ELSEVIER

Food Chemistry 64 (1999) 445–450

Food Chemistry

Dietary fibre in Hungarian foods measured by the Englyst NSP procedure and the AOAC Prosky procedure: a comparison study

M. Kontraszti[a], G.J. Hudson[b,*], H.N. Englyst[b]

[a]*National Institute of Food Hygiene and Nutrition, Budapest, Hungary*
[b]*MRC Dunn Clinical Nutrition Centre, Hills Road, Cambridge CB2 2DH, UK*

Received 13 September 1996; received in revised form 30 June 1998; accepted 31 July 1998

Abstract

Seventeen individual Hungarian foods and ten duplicate meals were analysed for dietary fibre by two current methods; the Englyst procedure (an enzymic-chemical method) for measuring dietary fibre as plant cell-wall non-starch polysaccharides (NSP) and the Prosky procedure (an enzymic-gravimetric method). The results obtained by these two methods are compared. The values obtained by the Prosky method are higher than those obtained by the Englyst method for 16 of the 17 individual foods and for all of the meal samples. National dietary guidelines recommend an increased intake of dietary fibre in the form of fruits, vegetables and whole grains. NSP values for unfortified plant foods provide a reliable marker for the cell-wall material present in the recommended, largely unrefined, plant foods. The Prosky values can represent the measurement of a range of materials formed during food processing and thus do not serve as a reliable guide to the composition of food products or the recommended, naturally occurring high-fibre diet.

Keywords: NSP, non-starch polysaccharides; RS, resistant starch; Fibre intake; Englyst procedure; Prosky procedure

1. Introduction

Two of the widely used methods for measuring dietary fibre are the Englyst enzymic-chemical method (Englyst, Quigley & Hudson, 1994; Quigley & Englyst, 1994) for the measurement of plant cell-wall non-starch polysaccharides (NSP) and the Prosky enzymic-gravimetric method (Prosky, Asp, Schweizer, DeVries & Furda, 1988), which measures a residue of unknown composition. In the Englyst procedure, starch is removed completely by dispersion and enzymic hydrolysis before precipitation of the NSP, which are measured directly as their component sugars after hydrolysis of the polysaccharides. In the Prosky procedure, there is an enzymic starch hydrolysis step but the starch dispersal step is inefficient and some starch remains unhydrolysed. The weight of the ethanol-insoluble residue is determined and corrections are made for the ash content and crude protein (total nitrogen × 6.25) content but the remaining material, which may include some starch, is not identified.

This study compares the results obtained by these two methods for 17 individual foods and for ten duplicate meals collected in Hungary. The Prosky measurements were made in Budapest and the NSP measurements were made in Cambridge.

The stated objectives of the Englyst and the Prosky methods are different, and different values are therefore to be expected. The aim of the Englyst procedure is to measure plant cell-wall NSP. The aim of the Prosky procedure is to measure the sum of indigestible polysaccharides and lignin, and is thus not confined to carbohydrates. An explanation is given for the differences between the values obtained by the analysis of some Hungarian foods by the Englyst method and by the Prosky method. The implications of using the different values are discussed, particularly with respect to the calculation of "dietary fibre" intakes and the information provided to the consumer.

* Corresponding author.

0308-8146/99/$—see front matter
PII: S0308-8146(98)00188-5

2. Materials and methods

2.1. Samples

2.1.1. Individual foods

Individual food samples ($n=17$) were collected and prepared in Hungary. All samples were washed, prepared as ready for cooking (i.e. peeled, etc. but not cooked) and dried at 70°C overnight, then milled to a particle size of less than 0.5 mm.

2.1.2. Diet samples

Duplicate whole meals ($n=10$) were collected in Hungary on ten consecutive days (Table 1) as part of a survey carried out by the Hungarian National Institute of Food Hygiene and Nutrition in the summer in colleges in different parts of the country. These are typical Hungarian meals, and the same meals were eaten by both students and teachers.

