were stored at −5°C in sealed plastic containers before drying. The dried samples were transported to the U.K. in sealed jars for analysis.

Analysis of the samples

Analyses of moisture, nitrogen, fat, fibre and ash were performed separately on the dried samples by Thomas McLachlan and Partners, London and the Department of Food Science, University of Strathclyde, Glasgow. Gross energy content was determined at the Institute of Physiology, University of Glasgow.

MOISTURE

The moisture content of the field dried samples was determined by mixing the samples with acid-washed sand and 95% (V/V) ethanol, removing the ethanol by gentle heating on a water bath and drying the mixture to constant weight at 103 ± 2°C. The moisture content of the dried samples was considered to be a measure of the residual water remaining after drying in the field.

FAT

Fat was determined by a 5 hr extraction of samples with light petroleum spirit, boiling point 40-60°C. For samples presumed to have a fat content > 10% the extraction period was lengthened. The petroleum spirit extract remaining after drying at 100°C was regarded as fat.

PROTEIN

The nitrogen content of foods was determined by a standard semi-micro Kjeldahl method. Protein was calculated from N × 6.25 except for nuts and seeds (N × 5.30), rice (N × 5.95) flour and bread (N × 5.8) (Watt and Merrill 1950).

CRUDE FIBRE

Crude fibre was determined as the insoluble material remaining after extraction with petroleum spirit, acid hydrolysis (200 ml of 2.55N H_2SO_4 per 3 g sample boiled for 30 min), alkaline hydrolysis (200 ml of 0.313N NaOH per residue for 30 min) less the ash of the insoluble material. Crude fibre differs from dietary fibre in that it includes cellulose and lignin but not pectins and hemi-celluloses.

ASH

Samples were incinerated at 500-600°C in a muffle furnace with magnesium acetate as an ashing aid. Ash was calculated as the weight of residue, corrected for the weight of magnesium oxide yielded by the added magnesium acetate.

CARBOHYDRATE

This was calculated as the difference between 100% and the sum of moisture, protein, fat, ash and crude fibre percentages. It is not synonymous with "total carbohydrate" or carbohydrate by difference, as understood by Merrill and

Watt (1955), as crude fibre has been subtracted. It includes all of the available carbohydrates (sugars, dextrins, starches) and some of the unavailable carbohydrates (pectins and hemicelluloses) but not celluloses. In some cases, crude fibre and ash were not determined directly, owing to insufficient material for analysis (see missing values in *Table 1*). They were estimated from the ash or crude fibre contents of similar foods, analysed here or given by Peters (1958).

ENERGY

Gross energy contents were determined by combustion of samples in an adiabatic bomb calorimeter (Gallenkamp Ltd., England), according to the method described by Southgate and Durnin (1970). Available energy contents were calculated using the energy conversion factors for protein, fat and carbohydrate given by Merrill and Watt (1955). For starchy roots, fruits and nuts the conversion factors for protein are 11.63 kJ (2.78 kcal)/g, 14.06 kJ (3.36 kcal)/g, and 14.53 kJ (3.47 kcal)/g respectively; for fat 35.02 kJ (8.37 kcal)/g; and for carbohydrate 16.86 kJ (4.03 kcal)/g in starchy roots, 15.06 kJ (3.60 kcal)/g in fruits and 17.03 kJ (4.07 kcal)/g in nuts.

Expression of results

All analyses were performed on the field dried samples. The results are most usefully expressed on a wet weight basis. The method of calculation of the nutrient and energy contents of the food is shown in *Appendix 1*. It will be noted that the moisture content is a component of the dry weight (dry weight = moisture + protein + fat +ash +crude fibre + carbohydrate) and this has been taken into account. The water content was calculated from the water content determined in the field plus the moisture content of the field dried sample.

RESULTS

The energy and nutrient contents of the analysed foods are shown in *Table 1*. The figures refer to edible portions, except where stated. Information onthe edible portion percentage of some of these foods and of many others is given in *Appendix 2*. English and botanical names are given, if known, followed by the Melanesian Pidgin or vernacular name. The method of cooking is included where appropriate. In Kaul, foods were boiled in brackish water, in coconut water, or in coconut milk (prepared by scraping coconut flesh, separating the oil and mixing it with the water). Foodsboiled in different ways have not been listed separately. In Lufa, all boiled foods were boiled in fresh water. 'Roasted' refers to cooking over a fire or in hot ashes, not cooking with fat. 'Mumu'd' foods had been steamed in an earth oven, as described by Norgan *et al.* (1974). Foods cooked in green bamboo are considered to have undergone steaming.

