Dietary Fiber Content and Composition of Vegetables Determined by Two Methods of Analysis

Judith A. Marlett* and Nicholas W. Vollendorf

Department of Nutritional Sciences, University of Wisconsin—Madison, 1415 Linden Drive, Madison, Wisconsin 53706-1571

Forty-one samples representing different forms of 12 types of vegetables were analyzed for dietary fiber content using the Association of Official Analytical Chemists method and for fiber content and composition using the Uppsala method. Mean fiber content measured by the former method was 2.1 ± 0.9 g/100 g and by the latter method, 1.8 ± 0.8 g/100 g. The mean soluble fiber concentration determined by the Uppsala method was 15% of total vegetable fiber. Insoluble fiber contained more neutral sugars than uronic acid; soluble vegetable fiber was a mixture of uronic acid and polysaccharides containing galactose and arabinose. Cooking either had no effect or increased the proportion of total fiber extracted as soluble fiber. Some vegetables that are frequently treated as similar foods in nutritional studies (e.g., potatoes and cooked greens) contained different amounts of fiber. The results indicate that for some vegetables the source, preparation method, variety, and analytical method should be considered when daily intakes of total dietary fiber or fiber components are calculated.

INTRODUCTION

Vegetables are major sources of dietary fiber in the North American diet. One recent study reported that vegetables provided nearly one-fourth of the total dietary fiber consumed by women in the United States (Thompson et al., 1992). Two studies reported that 11% of daily dietary fiber was consumed as some form of potatoes (Krebs-Smith et al., 1992; Thompson et al., 1992). Several vegetables were grouped together for the determination of fiber intake in both studies (Krebs-Smith et al., 1992; Thompson et al., 1992). Vegetables of similar nutrient composition have been traditionally grouped together for determining nutrient intake. However, little is known about whether the dietary fiber content and composition of the foods in these traditional groups are similar. There are 470 entries, representing many different sources and forms, in *USDA Handbook 8* for vegetables (Haytowitz and Matthews, 1984), which indicates that grouping vegetables could alter fiber intakes if the foods in that group do not contain similar fiber contents.

Forms in which vegetables are typically consumed include fresh, cooked, canned, and frozen. Some preparation for consumption, such as removing the peel, would decrease the fiber content of the food (Mullin and Smith, 1991; Marlett, 1992). Canning may increase the proportion of the total dietary fiber recovered as soluble fiber, decrease total fiber content if it is lost in the canning liquid (Marlett et al., 1989a), or change the molecular weight of fiber components (Ben-Shalom et al., 1992). Cooking caused a slight increase in the proportion of total fiber that was solubilized in 10 vegetables commonly consumed in Italy (Lintas and Cappelloni, 1988). Thus, the available evidence suggests that canning and home preparation could affect the fiber composition of a food.

The two overall objectives of this research were to evaluate the fiber content and composition of different forms of vegetables and to compare two methods of fiber analysis. Two to four different forms of each of 10 vegetables, 5 different cooked greens, and 10 different potato samples were analyzed for a total of 41 samples. Fiber content and composition were determined using a modification of the Uppsala method A; total fiber concentration also was determined using the Association of Official Analytical Chemists (AOAC) procedure.

METHODS

Sample Source and Preparation. Fresh vegetables were purchased locally and, except for the home-grown tomatoes, were from regional or national suppliers. Inedible portions were removed as for human consumption, and vegetables were cooked by conventional methods. Three vegetables were analyzed raw and cooked: green beans, bean sprouts, and spinach. Canned vegetables were regional or national brands and were drained prior to blending. Frozen products were heated according to package directions. All foods were blended (Waring, Model 31 BL92, New Hartford, CT) with sufficient water to form a uniform homogenate for shell freezing and subsequent lyophilization (Virtis Freezemobile 24, The Virtis Co., Gardiner, NY). The lyophilized weight was used as the dry weight.

