# Dietary Fiber Content and Composition in Home-Prepared and Commercially Baked Products: Analysis and Prediction

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**ABSTRACT**

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The three objectives of this research were to: 1) compare dietary fiber data from the AOAC and Uppsala methods of analysis for 19 home-prepared (HP) baked products (and the nine ingredients used) and 11 commercial products; 2) test the hypothesis that fiber content of baked products could be predicted from the fiber content of recipe ingredients; and 3) compare the fiber composition of HP and commercial versions of the same baked product. The AOAC fiber value was usually larger than that measured using the Uppsala method, although data from the two methods were highly correlated. Depending on the ingredients in the product, the fiber value from one method could be predicted from the other with linear regression. In both methods, total dietary fiber content of most baked products was underpredicted by the fiber content of their ingredients. The fiber composition data from the Uppsala method showed that this was primarily due to high Klason lignin values in these products. Baking inconsistently increased the proportion of soluble fiber, limiting the ability to predict soluble and insoluble fiber content from the fiber composition of the ingredients. Dietary fiber content of HP and commercial products differed, probably because of differences in recipe ingredients.

The number of refined-grain products that provide fiber to the diet is very large. The third supplement to the British food composition tables (Holland et al 1988) provides nutrient composition for ~230 baked products. However, dietary fiber data are only estimated or are not available for many of these foods. The baked products section (8-18) of the new series of Agriculture Handbook 8 is in preparation, and it would be expected to have at least that number of entries. Determining the dietary fiber content and composition of such a large number of foods would be a substantial undertaking, particularly because only one class of foods provides dietary fiber. Further, commercially prepared products are continually being added to the food supply. The number of samples that would require fiber analysis would increase even more if all of the locally and regionally prepared baked goods were considered. Finally, little is known about the relationship between commercially and home-prepared (HP) baked products, but consideration of HP products would add still more samples for dietary fiber analysis.

Adequate dietary fiber data for baked products are needed to determine fiber intake and to study the relationships between dietary fiber and disease. Lanza and Butrum (1986) reported that it was difficult to develop a provisional table of dietary fiber values for the numerous specialty baked products and breads because available data in the literature were so limited. The overall aim of this research was to address the problem of inadequate dietary fiber data for baked products in three areas.

First, we compared total dietary fiber content determined by the AOAC method (Prosky et al 1988) with the fiber values obtained using the Uppsala method (Theander and Westerlund 1986, Theander et al 1990). The primary advantage of the AOAC method is efficiency. The Uppsala method provides more detailed information about the types of dietary fiber present. This detailed information is potentially useful in both clinical trials and epidemiological studies. However, AOAC data would be available for more foods because it is the method most used to provide information for food labels. Thus, an understanding of how the methods compare would be very useful.

Second, we determined whether the dietary fiber content of baked products could be predicted from the dietary fiber content and composition of the ingredients. This approach could greatly reduce the number of samples required for analysis and provide detailed dietary fiber data for foods more efficiently.

Third, we analyzed HP products with known recipes, which provided an opportunity to compare their dietary fiber content and composition to those of commercial products.

## METHODS

### Food Samples

Regional and national brands of ingredients and commercial products were purchased from local suppliers. Commercial foods were prepared as for consumption, if necessary, using package directions or conventional methods. Oatmeal and frozen pie crust were the only ingredients that were cooked before analysis. HP products were made using recipes from the 1965 *Better Homes and Gardens New Cookbook*. Bran muffins were made using recipes taken from a cereal box (All Bran), and apple and cherry pies were made using recipes from labels of canned pie filling.

The amounts of fiber-containing ingredients used in each HP

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product are listed in Table I. Most samples were blended (commercial model 34BL22, Waring, New Hartford, CT) with additional water to form a uniform homogenate and lyophilized to determine dry weight and fiber analysis. A few samples were either air-dried then ground dry or ground dry as is. Moisture contents of these foods were determined by vacuum oven drying (70°C, 5 hr) (Table II). About 300 g (dry weight) of each food was dried, and aliquots were taken for analysis by the two methods.

### Dietary Fiber Analysis

A modification of the Uppsala chemical method (Theander and Westerlund 1986) that involves high-performance liquid chromatography instead of gas chromatography to measure fiber-derived sugars (Shinnick et al 1988, Marlett 1992) was used to determine fiber content and composition. Using the AOAC gravimetric method (Prosky et al 1988), total dietary fiber was measured in quadruplicate, which provided duplicate samples for ash and protein determinations. Foods containing more than 5% fat (dwb) were defatted. Duplicate aliquots (10–15 g) of dry food were stirred three times with petroleum ether (25 ml/g) for 15 min. Solvent was removed by decanting through tared filter papers, and the residue was dried and weighed.