Highland Foods

SWEET POTATOES

The varieties of sweet potatoes showed a wide range of protein (0.6-2.6 g/100 g) and energy contents (320-670 kJ (77-160 kcal)/100 g). The variety 'mangalove' is one of four traditional varieties (those present before European contact) still grown and it has the lowest energy and protein content. It was analysed because of its antiquity; it occurred only once in the dietary survey out of some 3500 man-days. All the other varieties listed have been introduced into the area by Europeans or been taken from neighbouring areas since contact with Europeans. 'Konime' is widespread throughout the highlands and 'seyapan' (meaning Japan?), which has a high protein content, · is probably the Okinawa variety popular in the Mount Hagen area (Bailey 1968).

Table 1. — cont'd

NAME, LOCAL NAME AND METHOD OF COOKING	WATER	PROTEIN	FAT	CARBO-HYDRATE	ENERGY		GROSS ENERGY	FIBRE	ASH
	g (range)	g	g	g	kJ	kcal	kcal	g	g
Sweet potato, *Ipomoea batatas*, Ferama, roasted	57.8	2.0	0.4	37.4	669	160	170	1.0	1.4
Sweet potato, *Ipomoea batatas*, Karigoya, boiled	66.3	2.6	0.4	29.1	535	128	138	0.8	0.8
Sweet potato, *Ipomoea batatas*, Konime, boiled	71.2	0.8	0.2	25.0	439	105	114	0.6	2.1
Sweet potato, *Ipomoea batatas*, Konime, mumu'd (3)	66.5 (63-71)	1.9	0.1	29.6	523	125	135	0.7	1.3
Sweet potato, *Ipomoea batatas*, Konime, roasted	66.5	1.3	0.1	30.3	531	127	130	0.7	1.1
Sweet potato, *Ipomoea batatas*, Kopumeni, boiled	70.8	0.6	0.1	16.6	460	110	117	0.7	1.2
Sweet potato, *Ipomea batatas*, Kopumeni, mumu'd	64.6	1.6	0.1	31.8	556	133	136	1.2	0.8
Sweet potato, *Ipomoea batatas*, Kopumeni, roasted	70.7	1.5	0.3	25.6	460	110	116	0.6	1.3
Sweet potato, *Ipomoea batatas*, Mangalove, roasted	78.2	0.6	0.1	18.5	322	77	82	0.7	1.9
Sweet Potato, *Ipomoea batatas*, Miniminiso, boiled	73.5	0.9	0.1	24.1	418	100	105	0.6	0.9
Sweet potato, *Ipomoea batatas*, Miniminiso, mumu'd	75.7	1.5	0.1	21.3	380	91	97	0.6	0.8
Sweet potato, *Ipomoea batatas*, Miniminiso, roasted	61.8	1.8	0.8	33.8	619	148	154	0.5	1.3
Sweet potato, *Ipomoea batatas*, Seyapen, mumu'd	69.5	2.0	0.1	25.8	460	110	116	1.1	1.5
Sweet potato, *Ipomoea batatas*, Sorara, boiled	70.9	1.0	0.1	25.1	439	105	117	0.5	2.5
Sweet potato, *Ipomea batatas*, Sorara, mumu'd (2)	68.6 (67-70)	1.3	0.2	27.3	481	115	122	1.3	1.4
Sweet potato, *Ipomoea batatas*, Sorara, roasted	68.2	1.2	0.2	28.8	506	121	123	0.5	1.0
Sweet potato, *Ipomoea batatas*, Yambalualope, mumu'd	71.3	[illegible]	0.2	[illegible]	[illegible]	108	114	[illegible]	[illegible]

