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Content and Composition of Dietary Fibre in Some Fresh and Cooked Norwegian Vegetables

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ABSTRACT

The contents of dietary fibre in some fresh and cooked vegetables have been determined by two different methods and by a combination of the two.

(1) Cooking had little effect on the content and composition of dietary fibre.

(2) The dietary fibre content differed by a factor of 1·1 to 1·4 from method to method, depending upon the sample.

(3) The content and composition of total neutral non-starch polysaccharides seemed to be about the same for the two methods.

INTRODUCTION

The attention paid to dietary fibre (DF) in recent years has led to a series of investigations on the DF content and composition in various kinds of foods, including vegetables. However, relatively few determinations of DF have been carried out on cooked material (Southgate *et al.*, 1976;

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Paul & Southgate, 1978; Anderson & Clydesdale, 1980; Englyst, 1981; Herranz *et al.*, 1981, 1983), despite the fact that a major part is consumed in the cooked state. As cooking might influence the content and composition of DF, especially soluble fibre components, an investigation was undertaken to evaluate possible differences in DF content and composition between fresh and cooked vegetables.

Of most interest to us were vegetables widely used in Norwegian households. These are relatively inexpensive vegetables which can be grown in a temperate to cool climate, with good storing properties. Cabbage, carrot, cauliflower and rutabaga were used in the investigation.

MATERIALS

α-Amylase (Termamyl 60 L): Novo Industrier A/S, Copenhagen, Denmark.

α-Amylase from porcine pancreas, A4268, EC 3.2.1.1: Sigma Chemical Co.

Pullulanase from *Aerobacter aerogenes*, EC 3.2.1.41: Boehringer Mannheim GmbH.

Pepsin 7190: Merck.

Pancreatin 7133: Merck.

Monosaccharides: Sigma Chemical Co.

METHODS

Two methods were used for the determination of DF, one enzymatic gravimetric method (Asp's method) and one fractionation method (Englyst's method). Both methods have an initial enzymatic step to remove starch.

Asp's method is based on the method of Hellendoorn *et al.* (1975) with the modifications of Asp & Johansson (1981), and Frölich & Asp (1981). To remove starch, the method uses a heat-stable α-amylase (Termamyl 60 L) at 100 °C. The method further tries to simulate the conditions in the human gastro-intestinal tract, using pepsin at pH 1·5 and pancreatin at pH 6·8, both for 1 h at 40 °C. Insoluble DF conponents are recovered by filtration and soluble components by ethanol precipitation followed by filtration, using Celite as a filter aid. The recovered material is dried,

weighed and recorded as DF after correction for protein and ash contents. Protein is measured by the Kjeldahl method using a conversion factor of 6·25. The DF analyses were carried out in triplicate.

The non-starch polysaccharide (NSP) part of DF was also analysed according to Englyst (1981) with some minor modifications (Reistad, 1983) and is referred to as the Englyst method. In this method the starch is degraded by α-amylase and pullulanase at pH 5, and soluble NSP precipitated with ethanol. Acidic constituents in the precipitate are determined by colorimetry and neutral constituents by gas–liquid chromatography after acidic hydrolysis. Insoluble NSP is hydrolysed in acid and the constituents determined by colorimetry (uronic acids and cellulose) or GLC. These analyses were carried out in duplicate.

In addition, some of the samples were subjected to analysis by a combination of the two methods. The Asp procedure was followed past the filtration steps for both soluble and insoluble DF, and the residues in the filter crucibles were dried at 40 °C at reduced pressure (< 10 mm Hg). The residues were further analysed by the Englyst method.

Determination of moisture content

Moisture content in the freeze-dried material (see below) was determined by drying at 60 °C at reduced pressure (< 10 mm Hg) to constant weight.