Dietary Fiber Analysis. Total dietary fiber content was determined according to the AOAC procedure (Prosky et al., 1988) in quadruplicate so that nitrogen and ash contents of the fiber residues could be determined in duplicate. AOAC analysis was repeated if the coefficient of variation for the mean of the four analyses was >10%; this occurred for one food, potato granules. Fiber content and composition were determined by duplicate analyses of food samples using a modification (Shinnick et al., 1988; Marlett, 1992) of the Theander method A (Theander and Westerlund, 1986); the Theander methods have been recently renamed the Uppsala methods of fiber analysis (Theander et al., 1990). Samples for both methods were extracted prior to fiber analysis using petroleum ether (25 mL/g × 2; 15 min) with stirring if they contained ≥5% fat.

For the Uppsala analysis, preparation of the extractive free residue, starch extraction, separation of the sample into soluble and insoluble fractions, acid hydrolysis of the fiber fractions, and uronic acid and Klason lignin analyses have been previously described (Shinnick et al., 1988; Marlett, 1992). Neutral sugars in the acid hydrolysates were separated by high-performance liquid chromatography (HPLC) and quantitated by a recording integrator. Hydrolysis losses were determined using a mixture of standard sugars (Marlett, 1992). Galactose and rhamnose coelute on the HPLC column that was used; most hemicellulosic sugars in foods are probably galactose (Theander and Åman, 1979). The sum of the fiber components and residual starch and nitrogen in the fiber fractions was used to estimate recoveries of the fiber fractions (Marlett, 1992). Mean (±SD) recovery of the insoluble fiber fractions of the 41 samples was 91 ± 6% and of the soluble fractions, 77 ± 8%; both are similar to recoveries