Table 1. — cont'd

NAME, LOCAL NAME AND METHOD OF COOKING	WATER	PROTEIN	FAT	CARBO-HYDRATE	ENERGY		GROSS ENERGY	FIBRE	ASH
	g (range)	g	g	g	kJ	kcal	kcal	g	g
Taro, *Colocasia esculenta*, Fepi, mumu'd	64.1	1.2	0.1	32.7	568	136	148	0.7	1.1
Taro, Litina, mumu'd	57.7	1.4	0.2	39.4	686	164	169	0.5	0.8
Yam, *Dioscorea alata*, Hokepa, mumu'd	68.7	2.1	0.1	27.6	493	118	126	0.4	1.1
Yam, Wai, mumu'd	59.6	3.0	0.0	36.0	640	153	154	0.3	1.1
Yam, Wai, roasted	49.8	3.7	0.4	44.8	811	194	196	0.2	1.1
GREEN LEAVES (Kumu)									
Cabbage, *Brassica* spp., Apus, mumu'd	91.4	1.4	0.3	5.6	109	26	38	0.5	0.8
-, Fagasa, mumu'd (2)	84.9 (84-86)	5.4	0.6	6.5	172	41	65	1.5	1.2
-, Kio, mumu'd	84.8	4.1	1.4	5.2	167	40	64	1.5	2.9
-, Lengisi, mumu'd	89.1	4.6	0.1	4.6	117	28	51	0.1	1.4
Amaranthus spp., Maita, mumu'd	88.7	2.7	0.3	4.9	113	27	38	1.2	2.3
FRUITS									
Banana, *Musa* spp., Borua, roasted	66.3	1.0	0.1	30.9	481	115	137	0.4	1.3
Banana, *Musa* spp., Hayapa, roasted	49.2	1.7	0.5	46.7	744	178	200	0.7	1.4
Banana, *Musa* spp., Opine, mumu'd (2)	62.4 (61-64)	1.3	0.2	34.8	548	131	153	0.2	1.2
Banana, *Musa* spp., Opine, roasted	53.3	2.4	0.2	42.4	677	162	185	0.4	1.2
NUTS									
Pandanus julianetti?, Karuga, dried	6.0	11.7	43.8	26.5	2144	513	618	7.8	4.2
Pandanus julianetti?, Karuga, roasted	67.6	4.1	16.3	8.3	769	184	221	2.2	1.4

Table 1. — THE COMPOSITION OF PAPUA NEW GUINEAN FOODS
(all values expressed on the basis of wet weight, except where indicated, per 100 g edible portion)

HIGHLAND FOODS

NAME, LOCAL NAME AND METHOD OF COOKING	WATER	PROTEIN	FAT	CARBO-HYDRATE	ENERGY		GROSS ENERGY	FIBRE	ASH
VEGETABLES	g (range)	g	g	g	kJ	kcal	kcal	g	g
Beans, Katanaku, in bamboo	51.6	12.1	0.7	32.1	748	179	217	1.6	2.0
Beans, Katanaku, mumu'd	60.9	8.8	0.8	27.4	623	149	172	1.1	1.1
Winged bean, *Psophocarpus tetragonolobus*, Okani, mumu'd	70.6	8.1	5.4	12.9	527	126	152	1.9	1.1
Winged bean, *Psophocarpus tetragonolobus*, Okani, young pods, mumu'd	87.0	3.2	0.9	6.5	188	45	62	1.6	0.8
Winged bean, Ass bin, root, mumu'd	60.1	6.4	0.1	25.4	485	116	168	6.5	1.5
Corn, *Zea mays*, cob, mumu'd	73.3	3.6	1.0	20.5	422	101	119	0.8	0.8
Corn, *Zea mays*, cob, roasted	65.2	5.2	1.2	26.8	552	132	155	0.6	1.0
Setaria palmiflora, Pitpit, mumu'd	91.4	1.6	0.3	5.1	105	25	33	1.4	0.2
ROOTS AND TUBERS									
Manioc, *Manihot* spp., Kavabaya, mumu'd	58.9	1.4	0.3	37.8	665	159	163	0.8	0.8
Manioc, *Manihot* spp., Kavabaya, roasted (2)	54.1 (50-58)	2.0	0.3	41.5	729	175	-	0.8	1.4
Sweet potato, *Ipomoea batatas*, Ferama, boiled	68.2	1.1	0.3	28.0	493	118	129	0.8	1.5
Sweet potato, *Ipomoea batatas*, Ferama, mumu'd (3)	65.2 (61-68)	1.4	0.5	30.8	553	132	141	0.6	1.5

Table 1. — cont'd

NAME, LOCAL NAME AND METHOD OF COOKING	WATER g (range)	PROTEIN g	FAT g	CARBOHYDRATE g	ENERGY kJ	ENERGY kcal	GROSS ENERGY kcal	FIBRE g	ASH g
Pandanus conoideus? Marita, mumu'd with seeds (a)	64.7	2.5	9.1	9.1	527	126	177	12.4	2.2
Pandanus conoideus? Marita, sauce	75.8	1.4	16.7	5.4	732	175	-	-	-
MISCELLANEOUS									
Pig meat, roasted	64.1	30.1	4.1	0.1	694	166	208	0.1	1.4
White rice, boiled	61.8	3.2	0.1	34.5	656	157	155	0.1	0.2
Fried flour	41.4	7.2	12.4	37.7	1195	286	310	0.2	1.1

