Dietary fibre content of Australian foods. 1. Potatoes

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Four varieties of potatoes were analysed for their content of dietary fibre estimated as the sum of non-starch polysaccharides plus lignin. Peeled, boiled potatoes contained from 0.87 to 1.31 g dietary fibre per 100 g. Unpeeled potatoes contained more dietary fibre than peeled potatoes. Cooking seemed to have little effect on the content of non-starch polysaccharides; but the amount of starch resistant to α-amylase hydrolysis was significantly increased.

Dietary fibre has attained a place in human nutrition at least as significant as any of the essential nutrients. A deficiency can lead to unnecessary morbidity (Wahlqvist *et al.* 1981) and could reduce life expectancy (Kromhout *et al.* 1982). Since the original postulates of Burkitt, Walker & Painter (1972) and Trowell (1974) there have been considerable advances in our knowledge of the effects of dietary fibre on human health (Eastwood & Passmore 1983).

Dietary fibre in foods is a complex matrix made up largely of carbohydrate polymers of vegetable cell wall origin which are considered to be undigestible by endogenous enzymes. Also included in this definition are the food additive carbohydrate polymers used as modifying agents in some processed foods. The precise role of dietary fibre is still uncertain, but it is clear that different fibre fractions have different physiological effects (Cummings *et al.* 1978) and dietary intakes of cellulose and some sugars of the non-starch polysaccharides (NSP) are negatively correlated with colon cancer incidence (Englyst *et al.* 1982a). Data on the fibre content of foods are of varying usefulness in nutritional studies (Englyst *et al.* 1982a) because a number of different analytical protocols have been used, many of which are known to be inaccurate (Southgate 1976, Englyst, Anderson & Cummings 1983). In recent years, workers at the MRC Dunn Nutritional Laboratory, Cambridge, England, have developed more accurate methods for the estimation of dietary fibre in food which also provide information on the chemical composition of the carbohydrate polymers (Englyst, Wiggins & Cummings 1982b). We have used the method of Englyst *et al.* (1982b) in a survey of some Australian foods. In view of the high *per caput* consumption of potatoes compared with other vegetables (Australian Bureau of Statistics 1982) the present paper deals exclusively with the dietary fibre content of a number of varieties of potatoes which have been processed in different ways.

Materials and methods

Treatment of potato samples

Four of the most commonly consumed varieties of potatoes grown in Victoria (Australian Bureau of Statistics 1980) were obtained from a local Geelong, Vic. wholesaler. The samples were Pontiac (3 kg), Sequoia (3 kg), Coliban (3 kg) and Sebago (10 kg). Each variety was boiled with and without peeling; in addition Sebago potatoes were baked, roasted and fried in oil according to the Commonsense Cookery Books 1 and 2 (1981). Where a comparison was to be made between potatoes with and without the skin, several potatoes were cut into halves and halves of individual potatoes were pooled to provide the two samples. Potatoes were selected at random for each of the treatments and 400 g subsamples were frozen at −18°C immediately after cooking before freeze drying. The water content was calculated from the change in weight after freeze drying to constant weight. Dried samples were comminuted in a laboratory cutter mill (model 579AA, Anax, London) to pass through a 1 mm mesh sieve. The powders were freeze dried to constant weight to remove water absorbed during milling, then stored in screw-top glass containers and stored in a desiccator over silica gel until required for analysis.

The contents of two 200 g packets of plain crinkle cut potato crisps (Arnotts), purchased from a supermarket, were combined, dried and comminuted as above. The potato crisps and fried potato chips were defatted (petroleum ether, b.p. 40°–60°C) using a standard procedure (AOAC 1975).

Analytical procedures

Dietary fibre content was taken to be the sum of lignin and non-starch polysaccharides (NSP) estimated by separate analytical procedures. Lignin was estimated by permanganate oxidation of an acid detergent fibre food residue as described by Southgate (1976). NSP are the polysaccharides remaining in a food after the enzymic removal of starch and were measured according to Englyst *et al.* (1982b). The NSP are fractionated on the basis of their solubilities, in pH 7 buffer, 5M and 12M sulphuric acid. The polymers in each fraction are hydrolysed to their component monomers with acid. The neutral sugars released are measured by gas chromatography as alditol acetates; uronides are measured colourimetrically. This permits the estimation of total NSP, non-cellulosic non-starch polysaccharides (NCP) comprising uronides and pentose polymers and starch which is resistant to the initial amylase treatment (resistant starch). Resistant starch (RS) is determined by treating the residue which remains after an initial amylase hydrolysis with a hot 2M potassium hydroxide solution followed by a further amylase digestion.