0021-8561/93/1441-1608$04.00/0

Table I. Dietary Fiber Content and Composition of Vegetables

	g/100 g of fresh wt		g/100 g of dry wt						
	AOAC[a]		Uppsala[b]						
				soluble			insoluble		
sample	dry wt	total fiber	total fiber	neutral sugars	uronic acids	total	neutral sugars	uronic acids	Klason lignin	total
bean sprouts, mung										
raw	7.1	1.5	1.3	0.9	0.2	1.1	12.7	3.3	1.5	17.5
cooked	7.0	1.6	1.5	0.7	0.3	1.0	13.8	3.9	2.1	19.8
bean										
green, snap, fresh, raw	9.0	2.6	2.5	0.9	2.6	3.5	16.0	6.0	1.6	23.6
green, snap, fresh, cooked	9.8	3.0	2.6	0.7	0.4	1.1	16.7	9.0	1.5	27.2
yellow wax, canned	7.5	2.3	2.1	2.6	2.9	5.5	17.5	3.8	1.2	22.5
cabbage										
Chinese, fresh	5.3	1.4	1.2	0.6	1.0	1.6	13.2	6.9	0.9	21.0
green, steamed	9.2	2.3	2.3	0.6	1.2	1.8	15.6	6.4	1.1	23.1
red, fresh	9.9	2.6	2.5	0.7	0.8	1.5	16.1	6.1	0.9	23.1
sauerkraut, canned	9.9	3.1	2.6	1.7	1.1	2.8	15.4	7.2	0.4	23.0
carrot										
canned circles	7.2	2.3	2.2	4.9	4.8	9.7	15.4	4.3	1.3	21.0
fresh, circles, cooked	11.0	3.7	3.2	2.7	3.7	6.4	15.2	5.1	2.2	22.5
corn										
creamed, canned	17.8	1.1	1.3	1.9	0.1	2.0	4.3	0.2	0.8	5.3
fresh, yellow, cooked on cob	27.2	1.6	1.3	0.2	0.1	0.3	3.7	0.2	0.4	4.3
greens, cooked										
beet, fresh	9.0	35.0	24.8	1.1	3.1	4.2	15.0	3.3	2.3	20.6
collard, frozen	7.2	3.7	3.4	1.0	2.1	3.1	27.6	13.6	2.9	44.1
kale, fresh	12.4	4.7	3.8	1.0	2.3	3.3	17.1	8.6	2.0	27.7
mustard, frozen	5.8	2.9	3.0	1.2	4.1	5.3	29.6	12.7	3.3	45.6
Swiss chard, fresh	7.0	2.6	2.4	1.3	4.0	5.3	20.9	4.3	4.0	29.2
lettuce										
green leaf	5.5	1.6	1.4	0.6	0.6	1.2	13.8	8.1	2.6	24.5
red leaf	5.3	1.3	1.2	0.7	0.2	0.9	10.4	7.9	4.0	22.3
onion										
red, raw	11.1	1.6	1.5	0.3	0.3	0.6	9.0	3.4	0.0	12.4
white, raw	10.2	1.5	1.4	0.4	0.5	0.9	8.7	3.4	0.2	12.3
yellow, fresh, cooked	9.4	1.7	1.5	0.7	2.5	3.2	10.2	2.8	0.0	13.0
rings, frozen, cooked	65.3	2.9	2.5	0.5	0.4	0.9	2.4	0.3	0.2	2.9
potato										
Maine, boiled, no skin	19.2	1.5	1.2	1.0	0.7	1.7	4.0	0.3	0.2	4.5
red, boiled with skin	20.5	1.8	1.6	0.9	0.9	1.8	4.6	0.6	0.7	5.9
red, boiled, no skin	15.0	1.1	0.9	0.9	0.8	1.7	3.6	0.4	0.0	4.0
Wisconsin, boiled, no skin	18.0	1.8	1.4	0.6	0.7	1.3	6.1	0.6	0.1	6.8
Wisconsin, boiled, no skin, mashed	18.5	1.6	1.4	0.8	0.9	1.7	5.2	0.5	0.2	5.9
white, baked, skin removed	24.9	2.1	1.7	0.9	0.6	1.5	4.9	0.3	0.1	5.3
granules, cooked	27.0	2.0	1.4	0.4	0.4	0.8	3.9	0.4	0.1	4.4
hash, canned, corned beef	31.9	1.2	0.9	0.8	0.2	1.0	1.6	0.1	0.1	1.8
salad, American white	32.0	1.6	1.2	0.6	0.4	1.0	2.3	0.3	0.1	2.7
scalloped, frozen, cooked	20.5	0.9	0.7	0.4	0.2	0.6	2.4	0.4	0.1	2.9
spinach										
fresh, raw	10.3	2.6	2.2	0.7	1.7	2.4	11.2	4.2	3.7	19.1
fresh, cooked	8.3	2.6	2.0	0.5	2.4	2.9	13.5	4.4	3.0	20.9
squash										
acorn, fresh baked	9.0	2.2	2.0	0.7	3.5	4.2	14.2	3.6	0.3	18.1
butternut, fresh steamed	12.1	2.7	1.8	0.4	1.8	2.2	9.4	2.7	0.3	12.4
yellow zucchini, fresh, cooked	4.7	0.9	0.8	0.9	0.8	1.7	11.0	4.5	0.4	15.9
tomato										
fresh, California	5.9	1.0	0.9	0.9	2.2	3.1	8.7	1.4	2.6	12.7
fresh, home-grown	5.2	0.8	0.7	0.5	1.7	2.2	7.7	1.9	1.8	11.4

[a] Values are means of four measurements. [b] Values are means of two measurements.

previously determined (Marlett, 1992). Neutral and acidic sugars were expressed as polymers (×0.9).

Quality Control. Quality control was evaluated by repeated analyses of a mixture of glucose, xylose, galactose, arabinose, and mannose and of canned peas, as previously described (Vollendorf and Marlett, 1993).

Statistical Evaluation. The linear correlation and paired t test were done as described by Steele and Torrie (1960).