COASTAL FOODS

NAME, LOCAL NAME AND METHOD OF COOKING VEGETABLES	WATER g (range)	PROTEIN g	FAT g	CARBOHYDRATE g	ENERGY kJ	ENERGY kcal	GROSS ENERGY kcal	FIBRE g	ASH g
Taro, *Colocasia esculenta*, black, boiled	78.7	0.8	0.4	18.8	339	81	88	0.4	0.7
Taro, *Colocasia esculenta*, red, boiled	72.0	0.9	0.4	24.2	431	103	104	0.6	1.9
Taro, *Colocasia esculenta*, white, boiled (3)	74.6 (73-76)	0.9	0.6	22.4	410	98	101	0.5(b)	1.4(b)
Taro, *Colocasia esculenta*, white, roasted (2)	59.9 (53-67)	1.4	0.2	35.7	623	149	148	1.5	1.4
Taro, *Colocasia esculenta*, yellow, boiled	67.2	0.7	0.4	29.8	523	125	128	0.6	1.3
Chinese taro, *Xanthosoma* spp., boiled (4)	75.5 (73-78)	1.1	0.4	21.3	385	92	91	0.6(b)	1.4(b)
Chinese taro, *Xanthosoma* spp., roasted (2)	65.0 (60-70)	1.5	0.1	30.8	539	129	131	1.5	1.4
Taro, cooking water	93.1	0.6	2.2	2.8	134	32	33	0.1	1.0

Table 1. — cont'd

NAME, LOCAL NAME ANI METHOD OF COOKING	WATER	PROTEIN	FAT	CARBO-HYDRATE	ENERGY		GROSS ENERGY	FIBRE	ASH
GREEN LEAVES (c)	g (range)	g	g	g	kj	kcal	kcal	g	g
Hibiscus manihot, Aibika, boiled	77.0	3.4	2.0	7.4	213	51	139	-	-
Gnetum gnemon, Tulip, boiled	85.6	1.6	2.0	5.1	163	39	-	-	-
-, Tuwer, boiled	85.8	1.2	2.0	5.4	163	39	-	-	-
FRUITS									
Banana, *Musa* spp., Amı boiled	75.4	1.1	1.1	21.2	372	89	102	0.4	0.9
Banana, *Musa* spp., Ami roasted	71.2	1.4	0.1	25.1	401	96	111	1.1	1.1
Banana, *Musa* spp., Ara'ang, boiled	77.1	0.9	0.4	20.4	334	80	88	-	-
Banana, *Musa* spp., Sas boiled	74.5	1.4	0.1	22.9	368	88	100	0.3	0.9
Banana, *Musa* spp., Si nikin, boiled	77.1	1.2	0.5	19.9	334	80	90	0.5	1.0
Banana-galip purom ( ), Galuk (2)	64.1 (62-67)	1.1	8.8	24.6	690	165	200	-	-
Bread fruit, *Artocarpus altilis*, Kapiak, boiled	81.0	1.3	0.9	14.4	268	64	79	1.5	0.9
Bread fruit, *Artocarpus altilis*, Kapiak, roasted (2)	73.8 (72-75)	1.3	0.6	22.1	372	89	106	1.5	0.9
Bread fruit, *Artocarpus altilis*, Seeds, boiled	59.3	5.3	2.3	30.3	673	161	178	1.8	1.1
Bread fruit, *Artocarpus altilis*, Seeds, roasted	49.7	6.2	2.7	37.8	828	198	216	2.2	1.3
-, Mon, ripe	69.3	2.4	0.3	25.2	422	101	117	-	-

