Dietary fibre content of Australian foods 2. Vegetables

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Data are presented on the content of non-starch polysaccharides and lignin in a number of fresh and processed vegetables. Relatively high fibre contents were found in haricot and red kidney beans and the smallest amounts in marrow and squash. Beans and corn had lower uronan and higher pentosan components in their dietary fibre than other vegetables. Comparisons with published data reveal some major differences in fibre content for some foods.

In 1986-87 the apparent consumption of fresh and processed vegetables in Australia was 136.2 kg per head, with potatoes (42%) and tomatoes (12.4%) together accounting for more than one half of the total (Australian Bureau of Statistics 1987). In diets similar to the Australian one, it has been estimated that vegetables contribute more to the daily intake of dietary fibre than do cereal based foods (Southgate & 1978). We have analysed a variety of commonly consumed vegetables for both the content and chemical composition of dietary fibre.

Materials and methods

Food samples

Samples were purchased on a single occasion either from Geelong supermarkets or from a wholesale vegetable supplier who was often able to provide details concerning the variety, growing locality and seasonal availability. Canned, frozen and dried samples were purchased from local supermarkets and were cooked according to the directions on the label. Fresh vegetables were cooked using methods described in the Commonsense Cookery Books 1 and 2 (NSW 1981 a,b). Single purchases of each food item were made and the edible portion only was analysed for dietary fibre. Generally 1 kg of each vegetable was cooked or otherwise prepared and sub-sampled by quartering and coning. The sub-sample (approximately 300 g) was freeze-dried to constant weight, comminuted and stored according to Jones & (1985). Because the analyses were performed on single samples purchased in Geelong, Victoria, the data presented here are indicative of vegetable type and should not be interpreted as definitive values of the mean fibre content of vegetables available throughout Australia.

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Analytical procedures

Moisture was determined by freeze drying. Fried mushrooms (10% fat as eaten) and fried onions (5% fat as eaten) were defatted with petroleum ether (bp 40-60°C) using a standard procedure (AOAC 1975) before analysing the residue for dietary fibre; other foods were not subject to a prior fat extraction.

Dietary fibre content was taken to be the sum of non-starch polysaccharides (NSP) and lignin. NSP was fractionated into cellulose, total non-cellulosic polysaccharides (TNCP) and non-cellulosic polysaccharides insoluble in an aqueous buffer at pH7 (INCP). The proportion of non-cellulosic polysaccharides soluble in aqueous buffer (SNCP) was obtained by difference (TNCP − INCP).

Lignin and uronic acids were determined according to Jones & (1985) but some modifications to the procedure for determining NSP were introduced. These involved the use of allose as internal standard and slightly different conditions for chromatography to those described by Englyst and Cummings (1984) in their modified method. The injector temperature was maintained at 270°C and not 250°C and the nitrogen flow rate was 20 mL/min instead of 45 mL/min. However we did not adopt the derivatisation procedure advocated by Englyst and Cummings (1984) who used N-methyl imidazole as catalyst since, in our hands, the alditol acetate mixture so obtained could not be adequately resolved because of a large 'tail' on the solvent peak. Englyst and Cummings also used dimethylsulphoxide to remove all the starch from their food samples. We were interested in routinely measuring the proportion of starch resistant to an initial amylase treatment (resistant starch, RS) and this is solubilised with dimethylsulphoxide; therefore we did not adopt this modification but continued to use their earlier method (Englyst & 1982).

Quality control of analyses

As an additional check on the intra-laboratory variation of our analytical procedures, a sample of freeze-dried pear was

routinely included with each batch of foods analysed, along with the AACC food grade soft white wheat bran used in our previous report (Jones & 1985). This was to provide an intra-laboratory control sample with a fibre content more representative of fruits and vegetables, because the chemical composition of fruit fibre is different from that of cereal fibre and may exhibit different analytical variance. The pears were homogenised, freeze-dried and stored frozen under nitrogen by K. James of the Armed Forces Food Science Establishment, Scottsdale, Tasmania, from whom samples can be obtained. A coefficient of variation for total dietary fibre of 1.25% (n = 6) was typical for this material.