Preparation of samples

Samples were prepared within 24 h of purchase from Gartnerhallen A/L, the major Norwegian vegetable distributor. The following material, all grown in Norway, was collected as indicated: cauliflower (variety White Top) in August, cabbage (variety Toten Amager) in September, carrots (variety Nantes) in October and rutabagas (variety Bangholm) in November. The parts of the various vegetables normally used for human consumption were prepared for cooking and analysis.

Cabbage

Four heads were randomly picked from a total of 25 kg. These were cut into sectors, the thickest part about 5 cm wide. Most of the stem was removed, only enough being left to prevent the head from falling apart. One sector from each head was used in each cooking process, as well as for the preparation of fresh material.

Carrot
Carrots of medium size (80–120 g) were used. Prior to further handling they were scraped, but not cut. One carrot from each of five 1-kg bags was used in each cooking operation as well as for the preparation of fresh material.

Rutabaga
Four heads were randomly picked from a total of 25 kg. These were cut in half, each half was cut into 1·5 cm thick slices and these were peeled. One slice from each head was used for each cooking operation as well as for the preparation of fresh material.

Cauliflower
Eight heads were randomly only picked from a total of 25 kg. The part of the stem to which the green cover leaves are attached was removed, and the heads parted in four. Four such pieces, randomly picked, were used in each cooking operation, as well as for the preparation of fresh material.

Cooking and further preparation of samples
Cooking was carried out as described below, following a procedure recommended by home economics teachers in order to obtain a good end product from the consumer's, as well as the nutritionist's, point of view. To cover the usual ways of cooking vegetables in Norway, they were either steam-boiled or boiled in just enough water to cover the vegetables (Table 1). Salt was not added. A trial run to determine cooking time was carried out for each vegetable. The actual cooking was carried out in triplicate, and each sample was handled separately past the milling step. Then equal weights of the triplicates were thoroughly mixed prior to moisture and DF determinations.

In the boiling procedures the preweighed vegetables were put in boiling water or on a perforated stand above the boiling water level.

At the end of the cooking period the material was carefully transferred to a sieve, left for 5 min to let the water drain and then transferred to several layers of filter paper to get rid of as much as possible of the cooking water adhering to the outside of the vegetables.

The filter paper was changed twice. This somewhat extensive effort to remove adhering cooking water was carried out in order to be able to record the weight changes of vegetables upon cooking. After 10 min on the filter papers (to allow some cooling in order to achieve a stable weight)

TABLE 1
Some Data on the Material Used for Analysis

Sample		*Cooking time (min)*	*Dry matter (wt. %)*	*Loss upon cooking (wt. %)*
Cabbage	Fresh	0	8·8	—
	Boiled in water	12	6·6	8·0
	Steam boiled	15	8·9	9·2
Carrot	Fresh	0	11·1	—
	Boiled in water	17	11·3	13·6
	Steam boiled	22	13·1	16·2
Cauliflower	Fresh	0	8·4	—
	Boiled in water	8	7·6	3·4
	Steam boiled	10	8·3	5·2
Rutabaga	Fresh	0	10·3	—
	Boiled in water	10	9·7	13·2
	Steam boiled	14	10·9	12·7

the sample was reweighed, diced (approximately 3 mm^3), frozen at $-25\,°C$, freeze dried and milled in a grain mill (Casella & Co., London) fitted with a 0·5 mm screen. The powdered material was stored in small, tightly capped glass jars in desiccators above blue silica gel.

RESULTS AND DISCUSSION

Both the Asp and Englyst procedures separate soluble and insoluble DF, and precipitate the soluble DF in 80 % ethanol. In the Asp procedure the precipitates are weighed and recorded as DF after correction for protein and ash contents. In the Englyst procedure the precipitates are treated with acid, and the resulting carbohydrates determined by colorimetry or GLC.

The Asp method is much faster than the Englyst method. However, filtering some samples, especially cabbage, caused clogging of the glass filters, despite the use of Celite, thus extending the duration of the analysis. The difficulties were greatly reduced by using a smaller sample (0·5 g instead of 1 g), which did not seem to create any problems in the remaining analytical steps.