RESULTS AND DISCUSSION

Total Dietary Fiber Content of Vegetables. The mean (±SD) total dietary fiber content of the 41 vegetables was 1.8 ± 0.8 g/100 g (fresh weight), when it was measured using the Uppsala method, or 2.1 ± 0.9 g/100 g, when it was determined using the AOAC procedure (Table I). Homegrown tomatoes contained the lowest concentration and kale the highest concentration of fiber. The two data sets were not significantly different ($p > 0.05$). The mean total fiber content of these vegetables, which were selected for analysis to extend previous analyses using the Uppsala method, was slightly less than that of the 33 vegetables previously analyzed (2.0 ± 0.8 g/100 g) (Marlett, 1992). Other studies of vegetables using the AOAC method reported mean fiber contents of 2.4 ± 0.7 (n = 8) (Visser and Gurnsey, 1986) and 2.4 ± 1.2 g/100 g of fresh weight (n = 51) (Lintas and Cappelloni, 1988). Mongeau et al. (1989) measured an average of 1.8 ± 0.7 g/100 g total fiber

in 38 vegetables using a combination of the neutral detergent fiber procedure to measure the insoluble fiber fraction and a separate procedure to measure the soluble fraction. In another study the average fiber content of 15 vegetables was 2.3 ± 1.1% when it was measured using a modification of the Southgate (1969) method (Anderson and Bridges, 1988). The data suggest that vegetables contain about 2% dietary fiber, more than the average fiber content of fruits determined by the Uppsala method [1.4% (n = 23)], slightly less than the fiber content of refined grain products [2.3% (n = 32)], and much less than what is measured in legumes [4.0% (n = 7)] (Marlett, 1992).

Comparison of AOAC and Uppsala Fiber Values. About two-thirds of the AOAC fiber values were within 20% of those determined by the Uppsala method (Table I). Only two of the AOAC fiber values, those for creamed corn and mustard greens, were less than the comparable data determined by the Uppsala procedure. The two data sets were strongly correlated: Uppsala = 0.85(AOAC) + 0.04, $r^2 = 0.93$ ($p < 0.01$). Coprecipitation of simple sugars with the fiber polysaccharides may be one reason for the measurement of more fiber with the AOAC method (Marlett and Navis, 1988). Second, incomplete starch hydrolysis may be responsible for some of the higher AOAC values, compared to the Uppsala data (Marlett and Navis, 1988; Vollendorf and Marlett, 1993). The dietary fiber contents measured by the AOAC method for 7 of the 10 potato samples were more than 20% greater than those determined using the Uppsala procedure. One enzymatic starch hydrolysis step in the AOAC procedure is short (0.5 h), compared to that in the Uppsala method (overnight). Finally, the AOAC values for some of the vegetables containing oxalate (beet greens, kale, and spinach) also were higher than those obtained using the Uppsala procedure, suggesting oxalate could be more completely recovered in the AOAC fiber residue (Table I).

Soluble and Insoluble Fiber Fractions. The soluble fiber content ranged from 0.3 to 9.7 g/100 g of dry weight (Table I) and averaged 0.3 ± 0.2 g/100 g or 15% of the total fiber in the 41 vegetables. This is similar to the soluble fiber content in 33 vegetables measured previously, of 13%, using the same method (Marlett, 1992). More of the total fiber (~30–40%) was recovered in the soluble fraction when procedures were used that involved more extractive steps or when lignin was not included as part of the fiber (Anderson and Bridges, 1988; Graham et al., 1988; Mongeau et al., 1988; Mongeau and Brassard, 1989; Marlett et al., 1989b; Marlett, 1990). Neither uronic acid nor neutral sugar polysaccharides were consistently the dominant fiber component in the soluble fraction of vegetables, although uronic acid-containing polymers were the major soluble constituent in tomatoes, some squashes, and several of the green leafy vegetables (cabbage, greens, and spinach) (Table I).