Results and discussion

Vegetables, as eaten, vary both quantitatively and qualitatively in their dietary fibre content (Table 1). Vegetables with less than 1% fibre include marrow, lettuce, cucumber, squash and canned tomatoes. Amongst those with the highest values (3-8%) were haricot beans, red kidney beans, garden peas, canned mixed beans, swede, parsnip and Brassica vegetables. The fibre content of most vegetables fell within the rather narrow range of 1 to 4%.

In general there was great similarity in the proportions of lignin, cellulose and TNCP in fibre from different vegetables. Expressed as a proportion of total dietary fibre,

Table 1. Dietary fibre content of vegetables (g/100 g dried food except last column which is g/100 g food as eaten).

Vegetable	Moisture	INCP*				TNCP†				Cellulose	Lignin	Resistant Starch	Dietary fibre excluding resistant starch	Dietary fibre in food as eaten excluding resistant starch
		Hexoses	Pentoses	Uronic acids	Total INCP	Hexoses	Pentoses	Uronic acids	Total NCP					
Artichoke, Jerusalem (boiled)	82	0.76	0.92	0.25	1.93	7.26	2.30	2.50	(75)‡ 12.1	(20)‡ 3.32	(5)‡ 0.82	0	16.2	2.9
Asparagus (boiled)	93	2.01	4.55	0.39	6.95	10.54	6.52	3.82	(73) 20.9	(20) 5.89	(7) 1.92	0	28.7	2.0
Aubergine (baked)	85	0.64	1.58	0.46	2.68	6.08	3.41	5.85	(58) 15.3	(30) 7.80	(12) 3.04	0	26.1	3.9
Beans, stringless, round (raw)	88	2.01	1.53	0.38	3.92	3.12	2.31	5.27	(57) 10.70	(37) 6.88	(6) 1.07	0.29	18.7	2.2
Beans, stringless, round (boiled)	89	5.85	1.48	0.45	7.78	5.67	2.57	7.74	(81) 16.0	(11) 2.14	(8) 1.69	1.27	19.8	2.2
Beans, red kidney (steamed and boiled)	67	0.94	3.88	0.76	5.58	3.45	7.44	2.77	(68) 13.7	(23) 4.71	(9) 1.80	2.96	20.2	6.7
Beans, Haricot (steamed and boiled)	60	0.81	3.11	0.52	4.42	2.20	9.31	2.81	(68) 14.3	(23) 4.84	(9) 1.89	4.13	21.0	8.4
Beans, Heinz baked (canned)	77	0.58	0.92	0.12	1.62	1.94	4.19	1.97	(63) 8.10	(26) 3.31	(11) 1.38	2.58	12.8	2.9
Beans, Edgell 4 bean mix (canned)	68	0.65	1.72	0.30	2.67	1.95	3.79	1.68	(53) 7.42	(30) 4.12	(17) 2.36	3.77	13.9	4.4
Beetroot, Edgell (canned)	86	0.64	1.83	0.39	2.86	2.63	6.13	4.48	(64) 13.2	(30) 6.14	(6) 1.12	0	20.5	2.9
Broccoli (boiled)	90	3.66	4.48	0.58	8.72	8.00	9.73	9.46	(76) 27.2	(20) 7.14	(4) 1.29	0	35.6	3.6
Brussell sprout (boiled)	88	1.67	2.02	0.54	4.23	4.56	6.62	8.19	(73) 19.4	(20) 5.37	(7) 1.84	0	26.6	3.2
Cabbage (*Ballhead*, boiled)	88	1.97	3.67	0.54	6.18	4.11	6.22	6.50	(62) 16.8	(34) 9.15	(4) 1.07	0	27.1	3.2
Cabbage (*Ballhead*, boiled)	91	1.14	1.37	0.45	2.96	4.05	4.88	6.75	(58) 15.7	(34) 8.98	(8) 2.21	0	26.9	2.4
Cabbage (*Savoy* boiled)	92	1.65	1.81	0.43	3.89	4.62	3.62	4.68	(59) 12.9	(32) 7.11	(9) 1.88	0	21.9	1.8
Carrot (*Western Red*, raw, unpeeled)	87	2.05	0.55	0.29	2.89	7.53	3.03	7.32	(71) 17.9	(24) 6.06	(5) 1.39	tr	25.3	3.3
Carrot (*Western Red*, raw, peeled)	88	1.42	0.55	0.26	2.23	5.64	2.84	7.79	(69) 16.3	(27) 6.33	(4) 0.92	0.22	23.5	2.8
Carrot (*Western Red*, boiled, unpeeled)	88	2.51	0.56	0.36	3.43	7.44	3.10	7.78	(69) 18.3	(26) 6.73	(5) 1.29	0.10	26.3	3.2
Carrot (*Western Red*, boiled, peeled)	86	1.60	0.44	0.36	2.40	6.79	3.63	6.33	(72) 16.8	(25) 5.97	(3) 0.73	0.22	23.5	3.3
Cauliflower (*Paleface*, raw)	91	1.88	2.07	0.51	4.46	4.94	4.59	6.85	(64) 16.4	(35) 8.94	(1) 0.28	0	25.6	2.3
Cauliflower (*Paleface*, boiled)	92	1.67	1.86	0.57	4.10	4.65	4.38	6.73	(66) 15.8	(32) 7.82	(2) 0.51	0.27	24.1	1.9
Celery (raw)	95	0.87	1.27	0.58	2.72	3.35	2.92	7.24	(54) 13.5	(41) 10.4	(5) 1.26	tr	25.2	1.3
Choko (boiled)	94	1.51	1.02	0.20	2.73	4.06	1.47	2.59	(46) 8.12	(49) 8.57	(5) 0.80	0	17.5	1.0

