Carrot AIR serves as a working model for carrot fiber, since it is largely composed of undigestible cell wall material. Several properties of carrot AIR have now been identified that make it an increasingly attractive food additive. The large water holding capacity of carrot AIR is very likely responsible for the reduced fecal transient time reported by Robertson et al. (1979) for human subjects who ingested carrots as a dietary supplement. The cationic exchange capacity of carrot AIR might be used to enhance ingestion of trace minerals.

Blood levels of cholesterol could be expected to be lowered by ingested carrot AIR since this material binds bile acids. In this regard, Bergstrom (1961) has estimated that human beings excrete about 0.8 g of fecal bile acids/day. A 100-g portion of ingested carrot containing about 3% insoluble fiber that can cobind a total of at least 3% of bile acids under physiological conditions could be expected to increase fecal bile acids by about 90 mg or over 10% of the normal level. To maintain the bile acid pool of 3–5 g (Bergstrom, 1961), the conversion of cholesterol to bile acids would have to increase by over 10% its measured rate of 0.7 g/day. Bound bile acids would also be unavailable for absorption of dietary cholesterol. Robertson et al. (1979) reported a significant 11% reduction in serum cholesterol levels of adults who ingested 200 g of raw carrot/day for 3 weeks. They also observed an increase in fecal bile acids, as well as fats.

Carrot AIR could also be a source of dietary calcium that would be released upon breakdown of calcium pectate in the intestinal tract. The release of calcium in the colon could prevent the reported adverse effects of free fatty acids (Newmark et al., 1983). Carrot AIR has potential applications in the food industry as a baking ingredient or a meat extender.

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Registry No. Chenodeoxycholate, 474-25-9; deoxycholate, 83-44-3; cholate, 81-25-4.

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Dietary Fiber and Starch Contents of Some Southeast Asian Vegetables

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Dietary fiber and its components, as well as starch, have been determined in those vegetables that are extensively grown and consumed in Southeast Asia, by the Southgate procedure. The richest sources of total dietary fiber among the 24 vegetables examined were *Pithecellobium jiringa* (stinkbean), *Hibiscus esculentus* (lady's finger), and *Pisum sativum* var. macrocarpon (snow pea).

Standard collations of foodstuff assays such as that of Paul and Southgate (1978) include "dietary fiber", but in the case of even this comprehensive work there is no breakdown of fiber components and single figures only are available, giving no idea of the variance associated with the assays. Ross et al. (1985) have presented extensive analyses of fiber components of Western vegetables, based on 4–16 assays/sample. Some Chinese vegetables were estimated for dietary fiber (residue remaining after starch digestion, with corrections for protein and ash) in Australia by Wills et al. (1984), with single figures only given. Lund and Smoot (1982) presented analyses of cellulose, hemicelluloses, lignin, and cutin in various tropical fruits, but in only two tropical vegetables, the sweet potato and the yam.

More analyses of fiber components in tropical vegetables are required, not the least of which are those in the diets of the very extensive Southeast Asian populations, with the added purpose of complementing the epidemiological studies of cancers, heart disease, and metabolic disorders.

This paper presents the starch and fiber contents of some common Southeast Asian vegetables available in Singapore. As most of the foods are imported from around the region, these results may be taken as representative

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Table I. Nomenclature, Popularity, and Inedible Portion of Vegetables Analyzed

botanical name	common name: English (local[a])	popularity rank[b]
Brassica parachinensis	Chinese flowering cabbage (chye sim)	1
Spinacia oleracea	Chinese spinach, pointed leaf	4
Amaranthus tricolour	Chinese spinach, rounded leaf	4
Cucumis sativus	locally grown cucumber (timun)	6
Ipomoea aquatica	water convolvulus (kangkong/eng chye)	8
Brassica chinensis	Chinese cabbage, big (pek chye)	9
Brassica chinensis	Chinese cabbage, small (sio pek chye)	9
Brassica oleracea var. acephala	collard (kai lan)	11
Phaseolus vulgaris	local French bean	15
Cucumis sp.	hairy gourd/cucumber	17
Momordica charantia	bitter gourd	18
Lactuca scariola	local Chinese lettuce	23
Ipomoea batatas	sweet potato leaves	24
Hibiscus esculentus	lady's finger	27
Pachyrhizus erosus	yambean tuber (bangkwang)	29
Eleocharis tuberosa	waterchestnut	34
Solanum melongena	purple eggplant (brinjal)	35
Chrysanthemum coronarium	garland chrysanthemum leaves (tung ho)	38
Pisum sativum var. macrocarpon	snow pea, edible-podded	39
Nelumbo nucifera	lotus tuber	40
Pithecellobium jiringa	stinkbean (petai)	47
Raphanus sativus var.	oriental radish	49
Cucumis sp.	old/brown cucumber	50
Benincasa hispida	wax gourd (wintermelon)	50

[a] As used in Singapore although there are many variants throughout Southeast Asia. [b] In Singapore, on a daily consumption basis. Western vegetables occurred in the ranking but were not analyzed.