TABLE 2
Content of Dietary Fiber (DF) in Some Fresh and Cooked Vegetables, Analysed by the Asp Procedure (Weight %)

Sample		*DF based on dry weight*			*DF based on weight of fresh or cooked material*			*DF based on fresh weight*
		Soluble	*Insoluble*	*Total*	*Soluble*	*Insoluble*	*Total*	*Total*
Cabbage	Fresh	5·4	16·6	22·0	0·5	1·4	1·9	1·9
	Boiled in water	10·4	20·8	31·2	0·7	1·4	2·1	1·9
	Steam boiled	8·1	15·7	23·8	0·7	1·4	2·1	1·9
Carrot	Fresh	7·8	14·8	22·6	0·9	1·6	2·5	2·5
	Boiled in water	10·9	15·7	26·6	1·2	1·8	3·0	2·6
	Steam boiled	11·0	14·0	25·0	1·4	1·8	3·2	2·7
Cauliflower	Fresh	7·2	19·2	26·4	0·6	1·6	2·2	2·2
	Boiled in water	8·6	19·6	28·2	0·7	1·5	2·2	2·1
	Steam boiled	7·8	19·3	27·1	0·7	1·6	2·3	2·2
Rutabaga	Fresh	7·5	14·5	22·0	0·8	1·5	2·3	2·3
	Boiled in water	10·4	17·8	28·2	1·0	1·7	2·7	2·3
	Steam boiled	9·2	14·8	24·0	1·0	1·6	2·6	2·3

Effect of cooking on DF

It seems from Tables 2 and 3 that cooking resulted in an increase in total DF and NSP contents for most of the samples, both on a dry and on a fresh/cooked weight basis. Rather than an increase, it might be expected that cooking would damage the plant cell walls, resulting in leakage and subsequent loss of soluble cell content, including soluble DF, into the surrounding medium.

Englyst *et al.* (1982) found little difference in NSP between raw and boiled potatoes. Matthee & Appledorf (1978) observed that cooking increased the DF content in some vegetables, especially cellulose, while hemicellulose was not affected. Anderson and Clydesdale (1980), investigating the effect of processing on some pureed vegetables, found that boiling and retorting solubilised neutral and acidic NSP, thus reducing the content of DF. Herranz *et al.* (1981) found that the contents of hemicellulose and cellulose increased upon boiling for most of the vegetables investigated. Thus, the results are not consistent. Direct comparisons are difficult, as treatment before cooking such as cutting, pureeing, etc., and the cooking procedure itself, as well as analytical procedures, vary from investigation to investigation.

However, in the present work the DF content of the cooked samples is also related to the weight of fresh material (Tables 2 and 3, last column). This needs explanation.

Cooking of the vegetables gave a weight loss of up to about 16 % (Table 1). If the results are calculated on a fresh weight basis, it can be seen that the apparent gain in DF on cooking is due to a loss of non-DF constituents during cooking.

Tables 4 and 5 support this explanation, showing that cooking had little effect on the contents of the various NSP constituents, whether soluble or insoluble.

Determination of DF by two methods

Total DF was 1·1–1·4 times higher by the Asp procedure than the NSP content determined according to Englyst (Table 6). Somewhat higher results might be expected from the Asp method, taking into consideration the different approaches of the two methods. In the Asp procedure, DF is determined by removing non-DF constituents and recording the residue as DF. Consequently, the method is dependent upon a complete removal

TABLE 3

Content of Non-Starch Polysaccharides (NSP) in Some Fresh and Cooked Vegetables, Analysed by the Englyst Procedure (Weight %, Calculated as Polymers)