* INCP = Insoluble non-cellulosic polysaccharides
† TNCP = Total non-cellulosic polysaccharides.
‡ Values in parentheses are % of total dietary fibre

Table 1. Dietary fibre content of vegetables (g/100 g dried food except last column which is g/100 g food as eaten) — Continued.

Vegetable	Moisture	INCP*				TNCP†				Cellulose	Lignin	Resistant Starch	Dietary fibre excluding resistant starch	Dietary fibre in food as eaten excluding resistant starch
		Hexoses	Pentoses	Uronic acids	Total INCP	Hexoses	Pentoses	Uronic acids	Total NCP					
Cucumber (unpeeled)	96	1.41	2.87	0.73	5.01	2.59	2.77	5.28	(46) 10.6	(36) 8.18	(18) 4.18	0	23.0	0.92
Cucumber (peeled)	96	0.87	3.36	1.00	5.23	1.87	3.59	4.41	(45) 9.87	(36) 7.74	(19) 4.09	0	21.7	0.87
Leek (boiled)	92	2.67	2.68	0.44	5.79	6.10	4.59	7.53	(57) 18.2	(36) 11.6	(7) 2.40	tr	32.2	2.6
Lettuce	95	1.14	1.41	0.50	3.05	2.41	1.78	6.26	(59) 10.5	(34) 6.20	(7) 1.26	0	17.9	0.9
Marrow (boiled)	95	0.27	2.60	0.72	3.59	1.88	2.39	4.73	(75) 9.00	(13) 1.60	(12) 1.44	0.99	12.0	0.6
Mushroom (fried)	79	8.21	0.29	0.08	8.58	13.9	0.42	0.09	(78) 14.4	(17) 3.12	(5) 0.89	0	18.4	1.9
Onion (*Creamy Gold*, raw)	90	0.91	0.42	0.18	1.51	3.43	0.39	4.49	(59) 8.31	(32) 4.56	(9) 1.23	tr	14.1	1.4
Onion (*Creamy Gold*, fried)	79	0.80	0.37	0.11	1.28	3.71	0.59	5.67	(64) 9.97	(28) 4.41	(8) 1.24	0	15.6	2.5
Onion, spring (raw)	91	1.85	1.33	0.36	3.54	5.14	2.36	8.84	(75) 16.3	(14) 3.05	(11) 2.49	0	21.9	2.0
Parsnip (boiled)	85	1.09	1.89	0.43	3.41	4.13	4.77	8.13	(72) 17.0	(23) 5.41	(5) 1.29	0.61	23.7	3.6
Peas, canned (boiled)	81	0.48	2.72	0.63	3.83	1.00	5.28	2.84	(54) 9.12	(34) 5.80	(12) 2.07	6.13	17.0	3.2
Peas, frozen (boiled)	80	0.34	3.36	0.87	4.57	2.45	5.41	3.17	(69) 11.0	(18) 2.86	(13) 2.11	6.71	16.0	3.2
Peas, garden (raw)	76	0.93	0.50	0.57	2.00	2.51	6.47	3.17	(55) 12.2	(38) 8.54	(7) 1.44	4.77	22.2	5.3