Slight modifications to the method of Englyst *et al.* (1982b) were required. The fractionation was carried out in 50 mL screw-capped polypropylene centrifuge tubes rather than glass tubes. Also, during the enzymic hydrolysis of starch the tube contents were mixed using teflon-coated stirrer bars (14 tubes conveniently fit into a 2 L beaker on a magnetic stirrer which was placed in a 37°C incubator overnight). To improve the separation of residues from supernatants, the tubes were always centrifuged at 20 000 rpm for 20 min. This resulted in a firm 'plug' of material and helped minimise losses during aspiration of the supernatants. Particles adhering to the walls of the centrifuge tube were scraped down with glass rods which had been treated with a silanising solution. Derivatisation of the sugars was performed in McCartney bottles and evaporations were conducted in an oven at 45°C under a stream of nitrogen. It was found necessary to carry out the acetylation in the presence of pyridine

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Table 1. Dietary fibre content of some foods

Sample	Moisture content (%)	I-NCP[1] (g/100g dried food)				T-NCP[2] (g/100g dried food)				Cellulose (g/100g dried food)	Lignin (g/100g dried food)	Total dietary fibre in dried food (g/100g)	Resistant starch (RS) (g/100g dried food)	Total dietary fibre in foods as eaten excluding RS (g/100g)
		Hexose	Pentose	Uronic Acids	Total I-NCP	Hexose	Pentose	Uronic Acids	Total T-NCP					
AACC Wheat bran[3]	8	1.96	24.0	0.48	26.4	3.88	25.6	0.81	30.3	8.57	2.58	41.5	0.8	38.1
Potatoes														
Variety Sebago, raw (no skin)	82	2.09	0.28	0.10	2.47	1.89	0.45	1.60	3.94	1.77	0.20	5.91	0.31	1.06
Variety Sebago, raw (with skin)	82	0.30	0.23	tr	0.53	1.77	0.41	1.71	3.89	2.18	0.39	6.46	tr	1.16
Variety Sebago boiled (no skin)	82	0.50	0.28	0.10	0.88	2.81	0.47	1.35	4.63	2.03	0.60	7.26	2.89	1.31
Variety Sebago, boiled (with skin)	80	0.96	0.37	0.10	1.43	3.35	0.63	1.14	5.12	1.16	0.76	7.04	3.27	1.41
Variety Sebago, baked in skin (flesh only)	81	0.58	0.11	tr	0.69	1.91	0.36	1.03	3.31	1.81	0.55	5.66	1.73	1.07
Variety Sebago, baked in skin(whole potato)	79	0.30	0.21	0.14	0.65	1.64	0.46	1.51	3.61	1.62	0.65	5.88	2.64	1.23
Variety Sebago, roasted (no skin)	70	0.34	0.20	0.09	0.63	1.66	0.40	1.09	3.15	1.70	0.94	5.79	2.08	1.74
Variety Sebago[4], peeled, chipped & deep fat fried	66	1.26	1.12	0.13	2.51	2.28	0.40	1.18	3.86	1.59	0.65	6.10	1.09	1.96
Variety Coliban, boiled (no skin)	76	0.18	0.11	tr	0.29	1.15	0.27	0.60	2.02	1.20	0.40	3.62	2.22	0.87
Variety Coliban, boiled (with skin)	77	0.23	0.21	0.12	0.56	1.30	0.40	0.84	2.54	1.62	0.68	4.84	2.07	1.11
Variety Pontiac, boiled (no skin)	81	0.33	0.29	0.06	0.68	1.67	0.44	0.89	3.00	1.41	0.46	4.87	2.38	0.92
Variety Pontiac, boiled (with skin)	81	1.32	0.42	0.08	1.82	1.59	0.68	0.94	3.21	1.84	0.69	5.74	2.41	1.09
Variety Sequoia, boiled (no skin)	81	0.26	0.21	0.04	0.51	1.58	0.45	1.24	3.27	2.45	0.45	6.17	2.87	1.17
Variety Sequoia, boiled (with skin)	79	0.76	0.26	0.09	1.11	1.84	0.51	1.84	4.19	2.75	0.71	7.65	2.57	1.60
Potato crisps[5] (salted, crinkle cut)	1	0.24	0.22	tr	0.46	2.69	0.37	1.02	4.09	1.38	0.24	5.70	0.1	3.88

1 I-NCP: non-cellulosic, non-starch polysaccharides insoluble in 0.2M phosphate buffer (pH7)
2 T-NCP: total non-cellulosic, non-starch polysaccharides in food samples
3 Values are the mean of quadruplicate analyses carried out at different times
4 Contain 5.4% fat
5 Contain 31% fat

Table 2. Comparison of results for potato non-starch polysaccharide (NSP) composition