The mean insoluble fiber content of the vegetables was 1.5 ± 0.7 g/100 g. Uronic acids were major components of the insoluble fiber fraction of most vegetables except for potatoes and corn (Table I). All of the vegetables, except for corn and onions, contained more glucose than other neutral sugars in the insoluble fiber fraction (Table II). Galactose and arabinose were the dominant hemicellulosic sugars in the soluble fiber fractions of all vegetables except for two processed samples, creamed corn and scalloped potatoes (Table II). The different approaches used to report data limit possible comparisons of our results with the other published data. In general, others (Anderson and Bridges, 1988; Mongeau and Brassard, 1989) also report the presence of similar fiber components in vegetables.

Glucose in the insoluble fiber fraction originates mainly from cellulose in many foods (Theander and Åman, 1981; Theander et al., 1993) and has been used as an estimate of the cellulose content of foods; the remainder of the neutral sugars in the insoluble fraction and all of the neutral sugars in the soluble fraction have been used as measures of hemicelluloses. However, such calculations are only approximations of the cellulose and hemicellulose content of foods. Incompletely extracted starch and mixed-linked β-glucans would be sources of glucose; even if they are completely accounted for, some of the glucose in the insoluble fiber fraction may originate from xyloglucans (Theander et al., 1993). A portion of the other neutral sugars do not represent hemicelluloses but rather side chains of pectin, or, in the case of rhamnose, part of the uronic acid chain (Theander and Åman, 1979). Because of the presence of neutral sugar side chains in pectin (Theander and Åman, 1979), the use of uronic acids as a measure of pectins also is an approximation.

Cooking Effects on Fiber Content. Cooking had no effect on the total fiber content of bean sprouts, green beans, or spinach (Table I). However, cooking increased the proportion of the total pectin in green beans that was extracted into the soluble fraction (Table I). Others have reported no change (Marlett, 1992) or a slight increase (Lintas and Cappelloni, 1988) in the soluble fiber content measured by the AOAC method when vegetables were cooked; Mongeau et al. (1989) measured less soluble fiber using a different method of analysis in some vegetables after they were cooked.

Dietary Fiber Content of Different Sources of Vegetables. Some of the different sources and forms of vegetables that are frequently treated as the same food in nutritional studies contained different amounts or proportions of soluble and insoluble fiber, whereas others had similar dietary fiber contents. The dietary fiber contents of the corn samples, leaf lettuces, onions, and tomatoes were similar (Table I). However, the creamed corn contained more soluble fiber than the corn on the cob, and the cooked yellow onion contained more total pectin than the raw samples (Table I). Breading added to the onion rings increased the fiber content ~75%. The two starch-containing squashes contained similar amounts of total fiber, greater than twice the amount in the low-starch squash (Table I). The fiber content and composition of the zucchini squash were similar to those of cucumber (Marlett, 1992). Chinese cabbage had a fiber content and composition similar to those of the leaf lettuces (Table I). Fiber contents of the other three cabbage samples were similar, although sauerkraut contained more neutral sugars in the soluble fiber fraction than the other two cabbage samples (Table I). Differences in fiber contents and compositions of the two carrot samples were probably a consequence of different varieties, as was the difference between cooked green beans and canned yellow wax beans (Table I).

Although cooked greens are frequently grouped together for nutritional studies, differences in their dietary fiber content and composition suggest such grouping may lead to errors in dietary fiber intakes. The total fiber content among the five greens we analyzed ranged from 2.4 to 4.7 g/100 g (fresh weight), depending on the method of analysis, although soluble fiber was consistently only a small proportion of the total fiber (Table I). Further, the amounts of the individual fiber constituents in the insoluble fraction and the uronic acids in the soluble