Peas, garden (boiled)	77	0.98	0.59	0.66	2.23	3.52	7.10	2.87	(60) 13.5	(33) 7.29	(7) 1.59	7.24	22.4	5.2
Pepper, green (raw)	93	1.54	1.26	0.15	2.95	3.87	1.77	6.96	(55) 12.6	(34) 7.86	(11) 2.55	0	23.0	1.6
Pumpkin, butternut (boiled)	85	0.62	0.41	0.33	1.36	1.14	0.53	4.39	(47) 6.06	(51) 6.65	(2) 0.24	0.60	13.0	2.0
Pumpkin, (*Qld Blue*, boiled)	89	2.35	0.86	0.42	3.62	3.21	0.59	5.46	(47) 9.26	(50) 9.78	(3) 0.70	0	19.7	2.2
Radish (raw)	94	2.89	1.29	0.51	4.69	3.98	2.46	6.99	(79) 13.4	(11) 1.89	(10) 1.66	1.84	17.0	1.0
Silverbeet (boiled)	90	2.31	4.86	1.02	8.19	5.48	8.30	7.44	(75) 21.2	(21) 5.98	(4) 1.22	0	28.4	2.8
Spinach (boiled)	91	2.15	4.08	0.84	7.07	3.28	5.54	6.02	(65) 14.84	(26) 5.88	(9) 2.02	0	22.7	2.0
Squash (boiled)	95	3.03	1.12	0.76	4.91	3.05	2.50	4.47	(81) 10.0	(4) 0.53	(15) 1.91	1.70	12.4	0.62
Swede (boiled)	88	2.43	3.58	0.53	6.54	5.50	7.01	10.7	(72) 23.2	(24) 7.60	(4) 1.23	0.22	32.0	3.8
Sweet corn (boiled on-the-cob)	72	0.38	1.91	0.08	2.37	0.61	2.88	0.24	(61) 3.73	(26) 1.56	(13) 0.80	1.02	6.09	1.7
Sweet potato (boiled, peeled)	72	1.15	0.41	0.35	1.91	3.06	1.09	2.04	(84) 6.19	(4) 0.26	(12) 0.88	3.14	7.33	2.1
Tomato (SPC canned)	92	1.10	0.56	0.11	1.77	1.36	0.71	3.46	(49) 5.53	(30) 3.38	(21) 2.36	0.08	11.3	0.91
Tomato, (*Floradade*, whole, raw)	95	1.67	1.15	0.25	3.07	5.17	2.86	6.60	(54) 14.6	(37) 10.0	(9) 2.24	0	26.9	1.3
Turnip, white (boiled)	92	2.15	2.47	0.45	5.07	5.42	4.88	7.68	(57) 18.0	(40) 12.5	(3) 0.98	0	31.5	2.5
Zucchini (boiled)	94	3.82	1.65	0.56	6.03	6.34	2.68	6.05	(88) 15.1	(6) 1.13	(6) 1.04	0.83	17.2	1.0
AACC Wheat Bran (n=23)	8	3.05	26.1	0.37	29.9	4.79	26.5	0.75	(75) 31.8	(17) 7.70	(8) 3.32	0.69	42.6	39.2
Tasmania Pear Standard. (n=9)	0	1.31	4.15	0.44	5.90	1.42	6.17	2.97	(64) 10.6	(23) 3.88	(13) 2.12	tr	16.6	—

* INCP = Insoluble non-cellulosic polysaccharides

† TNCP = Total non-cellulosic polysaccharides.