Sample		*NSP based on dry weight*			*NSP based on weight of fresh or cooked material*			*NSP based on fresh weight*
		Soluble	*Insoluble*	*Total*	*Soluble*	*Insoluble*	*Total*	*Total*
Cabbage	Fresh	3·4	12·3	15·7	0·3	1·1	1·4	1·4
	Boiled in water	5·8	16·6	22·4	0·4	1·1	1·5	1·4
	Steam boiled	4·3	13·6	17·9	0·4	1·2	1·6	1·4
Carrot	Fresh	9·9	11·3	21·2	1·1	1·3	2·4	2·4
	Boiled in water	11·1	12·7	23·8	1·3	1·4	2·7	2·3
	Steam boiled	10·7	10·9	21·6	1·4	1·4	2·8	2·4
Cauliflower	Fresh	7·0	11·9	18·9	0·6	1·0	1·6	1·6
	Boiled in water	8·2	12·8	21·0	0·6	1·0	1·6	1·6
	Steam boiled	7·2	12·1	19·3	0·6	1·0	1·6	1·5
Rutabaga	Fresh	7·4	11·2	18·6	0·8	1·1	1·9	1·9
	Boiled in water	8·8	13·0	21·8	0·9	1·3	2·2	1·9
	Steam boiled	7·8	11·2	19·0	0·9	1·2	2·1	1·8

TABLE 4

Constituents of Soluble, Non-Starch Polysaccharides of Some Fresh and Cooked Vegetables, Analysed by the Englyst Procedure (Weight % on a Dry Weight Basis, Calculated as Polymers)

Sample		*Neutr.*	*Ur.a.*	*Rha*	*Fuc*	*Ara*	*Xyl*	*Man*	*Gal*	*Glu*
Cabbage	Fresh	1·1	2·3	tr	—	0·7	tr	—	0·4	—
	Boiled in water	1·9	3·9	0·1	—	1·2	—	—	0·6	—
	Steam boiled	1·3	3·0	0·1	—	0·8	tr	—	0·4	—
Carrot	Fresh	3·2	6·7	0·1	—	1·2	—	—	1·9	—
	Boiled in water	4·1	7·0	0·1	—	1·5	—	—	2·5	—
	Steam boiled	3·8	6·9	0·1	—	1·4	—	—	2·3	—
Cauliflower	Fresh	2·1	4·9	tr	—	1·4	tr	—	0·7	—
	Boiled in water	2·7	5·5	0·1	—	1·6	0·1	—	0·9	—
	Steam boiled	2·0	5·2	0·1	—	1·3	tr	—	0·6	—
Rutabaga	Fresh	1·9	5·5	0·2	—	1·1	tr	—	0·6	—
	Boiled in water	2·3	6·5	0·3	—	1·2	0·1	—	0·7	—
	Steam boiled	1·9	5·9	0·2	—	1·1	tr	—	0·6	—

tr = trace.
Neutr. = Sum of neutral constituents.
Ur. a. = Uronic acids, calculated as anhydrogalacturonic acid.
Dashes mean that none was detected.

Rha = Rhamnose.
Fuc = Fucose.
Ara = Arabinose.
Xyl = Xylose.
Man = Mannose.
Gal = Galactose.
Glu = Glucose.

TABLE 5

Constituents of Insoluble, Non-Starch Polysaccharides of Some Fresh and Cooked Vegetables Analysed by the Englyst Procedure (Weight % on a Dry Weight Basis, Calculated as Polymers)