Table II. Distribution of Neutral Sugars (NS) in the Soluble and Insoluble Fractions of Dietary Fiber from Vegetables

	soluble fiber fraction,[b] % of NS					insoluble fiber fraction,[b] % of NS				
sample[a]	Glc	Xyl	Gal/Rha	Ara	Man	Glc	Xyl	Gal/Rha	Ara	Man
bean sprouts										
cooked	8	3	60	25	4	59	10	15	12	4
raw	11	3	58	23	5	58	11	15	12	4
beans										
green, cooked	7	5	51	27	10	56	8	19	10	7
green, raw	10	6	44	32	8	55	8	20	10	7
yellow wax, cooked	4	3	67	23	3	62	8	14	8	8
cabbage										
Chinese	5	3	46	40	6	65	10	11	10	4
green, cooked	7	4	38	40	11	52	10	16	18	4
red	8	4	37	40	11	52	9	11	24	4
sauerkraut	16	4	32	45	3	62	19	14	11	4
carrot										
canned	2	tr[c]	62	32	4	69	5	13	9	4
fresh, cooked	3	0	62	32	3	52	5	25	13	5
corn										
creamed, canned	62	15	10	12	1	40	32	6	21	1
on cob	18	18	34	24	6	42	28	7	23	tr
greens, cooked										
beet, fresh	4	tr	38	58	tr	60	12	10	14	4
collard, frozen	5	3	42	40	10	58	12	10	14	6
kale, fresh	4	3	37	50	6	53	9	11	23	4
mustard greens	4	3	40	48	5	63	12	7	14	4
Swiss chard, fresh	5	4	47	41	3	58	8	12	18	3
lettuce										
green leaf	8	3	52	29	8	60	10	15	10	5
red leaf	12	2	49	27	10	65	11	13	7	4
onion										
red	11	4	62	15	8	45	5	42	5	3
white	5	2	76	12	5	49	5	40	4	2
yellow, cooked	3	tr	70	23	4	50	6	36	6	2
rings	9	31	33	24	3	62	8	21	6	3
potato										
Maine, boiled	5	tr	75	16	4	58	3	29	7	3
red, with skin	8	2	67	19	4	60	4	25	8	3
red, no skin	6	2	72	16	4	56	4	30	7	3
Wisconsin, boiled	16	2	62	15	5	57	2	33	6	2
Wisconsin, mashed	14	tr	68	14	4	57	3	32	6	2
white, baked	6	tr	81	10	3	64	1	30	4	1
granules	18	4	57	13	8	54	tr	38	6	2
hash	9	0	79	9	3	83	0	6	5	6
salad	22	0	63	13	2	68	3	21	5	3
scalloped	36	8	36	13	7	64	3	25	6	2
spinach										
raw	13	7	41	34	5	57	10	17	13	3
cooked	12	2	49	34	3	61	7	14	14	4
squash										
acorn	10	2	44	32	12	68	12	10	5	5
butternut	13	2	48	32	5	80	4	9	3	4
yellow zucchini	5	4	54	31	6	63	11	17	6	3
tomato										
fresh, California	11	9	53	19	8	66	10	6	3	15
fresh, home-grown	6	7	24	55	8	69	9	3	7	12

[a] See Table I for more complete description of samples. [b] Glc, glucose; Xyl, xylose; Gal, galactose; Rha, rhamnose; Ara, arabinose; Man, mannose. [c] Trace, <0.5%.

fraction varied substantially (Table I). Despite these differences, the neutral sugar compositions of the soluble and insoluble fiber fractions from the greens were similar (Table II).

The concentration of fiber among the 10 potato samples ranged from 0.7 to 2.1 g/100 g, depending on the method of analysis (Table I). Combining the potatoes with other ingredients (hash, potato salad, or scalloped potatoes) did not decrease the total fiber content below what was measured in the peeled red potatoes. Variety appeared to influence fiber content; the total fiber content of peeled and boiled white Maine or Wisconsin potatoes and of peeled and boiled red potatoes ranged from 0.9 to 1.4 g/100 g when it was measured by the Uppsala method and from 1.1 to 1.8 g/100 g when it was determined using the AOAC procedure (Table I). Peeling decreased the fiber content of red potatoes 44%, as was shown previously with white potatoes (Marlett, 1992). Processing the potatoes in various other ways had no consistent effect on the composition of the fiber or on the distribution of neutral sugars in the soluble and insoluble fractions (Tables I and II).