Each day's food collection was pooled and homogenised. Samples of ~85 g were removed, dried at 70°C overnight, defatted with 3 × 100 ml of carbon tetrachloride and then dried at room temperature. Portions (5 g) of the defatted sample were extracted twice with 80% (v/v) ethanol and dried at room temperature before analysis.

Table 1
Content and amount of the ten daily meal collections

Sample	Meal	Foods (total wet weight)
1	Breakfast	Cocoa, Plain cake
	Lunch	Mushroom soup, potato pastry, paprika salad
	Dinner	Cabbage in tomato sauce with fried meat
		(1850 g)
2	Breakfast	Tea, cake
	Lunch	Cauliflower soup, rice with stew
	Dinner	Tea, cake
		(1700 g)
3	Breakfast	Milk, honey, cake
	Lunch	Breaded cutlet, cabbage salad
	Dinner	"Letsho"/paprika, tomato, onion
		(1850 g)
4	Breakfast	Tea, egg, bread, paprika
	Lunch	Meat with vegetable
	Dinner	Stew with noodles, beetroot
		(1850 g)
5	Breakfast	Tea, cake, salami
	Lunch	Bean soup, pastry
	Dinner	–
		(850 g)
6	Breakfast	Tea, salami, cake
	Lunch	Vegetable soup, pastry with cabbage
	Dinner	Meat, paprika salad
		(1600 g)
7	Breakfast	Milk, cake
	Lunch	Kohlrabi soup, tomato sauce, meat
	Dinner	Milk, cake
		(1800 g)
8	Breakfast	Tea, buttered roll, paprika, tomato
	Lunch	Stew, rice, beetroot
	Dinner	Spinach, meat
		(1400 g)
9	Breakfast	Cocoa, cake
	Lunch	Green pea soup, chicken, potato, cabbage salad
	Dinner	Pastry
		(1700 g)
10	Breakfast	Tea, cake
	Lunch	Vegetable soup, apple cake
	Dinner	–
		(1100 g)

2.2. Englyst procedure with gas–liquid chromatography (GLC) end-point

The Englyst NSP procedure with gas–liquid chromatography end-point measurement of neutral sugars as alditol acetate derivatives and colorimetric measurement of uronic acids was as published (Englyst, Quigley & Hudson, 1994). Samples were analysed in duplicate, and haricot bean reference material was included in each analytical run.

2.3. Prosky method

Reagents and conditions were as published (Prosky, Asp, Schweizer, DeVries & Furda, 1988), with all samples analysed in duplicate. Following the protocol, one duplicate was used to determine total nitrogen by the Kjeldahl method, using a Kjeltec Autoanalyser 1030 (TECATOR, Höganös, Sweden). Crude protein was calculated as total nitrogen × 6.25. The other duplicate was used to determine total ash as the inorganic material remaining after heating the analytical residue at 525°C for 16 h in a muffle furnace.

3. Results

3.1. Individual food samples

The 17 individual food samples were analysed by the Englyst NSP procedure with GLC end-point and the details of the sugar composition of the polysaccharides are given in Table 2. The values are very similar to those reported in the UK Food Tables (Holland, Unwin, Buss, 1991). The values determined by the Prosky method for 16 of the 17 individual foods analysed were, on average, 98% (range 14–578%) higher than those obtained for NSP by the Englyst procedure (Table 3).

3.2. Diet samples

The ten daily meal collection samples were analysed by the Englyst NSP procedure and the details of the sugar composition are given in Table 4. The values determined by the Prosky method, as expected from the

Table 2
Total NSP in 17 foods (average of duplicate analyses)