Table 1. — cont'd

NAME, LOCAL NAME AND METHOD OF COOKING	WATER	PROTEIN	FAT	CARBO-HYDRATE	ENERGY		GROSS ENERGY	FIBRE	ASH
NUTS	g (range)	g	g	g	kJ	kcal	kcal	g	g
Terminalia spp., Talis, ripe	42.9	10.7	31.7	6.3	1367	327	409	6.1	2.4
Inocarpus edulis, Aila, boiled	56.7	4.1	1.7	34.5	706	169	175	-	-
Inocarpus edulis, Aila, roasted	42.0	5.9	4.2	43.7	978	234	247	-	-
Canarium spp., Galip, ripe	23.2	10.2	59.3	3.3	2278	545	647	-	-
Canarium spp., Galip, dried	12.1	12.1	51.8	24.0	2395	573	730	-	-
ANIMAL FOODS									
Phalanger, Cuscus, boiled	64.1	21.7	11.3	1.8	844	202	239	0.1	1.0
Flying fox, Black bokis, boiled	61.5	20.5	9.3	7.6	840	201	236	-	-
Pig, fat, boiled	26.5	4.0	68.3	0.0	2700	646	635	0.1	1.2
Pig, meat, boiled	68.5	19.5	6.5	4.8	673	161	195	-	-
Pig, meat and skin, (1:1), boiled	64.5	27.0	5.4	2.1	719	172	201	-	-
STORE FOODS									
Bread, local produce	39.5	8.9	0.5	49.9	941	225	255	0.5	0.6
Mackerel in natural oil, tinned	62.1	18.6	12.0	6.0	882	211	236	0.1	1.4
Flour, fried	12.4	12.1	5.2	68.9	1509	361	390	0.7	0.6
Rice, white, boiled	73.9	1.8	0.9	22.6	451	108	113	0.4	0.3
Rice, brown, boiled with fish	66.9	2.7	5.2	24.2	640	153	168	0.5	0.5

Footnotes:

Numbers in parantheses are the numbers of samples analysed.

— Not determined

(a) Analysed as served, waste usually 60%

(b) Mean of two samples

(c) Amount of fat determined was arbitrarily reduced to 2 g/100 g as it was considered that part of the material estimated as fat was waxes and other indigestible fatty residues.

(d) Boiled banana mixed with oil extracted from galip nuts.

Table 2. — The composition of sweet potatoes cooked in different ways (mean and standard deviations)

	Boiled	Mumu'd	Roasted[1]
Number of samples	6	12	5
Water %	70.0	67.9	65.1
	±2.3	±3.8	±4.8
Protein g/100 g	1.2	1.5	1.6
	±0.6	±0.4	±0.3
Energy kJ/100 g	464	502	556
	±39	±68	±75
kcal/100 g	111	120	133
	±9	±16	±18

[1] omitting 'mangalove'

It is not possible to make a strict comparison of the nutrient content of the different varieties or the effects of method of preparation on nutrient content because the origin of the samples, i.e. the type of soil, age and altitude of the garden from which they came, was not controlled. However, some useful information can be given.

The variety 'konime' was found to have a composition, when boiled, of 0.8 g protein, 440 kJ (105 kcal)/100 g; when roasted 1.3 g protein, 530 kJ (127 kcal)/100 g; and when mumu'd 1.9 g protein, 523 kJ (125 kcal)/100 g. The effect of method of preparation on consumption is illustrated more fully by the results in *Table 2.* The differences in composition between cooking methods reflect, to some extent, the differences in water content occurring with the method of preparation. The protein and energy contents listed are within the ranges for uncooked sweet potatoes given by Peters (1958) and those of Bailey (1968) calculated on a wet weight basis.

Of the other roots and tubers, taros have nutrient and energy contents similar to sweet potatoes, while those of yams are higher. Green leaves have higher protein contents than roots and tubers even though their water contents are appreciably higher. Cooked bananas and dried 'karuga' nuts were found to have a composition similar to those reported previously but the protein content of beans was considerably less than that reported by Bailey (1968).

Coastal Foods

TAROS

The energy contents of all cooked taros were considerably lower than those described for raw taros (Peters 1958). Taros do not appear to be superior in energy and protein content to sweet potatoes, neither does the high yielding Chinese taro (*Xanthosoma*) appear to be nutritionally inferior to 'true' taro *(Colocasia).* Roasted taros have higher nutrient contents than boiled taros, approximately 1.5 g protein and 585 kJ (140 kcal)/100 g compared to 1.0 g protein and 418 kJ (100 kcal)/100 g respectively, for white taro, reflecting their different water contents, 63% and 74%.

A small number of analyses of different samples of a food prepared in the same way was performed on coastal foods. The data suggest a fairly constant composition in the staple foodstuffs. White taro boiled in coconut milk (3 analyses) shows the following ranges: water, 73.4-74.9 %; protein, 0.8-1.0 g/100 g; fat, 0.3-0.8 g/100 g; and energy, 397-426 kJ (95-102 kcal)/100 g. For boiled Chinese taro the results of 4 analyses were: water, 73.4-78.4 %; protein, all = 1.1 g/100 g; fat, 0.3-0.5 g/100 g; carbohydrate, 18.4-23.6 g/100 g; and energy, 334-426 kJ (80-102 kcal)/100 g.