Conclusions. Several conclusions can be drawn from our results. First, the AOAC method generates higher fiber values than does the Uppsala procedure. Results from the two methods for potatoes and one starch-containing squash (butternut) suggest that the disparity between the results from the two methods is greater when some, but not all, high-starch foods are analyzed. Since recommended adequate fiber intakes are only 20–35 g/day (Pilch, 1987), the differences are sufficiently large to affect calculated fiber intakes. For example, one cup of prepared instant potato granules (~200 g) would be 2.8 g of Uppsala fiber or 4.0 g AOAC fiber; one cup of butternut squash

(~200 g) would be 3.6 vs 5.4 g, respectively. Dietary fiber intakes from some of the cooked greens also would be greater if the AOAC rather than the Uppsala data were used.

Second, comparison of the soluble fiber we measured with that reported by others indicates that the Uppsala procedure recovers less of the total fiber in the soluble fraction than most other methods (Anderson and Bridges, 1988; Mongeau et al., 1989). This difference in soluble vs insoluble fiber contents obtained by different procedures would confound the determination of soluble and insoluble fiber intakes if a database consisting of data from several methods was used. Measurement of soluble fiber is of interest because it appears to have different physiological effects in the gastrointestinal tract from those of insoluble fiber (Pilch, 1987). However, the relationship between analytically determined soluble fiber and that fraction which behaves like soluble fiber in vivo is not known (Marlett, 1990).

Third, the grouping of foods traditionally done for nutritional studies may not be appropriate if dietary fiber intakes are to be part of the study. Independent of the method of analysis, the concentration of fiber among the cooked greens varied substantially; kale contained 65% more dietary fiber than beet greens. Peeled red potato contained 24–36% less fiber than the peeled Maine or Wisconsin potatoes. As reported previously (Lintas and Cappelloni, 1988; Marlett et al., 1989a; Mongeau et al., 1989), cooking and other forms of processing affected the composition and amount of soluble fiber measured in this study, although this effect was not consistent across the various vegetables.

ACKNOWLEDGMENT

We thank Ms. Jadwiga Forster, Ms. Peggy Kroll-Conner, and Mr. Richard Dow for their excellent technical assistance. The research was funded in part by National Institutes of Health Contract CN-85469 and the College of Agricultural and Life Sciences, University of Wisconin—Madison, Madison, WI.

LITERATURE CITED

Anderson, J. W.; Bridges, S. R. Dietary fiber content of selected foods. *Am. J. Clin. Nutr.* **1988**, *47*, 440–447.

Ben-Shalom, N.; Plat, D.; Levi, A.; Pinto, R. Changes in molecular weight of water-soluble and EDTA-soluble pectin fractions from carrot after heat treatments. *Food Chem.* **1992**, *40*, 243–245.

Graham, H.; Rydberg, M.-B. G.; Åman, P. Extraction of soluble dietary fiber. *J. Agric. Food Chem.* **1988**, *36*, 494–497.

Haytowitz, D. B.; Matthews, R. H. *Composition of Foods: Vegetables and Vegetable Products*; Agriculture Handbook Number 8–11; U.S. Department of Agriculture, U.S. Government Printing Office: Washington, DC, 1984.

Krebs-Smith, S. M.; Cronin, F. J.; Haytowitz, D. B.; Cook, D. A. Food sources of energy, macronutrients, cholesterol and fiber in diets of women. *J. Am. Diet. Assoc.* **1992**, *92*, 168–174.

Lintas, C.; Cappelloni, M. Content and composition of dietary fibre in raw and cooked vegetables. *Food Sci. Nutr.* **1988**, *42*, 117–124.