Food	Constituent neutral sugars (g/100 g DM)								Uronic acids	NSP Total
	Rha	Fuc	Ara	Xyl	Man	Gal	Glc	Total		
Beetroot	0.7	0.1	3.6	0.3	0.3	1.6	6.1	12.7	5.4	18.1
Carrot	0.8	–	2.3	0.4	0.6	3.3	6.3	13.7	6.6	20.3
Cucumber	0.3	0.1	0.8	1.0	0.5	3.3	5.7	11.7	4.0	15.7
Dill	0.7	–	1.3	0.8	0.8	2.0	6.4	12.0	7.2	19.2
Garlic	0.2	–	0.7	0.9	0.4	2.1	4.1	8.4	2.7	11.1
Gherkin	0.3	0.1	0.8	1.0	0.6	1.8	5.7	10.3	4.0	14.3
Green peas	0.2	–	1.9	0.5	–	0.5	8.3	11.4	2.8	14.2
Kohlrabi	0.5	–	1.9	1.2	0.5	1.2	6.8	12.1	5.3	17.4
Lettuce	0.6	–	1.5	1.0	0.9	1.6	8.0	13.6	8.0	21.6
Onion	0.3	0.1	0.6	0.6	0.3	3.7	5.2	10.8	5.1	15.9
Paprika	0.4	–	0.9	1.0	0.8	1.7	8.4	13.2	7.5	20.7
Parsley	0.4	–	2.0	0.8	0.6	2.3	6.7	12.8	6.0	18.8
Potato (new)	0.2	–	0.7	0.2	0.3	1.2	3.2	5.8	1.6	7.4
Puffed Rice	–	–	0.2	0.2	–	0.1	0.6	1.1	0.3	1.4
Radish	0.5	–	1.5	1.1	0.4	1.2	8.8	13.5	7.9	21.4
Rye bread	–	–	1.1	1.4	0.4	0.3	1.1	4.3	0.3	4.6
Tomato	0.3	–	1.0	0.9	1.1	1.3	8.0	12.6	4.3	16.9

Table 3
Individual foods analysed (in duplicate) by the Englyst (NSP) method and the Prosky method

Food	NSP (%fresh)	Prosky (% fresh)	Difference Prosky-NSP
Beetroot	2.1	3.3	1.2
Carrot	2.0	3.1	1.1
Cucumber	0.8	1.3	0.5
Dill	3.2	6.3	3.1
Garlic	3.0	6.4	3.4
Gherkin	0.6	0.5	−0.1
Green peas	3.2	4.8	1.6
Kohlrabi	1.3	1.9	0.6
Lettuce	0.8	1.5	0.7
Onion	2.1	2.4	0.3
Paprika	1.3	2.1	0.8
Parsley	3.6	5.6	2.0
Potato	1.1	1.6	0.5
Puffed rice	0.9	6.1	5.2
Radish	1.1	1.3	0.3
Rye bread	3.1	7.4	4.3
Tomato	1.0	1.8	0.8
Mean	1.8	3.4	1.6
SD	1.0	2.2	1.5
Min	0.6	0.5	−0.1
Max	3.6	7.4	5.2

results for the individual foods and from published data, were higher than those obtained for NSP by the Englyst procedure.

The analytical values obtained by the two procedures were used with the recorded weights of food to calculate daily intakes of "dietary fibre". Table 5 shows that using the Prosky procedure results in values for "dietary fibre" intakes that are, on average, 100% (range from 57% for meal 7–226% for meal 5) higher than the NSP values. Most NSP are included in the Prosky values (Englyst, Quigley, Englyst, Bravo & Hudson, 1996) but Table 5 shows the magnitude (ranging from 7 to 18 g/day) of Prosky "dietary fibre" intakes that cannot be accounted for as NSP (calculated as the difference between the Prosky and the Englyst NSP values for each daily meal collection). The Prosky values represent an average extra intake of "dietary fibre" of 12.4 g/day (SD 3.5). of material that is not accountable for as NSP.

4. Discussion

In the absence of international agreement upon a definition of dietary fibre or upon a method for its measurement, we have examined the consequences of applying two current methods, the Englyst procedure (Englyst, Quigley & Hudson, 1994) and the Prosky procedure (Prosky, Asp, Schweizer, DeVries & Furda, 1988), to the measurement of dietary fibre in the Hungarian diet. These two methods are based on different definitions of dietary fibre and are designed to include different fractions of foods. The stated aim of the Prosky procedure is to measure dietary fibre as the sum of indigestible polysaccharides and lignin, whereas the Englyst procedure is designed to measure non-starch polysaccharides (NSP) in plant foods to reflect the plant cell-wall content. As expected, the two methods can yield quite different "fibre" values for identical samples.