Taro cooking water was consumed frequently and in amounts of several hundred grams. The sample analysed [1] was thicker than usual and came from a pot where taro, beans and pig meat had been boiled in sea water and coconut milk. The protein and fat contents are not insubstantial when compared to other foods, such as taros.

Bananas and breadfruit were important in the diet of the coastal population studied, providing variety and acting as alternative staple foodstuffs. 'Galip' nuts and breadfruit seeds were good sources of vegetable protein.

Foods which may show the greatest variation in composition are those made from two or more ingredients. Such a food is 'galuk', a banana and 'galip'-oil dough. However, the two analyses agreed reasonably well; fat 7.1 and 10.4 g/100 g; energy, 620 and 760 kJ (148 and 182 kcal)/100 g.

DISCUSSION

The results indicate a low nutrient density in most of these Papua New Guinea foods. Beans, nuts and green leaves are the only protein rich vegetable foods and the distribution of fat is similarly limited, mainly to nuts and coconuts. Few of these foods are important in the diets of Papua New Guinean adults or children (Norgan *et al.* 1974; Ferro-Luzzi *et al.* 1975). The most common varieties of the staples, e.g. 'sorara' and 'konime' sweet potatoes in Lufa and white, 'true' taro in Kaul, which were popular because of their taste, texture, yield, etc. were not appreciably different in composition.

The diets of the Papua New Guineans of Lufa and Kaul are characterised by low protein (< 50 g/day), fat (< 40 g/day) and, in some cases, low energy intake (Norgan *et al.* 1974; Ferro-Luzzi *et al.* 1975). In Lufa, 76% of the total energy intake and 53% of the total protein intake was derived from vegetables, the contribution from sweet potatoes alone being 64% and 37% respectively. In Kaul, vegetables were similarly the most important food group and taros alone provided 42% of the total energy intake and 24% of the total protein intake. The dietary pattern in Kaul was more varied in that fruits, nuts and storefoods, e.g. rice, made significant contributions to the diet but in neither area was the contribution from animal foods noteworthy. Thus, the diets, like the foodstuffs, are of vegetable origin and of low nutrient density. A Lufan must consume 2 kg of sweet potato to derive 2400 kcal and 24 g protein while a Kaul villager would need to consume a larger quantity of taro to gain the same nutrient intake.

The calculation of nutrient and energy intakes requires accurate information on the true availability of the nutrients and energy in foods. The figures in *Table 1* are intended to represent available nutrient and energy contents. However, Oomen *et al.* (1961) found the real protein of New Guinea highland sweet potatoes to be, on average, 85% of 'crude' protein (N × 6.25). Since a substantial proportion of Papua New Guinean protein intakes is from vegetable sources, the real protein intakes may be lower than those calculated from N × 6.25. However, the

[1] Other samples taken were lost because they could not be separated from the evaporating basins after drying.

non-protein nitrogen in roots and tubers may include important amounts of amino-acids. Peters (1958) found that the amino-acid nitrogen as a percentage of total nitrogen was 90% for lowland sweet potatoes, 92% for taro, 79% for yams and 78% for coconuts. Also, Chick (1951) has shown that the addition of the non-protein nitrogen component of potatoes to diets containing potato protein 'tuberin' stimulated growth of rats to a greater extent than could be explained by the addition of free utilisable amino-acids.

A further factor reducing true protein intakes is the digestibility of crude protein, which for potatoes and starchy roots consumed by Europeans, is reported to be low, 74% on average (Merrill and Watt 1955). For taro protein, the value is even lower, 50%, range 20-75%. Until further information is available it is difficult to assign corrections applicable to Papua New Guinean diets. These corrections may be relatively minor as many studies have shown that N equilibrium can be achieved on low intakes of nitrogen from potatoes alone (Chick 1946), e.g. Kon and Klein (1928) maintained N equilibrium over 167 days on intakes of 5.7 gN/day in a male and 3.8 gN/day in a female. Thus, low intakes of protein from vegetable sources, as in New Guinea, could be adequate.