Table II. Moisture, Starch, and Dietary Fiber in Southeast Asian Vegetables (g/100 g of Edible Portion), Results Calculated for Three Assays (with Standard Deviations)

vegetable	moisture	starch	NCP[a]	cellulose	lignin	total dietary fiber
Chinese flowering cabbage	93.9 ± 0.36	0.080 ± 0.05	1.2 ± 0.2	0.60 ± 0.1	0.96 ± 1.5	2.8 ± 1.4
Chinese spinach, pointed leaf	92.5 ± 1.1	0.27 ± 0.1	1.5 ± 0.5	0.64 ± 0.1	0.13 ± 0.1	2.3 ± 0.7
Chinese spinach, rounded leaf	93.9 ± 0.36	0.73 ± 0.05	1.2 ± 0.1	0.51 ± 0.04	0.60 ± 0.06	2.3 ± 0.2
locally grown cucumber	95.9 ± 0.48	0.11 ± 0.01	0.72 ± 0.04	0.44 ± 0.03	0.080 ± 0.03	1.2 ± 0.1
water convolvulus	93.3 ± 1.2	0.087 ± 0.04	1.8 ± 0.4	0.98 ± 0.3	0.39 ± 0.2	3.2 ± 0.5
Chinese cabbage, big	95.0 ± 0.24	0.043 ± 0.02	0.94 ± 0.06	0.42 ± 0.04	0.080 ± 0.1	1.4 ± 0.2
Chinese cabbage, small	94.8 ± 1.3	0.047 ± 0.04	1.2 ± 0.4	0.54 ± 0.2	0.29 ± 0.09	2.0 ± 0.6
collard	91.3 ± 2.7	0.11 ± 0.02	1.9 ± 0.4	0.94 ± 0.2	0.20 ± 0.1	3.0 ± 0.6
local French bean	92.9 ± 1.4	0.25 ± 0.1	2.1 ± 0.5	0.87 ± 0.3	0.28 ± 0.2	3.2 ± 0.6
hairy gourd/cucumber	94.8 ± 0.73	0.30 ± 0.08	1.3 ± 0.2	0.61 ± 0.08	0.040 ± 0.02	1.9 ± 0.3
bitter gourd	95.2 ± 1.2	0.083 ± 0.04	1.6 ± 0.4	0.93 ± 0.3	0.20 ± 0.3	2.7 ± 0.9
local Chinese lettuce	90.2 ± 8.3	0.087 ± 0.06	2.1 ± 1.7	0.87 ± 0.6	0.43 ± 0.7	3.4 ± 2.9
sweet potato leaves	94.1 ± 0.33	0.087 ± 0.05	1.6 ± 0.1	0.81 ± 0.07	0.36 ± 0.4	2.8 ± 0.3
lady's finger	89.9 ± 1.8	0.52 ± 0.2	3.4 ± 0.2	0.98 ± 0.2	0.52 ± 0.2	4.9 ± 0.5
yambean tuber	89.2 ± 1.7	3.8 ± 0.9	1.7 ± 0.4	0.56 ± 0.04	0.043 ± 0.04	2.3 ± 0.4
waterchestnut	79.8 ± 1.1	5.6 ± 2.3	2.9 ± 0.3	0.70 ± 0.2	0	3.6 ± 0.2
purple eggplant	92.8 ± 0.93	0.34 ± 0.09	1.5 ± 0.2	0.87 ± 0.04	0.17 ± 0.1	2.5 ± 0.3
garland chrysanthemum leaves	94.0 ± 0.77	0.057 ± 0.03	1.3 ± 0.1	0.64 ± 0.05	0.40 ± 0.5	2.3 ± 0.7
snow pea, edible-podded	86.8 ± 1.6	1.3 ± 0.9	3.3 ± 1.1	1.1 ± 0.08	0.24 ± 0.4	4.6 ± 0.9
lotus tuber	85.2 ± 3.6	5.5 ± 4.5	0.64 ± 0.05	0.40 ± 0.5	1.0 ± 1.1	2.0 ± 1.9
stinkbean	74.8 ± 3.2	0.45 ± 0.2	4.5 ± 0.8	0.77 ± 0.04	0.31 ± 0.2	5.6 ± 1.0
oriental radish	95.2 ± 0.50	0.14 ± 0.04	1.1 ± 0.08	0.56 ± 0.05	0.037 ± 0.02	1.7 ± 0.1
old/brown cucumber	97.0 ± 0.21	0.047 ± 0.02	0.53 ± 0.03	0.40 ± 0.03	0.033 ± 0.01	0.96 ± 0.04
wax gourd	96.0 ± 0.14	0.19 ± 0.03	1.1 ± 0.04	0.61 ± 0.05	0.061 ± 0.1	1.8 ± 0.1

[a] Noncellulosic polysaccharides (individual values for uronic acids, pentoses, and hexoses can be made available on request).

of the vegetables found in this part of the world.