For the Uppsala method, an extractive-free residue was prepared by sonicating (15 min) the samples first in 80% ethanol (2 × 20 ml/g) and then in chloroform (2 × 15 ml/g). Each sonication was followed by centrifugation (15 min at 2,500 × *g*), after which the supernatant was decanted through tared filter paper. After the residue was dried, it was subjected to enzymatic starch hydrolysis while suspended in an acetate buffer (75 ml/5 g of sample; 0.1*M*, pH 5.0, 1.75 m*M* of $CaCl_2$). Two enzymes were used: 1) a heat-stable α-amylase (0.2 ml/5 g of sample; A3306, EC 3.2.1.1, Sigma Chemical, St. Louis, MO) at 92–94°C for 30 min; and 2) amyloglucosidase (0.3 ml/5 g of sample; 102875, EC 3.2.1.3, Boehringer Mannheim, Indianapolis, IN) at 55°C overnight. The soluble and insoluble fractions were separated by centrifugation. Starch hydrolysis products were removed from the soluble fraction by dialysis (Shinnick et al 1988). Quantitation by high-performance liquid chromatography of neutral sugars in both fractions was as previously described for the insoluble fraction (Shinnick et al 1988). The secondary hydrolysis step used an autoclave (121°C, 1 hr) instead of a boiling water bath. Measurement of Klason lignin, uronic acids (pectin), residual starch, and protein was also as previously described. Glucose in the neutral sugars was corrected for residual starch content. Protein and residual starch values were used to calculate recoveries of the fiber fractions. Mean (±SD, $n = 39$) recovery was 99 ± 5% for the insoluble fiber fractions and 77 ± 8% for the soluble fiber fractions. The recoveries were similar to those previously obtained (Marlett 1992).

β-Glucans were measured using an enzymatic method (McCleary and Glennie-Holmes 1985). A special grade of amyloglucosidase, free of β-glucanase activity (Boehringer Mannheim 1202367), was used for starch hydrolysis of the oatmeal and oatmeal cookies. Cellulose was calculated as all glucose in the insoluble fraction that was not residual starch or β-glucan (Theander and Westerlund 1986). Hemicelluloses were calculated as all of the other neutral sugars in the insoluble fraction and all neutral sugars in the soluble fraction.

### Prediction Calculations

The predicted dietary fiber content and composition of the HP products were calculated by summing the dietary fiber contributions of all fiber-containing ingredients. The dietary fiber contribution made by an ingredient was calculated as the percentage of that ingredient in the recipe (dry weight) (Table I) multiplied by its dietary fiber content and composition (Tables II and IV).

**TABLE I**
**Amounts of Fiber-Containing Ingredients Used in Home-Prepared Baked Products**

| Description | Product Number | Ingredients (g/100 g dry weight) White Flour | A[a] | B[b] |
|---|---|---|---|---|
| Cakes | | | | |
| Pound | 1 | 38.4 | ... | ... |
| Sponge | 2 | 36.5 | ... | ... |
| White | 3 | 40.2 | ... | ... |
| Cookies | | | | |
| Oatmeal | 4 | 23.3 | 28.8 | ... |
| Oatmeal raisin | 5 | 22.2 | 27.4 | 6.9 |
| Shortbread | 6 | 49.1 | ... | ... |
| Muffins | | | | |
| ALL BRAN | 7 | 36.3 | 21.8 | ... |
| Blueberry | 8 | 61.5 | 6.8 | ... |
| Plain | 9 | 72.0 | ... | ... |
| Pies | | | | |
| Apple | 10 | ... | 33.2 | 66.8[c] |
| Cherry | 11 | ... | 46.7 | 53.3[c] |
| Rolls, yeast | | | | |
| Plain | 12 | 96.1 | ... | ... |
| Sweet | 13 | 75.1 | ... | ... |
| Sweet, with cinnamon | 14 | 57.0 | ... | ... |
| Sweet, with cinnamon and pecans | 15 | 53.7 | 12.6 | ... |
| Miscellaneous | | | | |
| Doughnuts | 16 | 56.0 | ... | ... |
| Pancakes | 17 | 60.5 | ... | ... |
| Piecrust | 18 | 68.5 | ... | ... |
| Waffles | 19 | 60.6 | ... | ... |

[a] First fiber-containing ingredient, other than flour, listed in the description column.
[b] Second fiber-containing ingredient listed in the description column, except for frozen piecrust.
[c] Frozen piecrust.

## RESULTS AND DISCUSSION

### Comparison of AOAC and Uppsala Values for Total Dietary Fiber Content

Values for total dietary fiber content from both the AOAC and the Uppsala methods are listed in Table II. The dietary fiber content of the ingredients used in HP baked products ranged from 0.5 to 34.7 g/100 g (fresh weight) of sample. Total fiber values from the AOAC method were either similar to or slightly larger than Uppsala values for seven of the nine ingredients. AOAC values for All Bran cereal and pecans were much larger than the Uppsala values. The dietary fiber content of the HP baked products ranged from 0.9 to 6.5 g/100 g (fresh weight) of sample, whereas those for the commercial products ranged from 0.5 to 5.2/100 g (fresh weight) of sample. Nearly all of the AOAC values for both HP and commercial products were either larger or similar to the corresponding Uppsala values. Only HP oatmeal raisin cookies and piecrust had AOAC values that were lower than the Uppsala total fiber values.