4.1. The Prosky procedure

The method includes a heating step and incubation with enzymes (heat-stable α-amylase (Termamyl) and amyloglucosidase) designed to remove "digestible"

Table 4
Englyst NSP analysis (in duplicate) for the ten meal collections

Sample no.		Constituent neutral sugars								Uronic acids[a]	NSP total[a]	NSP (% fresh)
		Rha	Fuc	Ara	Xyl	Man	Gal	Glc	Total			
1	Total	0.07	0.01	0.71	0.97	0.34	0.56	1.83	4.49	0.96	5.46	1.14
	Insol	0.01	0.01	0.22	0.37	0.30	0.18	1.63	2.72	0.16	2.87	
	Sol	0.06	–	0.49	0.60	0.04	0.38	0.20	1.77	0.80	2.59	
2	Total	0.03	–	0.64	0.85	0.18	0.28	0.86	2.83	0.25	3.08	0.64
	Insol	0.00	–	0.19	0.33	0.14	0.07	0.55	1.26	0.05	1.31	
	Sol	0.03	–	0.45	0.52	0.04	0.21	0.31	1.57	0.20	1.77	
3	Total	0.05	0.01	0.66	0.92	0.20	0.45	1.20	3.49	0.58	4.07	0.82
	Insol	0.01	–	0.21	0.36	0.16	0.14	1.00	1.87	0.18	2.04	
	Sol	0.04	0.01	0.45	0.56	0.04	0.31	0.20	1.62	0.40	2.03	
4	Total	0.05	0.02	0.68	0.94	0.22	0.41	1.20	3.51	0.58	4.09	0.69
	Insol	0.01	–	0.25	0.39	0.18	0.14	0.96	1.93	0.11	2.04	
	Sol	0.04	0.02.	0.43	0.55	0.04	0.27	0.24	1.58	0.47	2.05	
5	Total	0.02	0.02	0.85	1.02	0.21	0.31	0.93	3.36	0.37	3.73	0.8
	Insol	0.01	–	0.23	0.35	0.17	0.07	0.69	1.52	0.08	1.61	
	Sol	0.02	0.02	0.62	0.67	0.04	0.24	0.24	1.84	0.29	2.12	
6	Total	0.06	0.01	0.69	0.88	0.23	0.43	1.47	3.76	0.57	4.32	1.06
	Insol	0.00	–	0.18	0.32	0.23	0.12	1.07	1.94	0.12	2.06	
	Sol	0.06	0.01	0.51	0.56	–	0.31	0.40	1.82	0.45	2.26	
7	Total	0.04	0.01	0.61	0.89	0.21	0.49	1.16	3.41	0.50	3.91	0.75
	Insol	0.01	–	0.19	0.35	0.18	0.17	0.94	1.84	0.09	1.93	
	Sol	0.04	0.01	0.42	0.54	0.03	0.32	0.22	1.57	0.41	1.98	
8	Total	0.04	–	0.53	0.72	0.16	0.35	1.11	2.93	0.50	3.43	0.72
	Insol	0.02	–	0.23	0.34	0.14	0.10	0.82	1.66	0.06	1.72	
	Sol	0.02	–	0.30	0.38	0.02	0.25	0.29	1.27	0.44	1.71	
9	Total	0.05	0.01	0.79	0.82	0.20	0.58	1.44	3.90	0.57	4.47	0.93
	Insol	0.02	–	0.23	0.33	0.16	0.17	1.17	2.06	0.12	2.18	
	Sol	0.03	0.01	0.56	0.49	0.04	0.41	0.27	1.84	0.45	2.29	
10	Total	0.06	0.02	0.83	1.03	0.27	0.49	1.63	4.34	0.77	5.11	0.96
	Insol	0.02	0.02	0.28	0.43	0.27	0.16	1.25	2.42	0.10	2.52	
	Sol	0.04	–	0.55	0.60	–	0.33	0.38	1.92	0.67	2.59	

[a] These units are g/100 g of dried, defatted, ethanol-extracted sample.