The energy conversion factors of Merrill and Watt (1955) have been used in the calculation of the available energy contents of the foods (see *Appendix 1*). They are based on the heat of combustion (gross energy) of protein, fat and carbohydrate adjusted for losses in digestibility and, in the case of protein, in metabolism. Individual factors have been derived for different groups of foods from studies in the literature. These have been derived, in the main, from limited measurements on Europeans consuming European foods and it is not known if they are applicable in other circumstances. The energy conversion factors for protein in the types of foods that form the bulk of Papua New Guinea foods are low (11.6-14.5 kJ/g) compared to the values for protein in cereal and meats (14.6-16.7 kJ/g) because of the nature of the foods. Thus, the energy conversion factors for protein include an adjustment for non-protein nitrogen and digestibility which for starchy roots is taken to be 40% and 75% respectively. In a similar way the energy conversion factor for fats 35.0 kJ/g, is lower than those for fats in vegetable oils or animal foods 36.8-37.7 kJ/g. Thus, the energy derived from protein and fat in Papua New Guinean foods is lower than that from identical intakes in European foods because of the chemical and physical properties of the foods. However, in these Papua New Guinean diets with relatively small amounts of protein and fat, the effect on the total energy intake is small. In contrast, carbohydrate represents approximately 80% of the total energy intake. The carbohydrate energy conversion factors of Merrill and Watt (1955) will underestimate the energy available from carbohydrate because they are for total carbohydrate (by difference) rather than the total carbohydrate minus crude fibre given in this paper. The underestimation will be, on average, 3% of the total energy intake, assuming the digestibility of carbohydrate to be 96% because of the crude fibre content, and the carbohydrate energy from starchy roots to be 75% of the total energy intake. The question of the applicability of heats of combustion measured on European foods and digestibility measured on Europeans to Papua New Guinean foods and subjects remains unanswered.

The gross energy contents of foods are not immediately useful in dietary surveys but they have been included in *Table 1* because if new information, e.g. on the digestibility of Papua New Guinean foods by Papua New Guineans, is published, the available energy contents of these foods could be modified.

Most of the published information on the composition of tropical foods refers to uncooked foods. These analyses of edible portions of cooked foods should reduce one source of error in dietary surveys, that is the effect of changes in the composition of foods with cooking. The information should be of use to nutritionists in many parts of the world and in Melanesia in particular, where so much interesting work has yet to be performed. As Platt (1962) has stated, perhaps the most important factor affecting the composition of tropical foods is the variability in water content of foods. When results are compared on a dry weight basis, many differences in composition disappear and perhaps the most useful measure that can be made under field conditions is the water content of the staple foods. Much more information is still required, particularly on the digestibility and availability of nutrients in Papua New Guinean foods. These await more sophisticated studies under difficult field conditions, although notable efforts have been made (Oomen *et al.* 1961; Luyken *et al.* 1964; Oomen and Corden 1970; Oomen 1972).

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REFERENCES

BAILEY, K.V. (1968). Composition of New Guinea highland foods. *Trop. geogr. Med.*, 20: 141-146.

CHICK, H., (1946). The nutritive value of the potato. In A.L. Bacharach and T. Rendle (eds), *The Nation's Food.* London: Soc. Chem.-Ind. Chap. VIII, pp. 101-104.

CHICK, H. (1951). Nutritive value of vegetable proteins and its enhancement by admixture. *Brit. J. Nutr.*, 5: 261-265.

FERRO-LUZZI, A., NORGAN, N.G. and DURNIN, J.V.G.A. (1975). Food intake and its apparent nutritional adequacy in New Guinean children. *Amer. J. clin. Nutr.*, 28: 1443-1453.

HIPSLEY, E.H. and CLEMENTS, F.W. (1950). *Report of the New Guinea Nutrition Expedition 1947.* Government Printer, Sydney.

KON, S.K. and KLEIN, A. (1928). The value of whole potato in human nutrition. *Biochem. J.*, 22: 258-260.

LUYKEN, R., LUYKEN-KONING, F.W.M. and PIKAAR, N.A. (1964). Nutrition studies in New Guinea. *Amer. J. clin. Nutr.*, 14: 13-27.

MASSAL, E. and BARRAU, J. (1956). *Food plants of the South Sea Islands,* South Pacific Comm., Noumea.

MERRILL, A.L. and WATT, B.K. (1955). Energy value of foods — basis and derivation. *U.S. Dept. Agric. Handb.*, No. 74, Washington.

NORGAN, N.G., FERRO-LUZZI, A. and DURNIN, J.V.G.A. (1974). The energy and nutrient intake and the energy expenditure of 204 New Guinean adults. *Phil. Trans. R. Soc. Lond. B.*, 268: 309-348.

OOMEN, H.A.P.C. (1972). Distribution of nitrogen and composition of nitrogen in food, urine and faeces in habitual consumers of sweet potato and taro. *Nutr. Metabol.*, 14: 65-82.