Sample		*Neutr.**	*Ur. a.*	*Cellul.*	*Rha*	*Fuc*	*Ara*	*Xyl*	*Man*	*Gal*	*Glu**
Cabbage	Fresh	3·8	2·3	6·2	0·1	0·1	1·7	0·6	0·1	1·0	0·2
	Boiled in water	5·1	2·6	8·9	0·1	0·2	2·1	0·8	0·1	1·5	0·3
	Steam boiled	4·5	2·1	7·0	0·1	0·2	1·8	0·7	0·1	1·3	0·3
Carrot	Fresh	2·8	2·7	5·8	0·1	—	0·8	0·1	0·1	1·5	0·2
	Boiled in water	3·3	2·8	6·6	0·1	—	0·8	0·1	0·1	1·6	0·6
	Steam boiled	2·3	2·2	6·4	tr	—	0·6	0·1	0·1	1·1	0·4
Cauliflower	Fresh	4·1	1·4	6·4	0·1	0·2	1·5	0·7	0·1	1·3	0·2
	Boiled in water	4·6	1·3	6·9	0·1	0·4	1·4	0·8	0·2	1·5	0·2
	Steam boiled	3·8	1·3	7·0	0·1	0·3	1·2	0·7	0·2	1·1	0·2
Rutabaga	Fresh	2·3	1·9	7·0	0·1	0·1	0·7	0·5	0·1	0·7	0·1
	Boiled in water	2·5	1·9	8·6	0·1	0·1	0·8	0·5	0·1	0·8	0·1
	Steam boiled	2·2	1·6	7·4	tr	0·1	0·7	0·5	0·1	0·7	0·1

tr = trace.
Neutr. = Sum of neutral constituents.
Ur. a. = Uronic acids, calculated as anhydrogalacturonic acid.
* Cellulose not included.
Dashes mean that none was detected.

Rha = Rhamnose.
Fuc = Fucose.
Ara = Arabinose.
Xyl = Xylose.
Man = Mannose.
Gal = Galactose.
Glu = Glucose.

TABLE 6

Contents and Ratios of Dietary Fibre Components Determined by the Asp and Englyst Methods (Weight %, Calculated as Polymers)

Sample		*Based on dry weight*								
		Soluble			*Insoluble*			*Total*		
		A	*E*	*A/E*	*A*	*E*	*A/E*	*A*	*E*	*A/E*
Cabbage	Fresh	5·4	3·4	1·6	16·6	12·3	1·3	22·0	15·7	1·4
	Boiled in water	10·4	5·8	1·8	20·8	16·6	1·3	31·2	22·4	1·4
	Steam boiled	8·1	4·3	1·9	15·7	13·6	1·2	23·8	17·9	1·3
Carrot	Fresh	7·8	9·9	0·8	14·8	11·3	1·3	22·6	21·2	1·1
	Boiled in water	10·9	11·1	1·0	15·7	12·7	1·2	26·6	23·8	1·1
	Steam boiled	11·0	10·7	1·0	14·0	10·9	1·3	25·0	21·6	1·2
Cauliflower	Fresh	7·2	7·0	1·0	19·2	11·9	1·6	26·4	18·9	1·4
	Boiled in water	8·6	8·2	1·0	19·6	12·8	1·5	28·2	21·0	1·3
	Steam boiled	7·8	7·2	1·1	19·3	12·1	1·6	27·1	19·3	1·4
Rutabaga	Fresh	7·5	7·4	1·0	14·5	11·2	1·3	22·0	18·6	1·2
	Boiled in water	10·4	8·8	1·2	17·8	13·0	1·4	28·2	21·8	1·3
	Steam boiled	9·2	7·8	1·2	14·8	11·2	1·3	24·0	19·0	1·3

A—Analysed by the Asp method.
E—Analysed by the Englyst method.
A/E—Ratios of the results of the two methods.

TABLE 7

Constituents of Soluble, Non-Starch Polysaccharides of Some Fresh and Cooked Vegetables, Analysed by a Combination of the Asp and Englyst Procedures (Weight % on a Dry Weight Basis, Calculated as Polymers)