Table 5
Prosky and NSP "dietary fibre" values and calculated intakes for ten meals

Meal number	Weight (g)	Prosky (% fresh)	NSP (% fresh)	Intake (g/day)		Difference Prosky-NSP
				Prosky	NSP	
1	1850	1.84	1.14	34.0	21.1	12.9
2	1700	1.32	0.64	22.4	10.9	11.5
3	1850	1.46	0.82	27.0	15.2	11.8
4	1850	1.65	0.69	30.5	12.8	17.7
5	850	2.61	0.8	22.2	6.8	15.4
6	1600	1.84	1.06	29.4	17.0	12.4
7	1800	1.18	0.75	21.2	13.5	7.7
8	1400	1.59	0.72	22.3	10.1	12.2
9	1700	1.58	0.93	26.9	15.8	11.1
10	1100	1.59	0.96	17.5	10.6	6.9
Mean				25.3	13.4	12
SD				5.1	4.1	3.2

Data from Rahotra, Gelroth & Eisenbraun, 1991; the values are mean (SD) for five bread flours and five pastry flours.

starch. However, some of the starch (mainly amylose) that is retrograded following food processing or during sample preparation (see below) will not be hydrolysed and will therefore be included in the measurement. Resistant starch (RS), which is included in the stated aims of the Prosky procedure, is currently defined as the starch (and starch degradation products) that, on average, reach the large intestine of healthy individuals (Englyst & Kingman, 1990; Englyst, Kingman & Cummings, 1992). RS has been subdivided into three categories (RS_1–RS_3) that reflect the reasons why starch may escape digestion in the small intestine

Table 6
Nutritional classification of starch

Type of starch	Example of occurrence	Probable digestion in small intestine
Rapidly digestible starch (RDS)	Freshly cooked starchy food	Rapid, complete
Slowly digestible starch (RDS)	Most raw cereals	Slow but complete
Resistant starch (RS)		
RS_1 Physically inaccessible starch	Partly milled grain and seed	Resistant
RS_2 Resistant starch granules	Raw potato and banana	Resistant
RS_3 Retrograded starch	Cooled, cooked potato bread and corn flakes	Resistant

From Englyst and Kingman (1990).

(Englyst & Kingman, 1990; see Table 6). Much of the starch (mainly amylose) that is retrograded as the result of food processing (RS_3) is included in the Prosky procedure. RS_1 is not included, because milling samples for analysis renders this fraction of starch accessible to the enzymes used in the Prosky procedure. Any RS_2 present in a sample will be gelatinised during the boiling step of the procedure and thus made susceptible to enzymic hydrolysis and not included in the analytical residue. Some of the starch that is readily digestible in food that is normally eaten hot may retrograde upon cooling before analysis. This retrograded starch will not be hydrolysed by Termamyl and will be included in the Prosky fibre values as an artefact; therefore, the starch that is included in the Prosky residue is not a measure of the RS content of foods as eaten. A study commissioned by the UK Ministry of Agriculture, Fisheries and Food (Englyst, Quigley, Englyst, Bravo & Hudson, 1996) used the Prosky procedure to analyse ten samples expected to represent the major sources of fibre in the UK diet. After correction of the analytical residue weight for ash and crude protein according to the Prosky protocol, and separate measurements of Klason lignin, starch and NSP, from 5% to 42% of the residue weight remained unaccounted for.

4.2. *The Englyst procedure*

The Englyst procedure for the measurement of NSP has been developed on the basis of the principles laid down by Southgate (1969). The procedure includes the use of dimethyl sulphoxide to ensure that all the starch in a sample is dispersed. The starch is hydrolysed enzymically before collection of the NSP by precipitation in ethanol.