OOMEN, H.A.P.C. and CORDEN, M.W. (1970). Metabolic studies in New Guineans: nitrogen metabolism in sweet potato eaters. *South Pacific Comm., Tech. Paper,* No. 163, Noumea.

OOMEN, H.A.P.C., SPOON, W., HEESTERMAN, J.E., RUINARD, J., LUYKEN, R. and SLUMP, P. (1961). The sweet potato as the staff of life of the highland Papuan. *Trop. geogr. Med.*, 13: 55-66.

PETERS, F.E. (1958). The chemical composition of South Pacific Foods. *South Pacific Comm. Tech. Paper,* No. 115, Noumea.

PLATT, B.S. (1962). Tables of representative values of foods commonly used in tropical countries. *Med. Res. Counc. Spec. Rep. Ser.* No. 302.

SOUTHGATE, D.A.T. and DURNIN, J.V.G.A. (1970). Calorie conversion factors. An experimental re-assessment of the factors used in the calculation of the energy value of human diets. *Brit. J. Nutr.*, 24: 517-535.

WATT, B.K. and MERRILL, A.L. (1950). Composition of foods — raw, processed, prepared. *U.S. Dept. Agric. Handb.*, No. 8, Washington.

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Appendix 1

Example of calculation of nutrient and energy content
Sample: Sweet potato, 'Konime', boiled
Field dry weight = 30.4%
Laboratory analysis of field dried sample.

moisture	= 5.29%
nitrogen	= 0.44%, protein (N × 6.25) = 2.75%
fat	= 0.57%
ash	= 7.07%
fibre	= 2.03%
carbohydrate (by difference)	= 82.3%
gross energy content	= 113 kcal/100 g (5.56MJ kg^{-1})
water content	= (100 − 30.4) + (5.29 × 30.4/100) = 71.2%

Nutrient content on wet weight basis:

Protein	Fat	Carbohydrate
30.4 × 2.75	30.4 × 0.57	30.4 × 82.3
= 0.8 g/100 g	0.2 g/100 g	25.0 g/100 g

Available energy = 0.8 × 2.78* 0.2 × 8.37* 25.0 × 4.03*
= 2.2 + 1.7 + 100.8
= 105 kcal/100 g wet weight

* Energy conversion factors (Merrill and Watt 1955)

Appendix 2

Information is given below on the edible portion, as a percentage, of cooked and raw foods that have an inedible part. Some figures are also given of the average size of discrete edible portions where these are fairly standard e.g. weights of nuts. Roots and tubers are very variable in size, particularly sweet potatoes, even if they are cut up into manageable pieces for boiling. Thus, these have not been included.

This information may be useful to nutritionists, anthropologists and ecologists wishing to estimate dietary intakes or horticultural energy balances from gross weight or other data.

	Edible portion		Type of portion	Weight of edible portions	
COASTAL FOODS	n	mean %		n	mean g
Aila nuts, boiled	-	-	1 peeled	46	40
Bananas,					
boiled in skin	-	62		-	-
sasi, roasted	-	-	1 peeled	18	40
sibiri, roasted	-	-	1 peeled	10	45
tamkilel, roasted	-	-	1 peeled	53	35
sigenikin, roasted	-	-	1 peeled	38	45
maike, roasted	-	-	1 peeled	16	65
Breadfruit, roasted	26	70		-	-
Breadfruit, seeds	-	-	boiled	96	5
Corn, boiled	4	70		-	-
Corn, roasted	6	67	1 cob	6	135
Crab, roasted	14	67	1 serving	14	75
Flying fox, boiled	15	75	1 serving	15	45
Galip nuts, ripe	-	-	1 kernal	320	2
Mons, raw	20	80	1 fruit	150	17
Papaya, raw	108	63	1 serving	-	180
Phalanger, cuscus, boiled	7	62	1 serving	-	25
Sok insects, roasted	-	-	1 roasted	6	30
HIGHLAND FOODS					
Winged bean (as bin) root, mumu'd	-	92		-	-
Bananas,					
opine, mumu'd	-	-	1 fruit	8	80
hayapa, roasted	-	-	1 fruit	14	40
Winged bean, mumu'd	10	60		–	-
Corn, roasted	20	60	1 cob	-	70
Pandanus nuts (% of comb and shell)	25	65		-	-
Pandanus, sauce	16	38		-	-
Setaria, pit-pit, mumu'd	7	65	1 stem	8	35
Sugar cane, raw	22	50		-	-
Sweet potatoes, roasted					
konime	30	87		-	-
sorara	54	83		-	-
kopumena	10	85		-	-
Passion fruit, raw	27	55		-	-