Sample		*Neutr.*	*Ur. a.*	*Rha*	*Fuc*	*Ara*	*Xyl*	*Man*	*Gal*	*Glu*
Cabbage	Fresh	1·1	1·6	0·1	—	0·6	tr	—	0·4	tr
	Boiled in water	2·1	3·2	0·1	0·1	1·2	0·1	—	0·6	tr
Carrot	Fresh	2·2	2·4	0·2	tr	1·1	—	—	0·8	0·1
	Boiled in water	3·4	3·0	0·3	tr	1·4	—	—	1·6	0·1
Cauliflower	Fresh	1·9	1·9	0·1	tr	1·1	tr	—	0·7	tr
	Boiled in water	1·9	2·5	0·1	0·1	1·1	tr	—	0·6	tr
Rutabaga	Fresh	1·4	3·5	0·2	tr	0·7	tr	—	0·5	tr
	Boiled in water	1·8	3·8	0·2	tr	0·9	tr	—	0·6	0·1

tr = trace.
Neutr. = Sum of neutral constituents.
Ur. a. = Uronic acids, calculated as anhydrogalacturonic acid.
Dashes mean that none was detected.

Rha = Rhamnose.
Fuc = Fucose.
Ara = Arabinose.
Xyl = Xylose.
Man = Mannose.
Gal = Galactose.
Glu = Glucose.

TABLE 8

Constituents of Insoluble, Non-Starch Polysaccharides of Some Fresh and Cooked Vegetables, Analysed by a Combination of the Asp and Englyst Procedures (Weight % on a Dry Weight Basis, Calculated as Polymers)

Sample		*Neutr.**	*Ur. a.*	*Cellul.*	*Rha*	*Fuc*	*Ara*	*Xyl*	*Man*	*Gal*	*Glu**
Cabbage	Fresh	3·7	2·7	6·7	0·1	0·1	1·7	0·5	0·1	1·1	0·1
	Boiled in water	4·9	2·7	9·0	0·1	0·1	2·1	0·8	0·1	1·6	0·1
Carrot	Fresh	2·8	1·2	5·9	0·1	tr	0·9	0·1	tr	1·5	0·2
	Boiled in water	2·7	0·9	6·8	0·1	tr	0·8	0·1	0·1	1·5	0·1
Cauliflower	Fresh	3·9	1·3	6·6	0·1	0·1	1·5	0·7	0·1	1·3	0·1
	Boiled in water	4·8	1·3	7·5	0·1	0·2	1·8	0·8	0·1	1·6	0·2
Rutabaga	Fresh	2·8	1·5	7·0	0·1	0·1	0·9	0·5	0·1	1·0	0·1
	Boiled in water	3·3	1·5	8·7	0·1	0·1	1·1	0·6	0·1	1·1	0·2

tr = trace.
Neutr. = Sum of neutral constituents.
Ur. a. = Uronic acids, calculated as anhydrogalacturonic acid.
* Cellulose not included.

Rha = Rhamnose.
Fuc = Fucose.
Ara = Arabinose.
Xyl = Xylose.
Man = Mannose.
Gal = Galactose.
Glu = Glucose.