The Englyst procedure does not include a measurement of lignin, which is a quantitatively minor component of the plant cell walls in the human diet, but is not a constant proportion of cell-wall material and therefore does not represent a reliable marker for plant cell-wall material.

This work has shown that very different values for dietary fibre are obtained by the two procedures studied and that this inevitably leads to the calculation of very different "fibre" intakes. Here, the Prosky values lead to calculation of an average daily intake of 25.3 (SD 5.05) g of fibre per day versus 13.4 (SD 4.08) g per day using the Englyst procedure (see Table 5).

It is extremely important to be aware of the origin of "dietary fibre" values when attempting to interpret the results of studies in the literature. Food tables and data bases in different countries contain fibre values obtained by several different methods; e.g. the UK food tables report fibre values as obtained by the Southgate procedure and the Englyst procedure, whereas the US tables contain values obtained by the Prosky procedure, making comparisons invalid.

The use of indigestibility as the sole criterion for distinguishing dietary fibre has led to the proposal that a range of indigestible polysaccharides and oligosaccharides, and some non-carbohydrate materials should be included as dietary fibre. However, Johnson & Southgate (1993) have stated "If the definition of dietary fibre was to be simplified to that of indigestibility alone, then there are arguments for including all the indigestible components of the diet. This approach, however, is divorced from the original concept of dietary fibre, and would require a new hypothesis; that the amount of indigestible matter in a diet, whatever its origin or composition, is responsible for protective effects. There is no evidence to support such a hypothesis".

In conclusion, any specific, chemically based method that accurately reflects the plant cell-wall content of foods will provide useful data for inclusion in food tables and for food labelling, where the values will guide the consumer in the choice of a fibre-rich diet for which health benefits are proven.

References

Englyst, H. N., & Kingman, S. M. (1990). Dietary fibre and resistant starch. A nutritional classification of plant polysaccharides. In D. Kritchevsky, C. Bonfield & J. W. Anderson, *Dietary Fibre* (pp. 49–65) New York: Plenum Press.

Englyst, H. N., Kingman, S. M., & Cummings, J.H. (1992). Classification and measurement of nutritionally important starch fractions. *Eur. J. Clin. Nutr., 46* (suppl. 2), S33–S50.

Englyst, H. N., Quigley, M. E., & Hudson, G. J. (1994). Determination of dietary fibre as non-starch polysaccharides with gas-liquid

chromatographic, high performance liquid chromatographic or spectrophotometric measurement of constituent sugars. *Analyst, 119*, 1479–1509.

Englyst, H. N., Quigley, M. E., Englyst, K. N., Bravo, L., & Hudson, G. J. (1996). 'DIETARY FIBRE'. Measurement by the Englyst NSP procedure. Measurement by the AOAC procedure. Explanation of the differences. Report of a study commissioned by MAFF. *J. Assoc. Publ. Analysts, 32*, 1–52.

Holland, B., Unwin, I. D., & Buss, D.H. (1991). *Vegetables, Herbs and Spices*. Fifth supplement to McCance & Widdowson's The Composition of Foods, Royal Society of Chemistry, Cambridge.

Johnson, I. T., & Southgate, D. A. T. (1993). *Dietary Fibre and Related Substances*. London: Chapman & Hall.

Prosky, L., Asp. N.-G., Schweizer, T. F., DeVries, J. W., & Furda, I. (1988). Determination of insoluble, soluble and total dietary fibre in foods and food products: interlaboratory study. *J. Assoc. Off. Anal. Chem., 71*(5), 1017–1023.

Quigley, M. E., & Englyst, H. N. (1994). Determination of the uronic acid constituents of non-starch polysaccharides by high-performance liquid chromatography with pulsed amperometric detection. *Analyst, 119*, 1511–1518.

Southgate, D. A. T. (1969). Determination of carbohydrates in foods. II. Unavailable carbohydrates. *J. Sci. Fd Agric., 20*, 331–335.