Potato	Author	Composition of neutral NSP (%)					
		Rhamnose	Arabinose	Xylose	Mannose	Galactose	Glucose
Unknown variety, raw	Englyst *et al.* (1982b)	3.6	8.3	2.4	1.5	39.1	45.5
Raw Sebago (no skin)	Present paper	2.4	8.5	2.4	1.5	37.9	47.2
Sebago, boiled (no skin)	As above	tr.	7.0	1.9	1.9	30.5	58.7
Pontiac, boiled (no skin)	As above	3.7	9.1	3.4	2.3	39.2	42.3
Sequoia, boiled (no skin)	As above	1.1	7.6	2.4	1.1	33.0	54.6
Coliban, boiled (no skin)	As above	1.9	8.0	2.3	2.3	39.6	45.8

(1 mL pyridine + 1 mL acetic anhydride) at 120°C overnight, following which the reaction mixture was evaporated to dryness and the residue redissolved in ethyl acetate for injection into the chromatograph. Using these modifications, reproducible results were obtained. Chromatography was carried out with a Varian model 3700, the only modification being that the column and detector temperatures were 225°C and 300°C respectively. Peaks were measured with a Hewlett Packard integrator model 3390A and quantitated against myo-inositol as the internal standard. When erythritol was used as an internal standard the results for both pentose acetates and hexose acetates were more variable than when myo-inositol was used. The reasons for these differences were not clear since under our conditions the acetylation appeared to proceed to completion. Uronic acids were determined using a colourimetric technique (Scott 1979) in which close control of the reaction time was required to produce reproducible results (Hutchison personal communication).

Food samples with a relatively high fat content (>5%) were extracted with petroleum ether before analysis as it was found that in the case of fried potato chips an un-extracted sample gave values for hexose in the total non-cellulose (T-NCP) fraction that was 150% higher than in a similar fat-extracted sample; presumably this was caused by fat interfering with the enzymatic starch hydrolysis.

Quality control of analyses

Unlike analyses for other nutrients in food, it is not possible to obtain a measure of the accuracy of a dietary fibre analysis by comparison with a reference substance of known purity. Also, whilst intra-laboratory variation can be quite satisfactory with this type of analysis, the inter-laboratory differences can be quite large (Southgate & White 1981). A sample of AACC certified food grade soft white bran (obtained from the American

Association of Cereal Chemists, St Paul, MN, USA) was used as a reference material for each batch of food samples. A coefficient of variation of 6.8% (n = 10) was obtained for total dietary fibre content.

Results and discussion

The results are given in Table 1. Values for individual sugars and uronic acids are expressed as their weight in food polymers. The values for different varieties of boiled potato (no skin) range from 7.26 to 3.62 g dietary fibre/100 g (dried potato) and these are in reasonable agreement with the value of 4.84 g/100 g published by Englyst *et al.* (1982b). The composition of sugars in the neutral non-starch polysaccharides (NSP) of the raw Sebago (no skin) cell wall is also very similar to that obtained by the British investigators as shown in Table 2. A comparison of the two tables shows that whilst the total dietary fibre content exhibits considerable differences between varieties of potato, the composition of the NSP remains reasonably constant. Also, the way in which potatoes are cooked has little effect on the fibre content except perhaps to increase the proportion of I-NCP, i.e. render the non-starch, non-cellulose polymers less soluble in phosphate buffer at pH 7.

Of interest is the content of starch resistant (RS) to hydrolysis by hog pancreatic α-amylase and pullulanase since this is present in only small quantities in raw potato but amounts to 30–50% by weight of the total dietary fibre content in cooked potato. Englyst *et al.* (1982b, 1983) proposed that this starch is produced as a result of subjecting foods to heat and/or dehydration processes, conferring a more ordered structure on the starch molecules which is less amenable to enzyme digestion. The effect of this is to cause an overestimate of dietary fibre content by methods that do not take account of these changes. Whether or not this resistant starch is digested in the human small intestine or passes unchanged into the colon is not known. If the latter, then RS should be considered as a part of dietary fibre since like fibre it may have significant effects on health mediated *via* the colon (Cummings 1983).

One apparently inconsistent result is the finding of more dietary fibre in the Sebago potato boiled with no skin than in the sample boiled with skin. Cell wall polymers are found in higher concentrations in the skin of potatoes than in the centre of the tuber (Warren & Woodman 1973, Van Soest 1978). An examination of the data showed that the values for glucose in the T-NCP fraction were higher in the sample with no skin. This could not be attributed to resistant starch content since all the results were corrected for this as a matter of routine. An alternative explanation could be that the samples analysed may not have been representative. The portion taken for analysis using the present technique weighs only 300 mg and although every precaution was taken to obtain a representative sample there is a risk that the sampling errors could be large. Also, since the distribution of dietary fibre within a potato is not uniform, different sized potatoes have different amounts of dietary fibre depending on the amount of skin included. For example a 100 g spherical potato has a surface area/weight ratio of 1.03 whereas a 500 g spherical potato has a ratio of 0.60.

The precise physiological role of dietary fibre components has yet to be established. However, the use of data such as those presented in the present paper, which gives information about the individual components that comprise dietary fibre, may help in differentiating the role of individual polymers in human health.

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