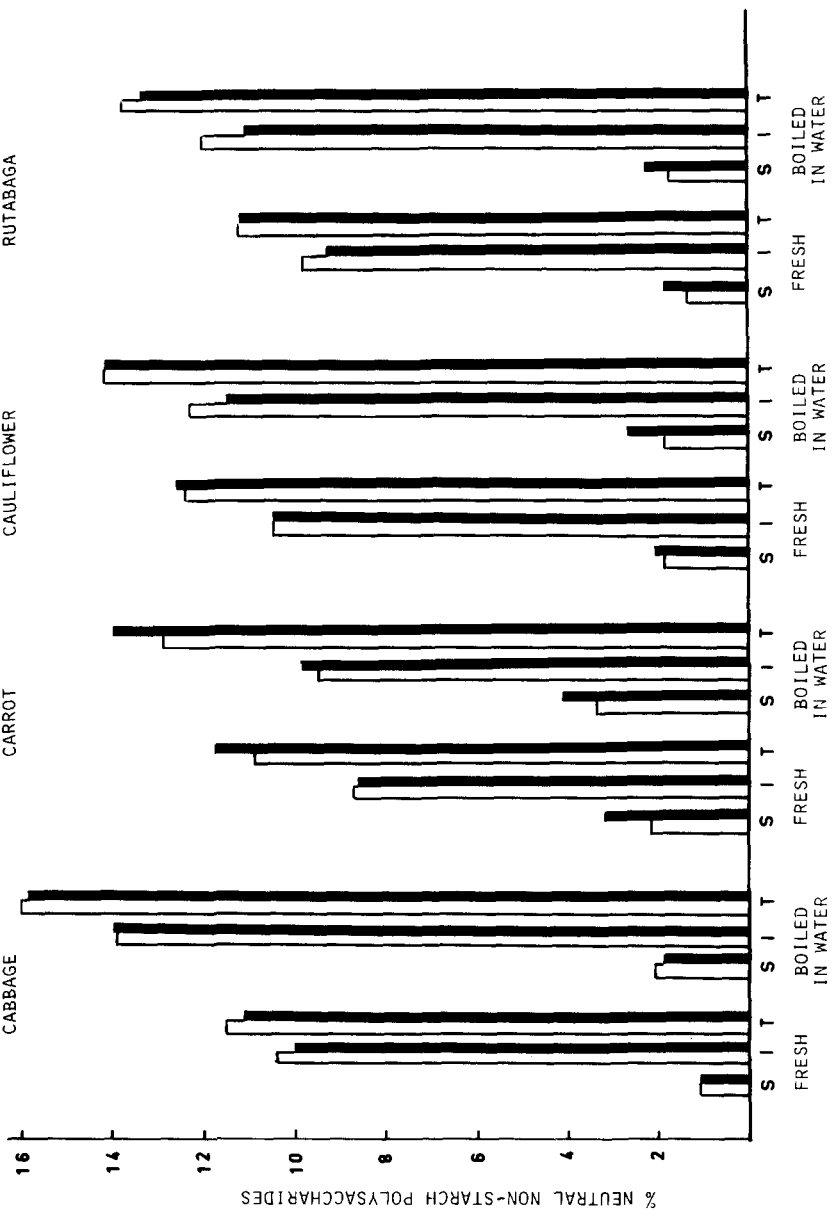

Fig. 1. A comparison of the contents of neutral non-starch polysaccharides of some fresh and cooked vegetables analysed by two methods. A combination of the Asp and Englyst methods—open columns. The Englyst method—filled columns. S = soluble. I = insoluble. T = Total.

of a variety of non-DF constituents, although corrections for ash and residual protein are carried out. On the other hand, in the Englyst procedure, the NSP constituents are positively identified and added together. The content of lignin, not included in the latter procedure, did not exceed 5% of dry weight in any of the samples (R. Reistad, unpublished), and cannot alone explain the higher content of DF when determined according to Asp.

The differences between the results of the two methods were somewhat greater when soluble and insoluble DF were considered separately (Table 6), probably reflecting a difference in degree of solubility of DF by the two aqueous extraction procedures.

In an attempt to explain the differences, some samples were run through a combined Asp–Englyst procedure as outlined in the 'Methods' section (Tables 7 and 8).

For each individual sample, the contents of neutral NSP were quite similar whether run through the combined Asp–Englyst or the Englyst procedure (Fig. 1). This suggests that the differences in results between the Asp and the Englyst methods found by us (Table 6) may be due to constituents other than NSP and/or an underestimation by the Englyst method.

Uronic acid contents were considerably lower in samples analysed by the combined Asp–Englyst than by the Englyst method, especially in soluble NSP (Tables 4 and 7).

This is contrary to other findings (N.-G. Asp, pers. comm.), and is not caused by a degradation of uronic acids by this method. The problem is being investigated.

In the present work, no effort was made to evaluate the influence of other than the described treatments of the vegetables on the content and composition of DF. Other treatments might include cutting the vegetables into smaller pieces before cooking and extending the cooking time beyond the point when the vegetables are to be judged tender enough, both of which might very well influence the content and composition of DF.

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