‡ Values in parentheses are % of total dietary fibre

lignin made up 5-10%, celluluse 20-40% and TNCP 60-75%. Within the TNCP the proportions of SNCP and INCP were variable. The majority of vegetables had substantially more SNCP than INCP; the highest proportions were found in okra, taro, artichoke, aubergine and fried onion. In mushrooms and corn there was more INCP than SNCP. This differentiation may be important because, with the exception of corn, the bulk of the uronide, and a substantial but varying proportion of the pentose-containing polysaccharides, are contained in the SNCP fraction. Pentosan and uronan polymers have been shown to stimulate gas production in the human large intestine (Marthinsen & Fleming 1982), and SNCP may therefore represent a more readily fermentable form of dietary fibre.

The fibre in beans was characterised by a lower proportion of uronans and a higher proportion of pentose-containing fibre polymers than other vegetables. A positive correlation has been demonstrated between the pentose content of food fibre and stool mass in human subjects (Cummings & 1978); consequently beans in diets may be important contributors to stool bulking. Corn (on the cob, boiled) had a similar fibre composition to beans but contained substantially smaller quantities of fibre in the edible portion because of high water content. Corn husks have been shown to be markedly resistant to degradation in the human large intestine (Olson & 1983). Peas had proportions of uronide and pentose sugars in the fibre which were intermediate between those of beans and most other vegetables.

Mushroom fibre was different from that of all other vegetables. It is more simple in composition, consisting largely of TNCP hexoses together with a smaller proportion of cellulose. Artichokes and asparagus differ from the other vegetables in that they contain significantly more hexoses in the TNCP fraction. Canned and frozen peas had substantially less dietary fibre than garden peas, probably owing to differences in seed maturity and variety.

The effect of preparation and cooking of vegetables had predictable results. Peeling reduced the fibre content by between 15% (carrots), and 7% (cucumber). Similarly, canned tomatoes had less fibre than the fresh vegetable because the skin is removed. Boiling or baking almost always caused an increase in the proportion of INCP. Lignin values were sometimes increased, perhaps due to the formation of artifacts that analysed as lignin.

Anomalous findings were the higher values for dietary fibre in fried onions compared with raw onions and the differences in cellulose and TNCP between boiled and raw stringless beans. Much of the difference was attributable to changes in hexose content. Whether these differences reflect real sample variation or are due to analytical errors is not clear. The cucumber (unpeeled), onion (raw), marrow and Queensland Blue pumpkin samples gave values for pentose sugars which were higher in the insoluble non-cellulosic polysaccharide fraction (INCP) than in the total non-cellulosic polysaccharide fraction (TNCP). This is analytically anomalous since values for total TNCP must be more than or at least equal to the values for INCP because the latter is a component of the former. We considered that the differences between INCP and TNCP for these foods were small enough to be within experimental error.

Little if any resistant starch was encountered except in beans, peas, marrow, sweet potato, squash, radish and corn. If resistant starch is considered as part of a dietary fibre some of these vegetables would have levels of dietary fibre similar to wholegrain cereal products. However since freeze-drying of the samples during preparation for analysis may cause starch to become crystalline these data must be considered with caution.

The data were compared with published values for dietary fibre content of foods in the UK (Paul & Southgate 1978), West Germany (Souci & 1986) and Australia (Wills & 1984a, b, Greenfield & 1985, Wills & 1986); there was agreement for many vegetables within about 25% of the mean values. Larger discrepancies were observed for foods in some data bases but not in others. For example, the fibre content of stringless beans as determined by us was in good agreement with the German but not the British data. It is not clear whether these discrepancies are real or apparent since they could be influenced by a number of factors such as sample heterogeneity, variations in analytical protocol and interference by residual starch.

Englyst in Cambridge, UK, has published data for NSP in some vegetables (Englyst & 1982, Englyst & Cummings 1984, Englyst & Cummings 1988) which are in reasonable agreement with our results for haricot beans (7.6 vs 6.9). Brussels sprouts (3.0 vs 3.3); carrot (3.1 vs 3.1), but in poor agreement for tomato (1.3 vs 0.78) and lettuce (0.84 vs 1.3). The values in parenthesis are g/100 g as eaten and our data are given first.

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