MATERIALS AND METHODS

All foodstuffs were purchased locally, in supermarkets and so-called "wet" markets (traditional morning markets selling fresh foods). Three samples of each vegetable were processed, and these were always purchased from different outlets over a period of 2–3 months, to allow for analytical results that would encompass the maximum physiological and processing variations.

The portions not normally consumed were trimmed off and weighed to give to an estimate of "refuse". The remainder was either freeze-dried or oven-dried to constant weight for an estimate of moisture.

A dried, weighed sample was then taken through the Southgate procedure for fiber (James and Theander, 1981). This yields figures for cellulose, noncellulosic polysaccharides, and lignin. Briefly, the alcohol-dry residue (after removal of free sugars and lipids) is gelatinized and digested with amyloglucosidase, which gives a measure of starch. It is then precipitated with ethanol and hydrolyzed with dilute acid to release hexoses, uronic acids, and pentoses from noncellulosic polysaccharides. The ethanol-dried residue is treated with 72% sulfuric acid to hydrolyze the glucosidic bonds in cellulose, leaving a residue designated as lignin. The sugars released at each stage are estimated by standard colorimetric methods, namely those of Bitter and Muir (1962) for uronic acids, Albaum and Umbreit (1947) for pentoses, and Roe (1955) for hexoses. In its earlier version, the Southgate method included a hot-water extraction to estimate pectins and gums, but according to the originator of the method (Southgate, 1984), the step is difficult to conduct in a reproducible manner and adds little to the value of the analysis as a whole.

One homogeneous sample of the green, leafy vegetable *Brassica chinesis* (pek chye) was put through the procedure three times to obtain an estimate of the analytical variance.

All chemicals were analytical grade.

RESULTS AND DISCUSSION

The triplicate analysis of pek chye gave coefficients of variation: cellulose, 3.0%; noncellulosic polysaccharides, 2.7%; lignin, 68%; starch, 24%. These represent an estimate of analytical variance, and it would be expected that the figures for the individual foodstuffs diversely purchased would show greater scatter, as is the case (Table II). For lignin the coefficient of variation is invariably over 50% and sometimes over 100%, emphasizing that its determination is the most difficult part of the assay. It represents the small residue of a multiple-stage procedure.

In Table I the vegetables are ranked in the order in which they are most extensively consumed in Singapore (Gourley, 1986). (The Western vegetables among the 50 most popular, as established by this dietary survey, were not analyzed.) It is evident that there is a considerable contribution of dietary fiber by the most popular vegetables. The stinkbean, *Pithecellobium jiringa*, has the largest quantity of total dietary fiber and noncellulosic polysaccharide; it comes only 47th in popularity, but in view of its cheapness, consumption might be encouraged by physicians in this area who wish to drastically enhance the intake of fiber by specific patients.

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Recovery of Protein-Rich Byproducts from Sweet Potato Stillage following Alcohol Distillation

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Sweet potato can yield 1000 gal of ethanol/acre compared with 250–300 gal/acre for corn. Sweet potatoes of normal, relatively high, and very high dry-matter contents were fermented to ethanol. Pectinase was necessary to decrease viscosity before fermentation for economic processing, especially for varieties of normal and relatively high dry-matter contents. Attained yield of ethanol was 90% of theoretical value. After ethanol was distilled, residual stillage was separated by screening and centrifugation into filter cake, centrifuged solids, and stillage solubles. Filter cake and centrifuged solids had crude protein contents (nitrogen × 6.25, dry basis) of 22–32% and 42–57%, respectively, and accounted for 44–85% and 0–17% of total sweet potato nitrogen. Sweet potatoes and their fermented products had 4.3–7.6 g of lysine/16 g of N and are expected to have good nutritional value. This practical method to ferment sweet potato for ethanol and to recover valuable protein-rich byproducts may have commercial potential.

Sweet potato is one of the most promising crops for energy production from biomass because it has a long growing season and can continue to increase in weight until it is harvested. The 5.5 tons/acre given in crop production statistics reflects only marketable yields for table use and is much lower than the potential total sweet potato yields. Jones et al. (1983) estimated yields of 570–760 and 712–1140 gal of ethanol/acre for Jewel and HiDry sweet potatoes, respectively. They believe that potential upper limits are higher than these estimates and that further improvements in dry-matter yields and conversion efficiencies are possible. Azhar and Hamdy (1981) reported alcohol fermentation of sweet potato in a membrane reactor. Matsuoka et al. (1982) carried out alcoholic fermentation of raw sweet potato in a one-step process. Chua et al. (1984) used low-temperature heating or no heating to convert sweet potato starch for ethanol fermentation. Practically no information is available, however, on yield and composition of fermentation residue from sweet potato after ethanol distillation. Optimum use of fermentation residues plays an important role in the commercial success

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