Marlett, J. A. Issues in dietary fiber analysis. In *New Developments in Dietary Fiber*; Furda, I., Brine, C. J., Eds.; Plenum Press: New York, 1990; pp 183–192.

Marlett, J. A. Content and composition of dietary fiber in 117 frequently consumed foods. *J. Am. Diet. Assoc.* **1992**, *92*, 175–186.

Marlett, J. A.; Navis, D. Comparison of gravimetric and chemical analyses of total dietary fiber in human foods. *J. Agric. Food Chem.* **1988**, *36*, 311–315.

Marlett, J. A.; Bogdanske, J. J.; Longacre, M. J. The effect of commercial processing on dietary fiber in vegetables and cereals. *FASEB J.* **1989a**, *3*, A1064.

Marlett, J. A.; Chesters, J. G.; Longacre, M. J.; Bogdanske, J. J. Recovery of soluble dietary fiber is dependent on the method of analysis. *Am. J. Clin. Nutr.* **1989b**, *50*, 479–485.

Mongeau, R.; Brassard, R. A comparison of three different methods for analyzing dietary fiber in 38 foods. *J. Food Compos. Anal.* **1989**, *2*, 189–199.

Mongeau, R.; Brassard, R.; Verdier, P. Measurement of dietary fiber in a total diet study. *J. Food Compos. Anal.* **1989**, *2*, 317–326.

Mullin, W. J.; Smith, J. M. Dietary fiber in raw and cooked potatoes. *J. Food Compos. Anal.* **1991**, *4*, 100–106.

Pilch, S. M., Ed. *Physiological Effects and Health Consequences of Dietary Fiber*; Life Sciences Research Office, Federation of American Societies for Experimental Biology: Bethesda, MD, 1987.

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

Shinnick, F. L.; Longacre, M. J.; Ink, S. L.; Marlett, J. A. Oat fiber: Composition vs. physiological function in rats. *J. Nutr.* **1988**, *118*, 144–151.

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

Steele, R. G. D.; Torrie, J. H. *Principles and Procedures of Statistics*; McGraw-Hill Book: New York, 1960.

Theander, O.; Åman, P. The chemistry, morphology and analysis dietary fiber components. In *Dietary fibers: Chemistry and nutrition*; Inglett, G. E., Falkehag, S. I., Eds.; Academic Press: New York, 1979; pp 215–244.

Theander, O.; Åman, P. Analysis of dietary fibers and their main constituents. In *The analysis of dietary fiber in food*; James, W. P. T., Theander, O., Eds.; Dekker: New York, 1981; pp 51–70.

Theander, O.; Westerlund, E. Studies on dietary fiber. 3 Improved procedures for analysis of dietary fiber. *J. Agric. Food Chem.* **1986**, *34*, 330–336.

Theander, O.; Åman, P.; Westerland, E.; Graham, H. The Uppsala method for rapid analysis of total dietary fiber. In *New Developments in Dietary Fiber*; Furda, I., Brine, C. J., Eds.; Plenum Press: New York, 1990; pp 273–281.

Theander, O.; Westerlund, E.; Åman, P. Structure and components of dietary fiber. *Cereal Foods World* **1993**, *38*, 135–141.

Thompson, F. E.; Sowers, M. F.; Frongillo, E. A.; Parpia, B. J. Sources of fiber and fat in diets of US women aged 19–50: Implications for nutrition education and policy. *Am. J. Public Health* **1992**, *82*, 695–702.

Visser, F. R.; Gurnsey, C. Inconsistent differences between neutral detergent fiber and total dietary fiber values of fruits and vegetables. *J. Assoc. Off. Anal. Chem.* **1986**, *69*, 565–567.

Vollendorf, N. W.; Marlett, J. A. Comparison of two methods of fiber analysis of 58 foods. *J. Food Compos. Anal.* **1993**, in press.

Received for review May 3, 1993. Accepted July 26, 1993.*

* Abstract published in *Advance ACS Abstracts*, September 15, 1993.