Regression analysis for all the baked products ($n = 30$) showed a linear relationship between the two sets of data:

$$\text{Uppsala} = 0.94\ (\text{AOAC}) - 0.16,\ r^2 = 0.91$$

Four products had Uppsala values that deviated by 0.5 g/100g of sample or more from those predicted by using the AOAC values in this equation. Analyzed Uppsala values for HP oatmeal cookie, HP oatmeal raisin cookie, and HP piecrust were greater than those predicted (0.6, 1.3, and 0.7 g/100g of sample, respectively), whereas the HP sweet roll value was 0.5 g/100 g of sample less than the predicted value. White flour, the predominant fiber-containing ingredient in most of these baked products (Table I), fit the equation almost perfectly, but oatmeal did not. The deviation of the HP oatmeal cookies, which derived over 75% of their fiber from oatmeal, can be explained as a consequence of the large amounts of oatmeal they contained (Table I). There were four other HP products with major fiber contributions from nonflour sources: bran muffins, blueberry muffins, apple pie, and cherry pie. Both All Bran cereal and blueberries

**TABLE II**
**Dietary Fiber Content (g/100 g fresh weight) of Ingredients and Home-Prepared (HP) and Commercial Products**

| | Source of Product Data[c] | Uppsala[a] | | | AOAC[b] | |
|---|---|---|---|---|---|---|
| | | Soluble Fiber[d] | Insoluble Fiber[e] | Total Fiber[f] | Total Fiber | Dry Weight[g] |
| Ingredients | | | | | | |
| Apple pie filling, canned | ... | 0.3 | 0.7 | 1.0 | 0.9 | 25.4 |
| Blueberries, frozen, thawed and drained | ... | 0.3 | 2.7 | 3.0 | 3.5 | 16.6 |
| Cereal, ALL BRAN | ... | 2.4 | 26.3 | 28.7 | 34.7 | 97.5[h] |
| Cereal, oatmeal | ... | 0.7 | 0.8 | 1.5 | 1.4 | 14.7 |
| Cherry pie filling, canned | ... | 0.5 | 0.3 | 0.8 | 0.5 | 29.8 |
| Flour, white wheat, all purpose | ... | 0.9 | 2.0 | 2.9 | 3.3 | 90.3[h] |
| Piecrust, frozen, baked | ... | 0.5 | 1.2 | 1.7 | 2.1 | 95.0 |
| Pecans | ... | 0.2 | 5.7 | 5.9 | 9.8 | 97.4[h] |
| Raisins | ... | 0.5 | 3.7 | 4.2 | 4.0 | 90.1 |
| Cakes | | | | | | |
| Pound | HP-A | 0.5 | 0.8 | 1.3 | 1.7 | 82.9 |
| | HP-P[i] | 0.3 | 0.7 | 1.0 | 1.2 | |
| | COM | 0.2 | 0.3 | 0.5 | 0.9 | 77.7 |
| Sponge | HP-A | 0.4 | 1.2 | 1.6 | 1.6 | 84.9 |
| | HP-P | 0.3 | 0.7 | 1.0 | 1.1 | |
| White | HP-A | 0.5 | 0.5 | 1.0 | 1.6 | 76.7 |
| | HP-P | 0.3 | 0.7 | 1.0 | 1.1 | |
| | COM | 0.3 | 0.4 | 0.7 | 1.1 | 67.9 |
| Cookies | | | | | | |
| Oatmeal | HP-A | 1.2 | 2.3 | 3.5 | 3.3 | 88.2 |
| | HP-P | 1.4 | 1.9 | 3.3 | 3.2 | |
| | COM | 1.0 | 1.9 | 2.9 | 3.3 | 93.2 |
| Oatmeal raisin | HP-A | 1.5 | 2.8 | 4.3 | 3.4 | 87.6 |
| | HP-P | 1.4 | 2.1 | 3.5 | 3.3 | |
| | COM | 1.2 | 1.5 | 2.7 | 2.8 | 92.2 |
| Shortbread | HP-A | 0.7 | 0.7 | 1.4 | 1.9 | 96.0 |
| | HP-P | 0.5 | 1.0 | 1.5 | 1.7 | |
| | COM | 0.5 | 1.0 | 1.5 | 1.9 | 95.4 |
| Muffins | | | | | | |
| Blueberry | HP-A | 0.6 | 2.0 | 2.6 | 2.7 | 64.9 |
| | HP-P | 0.5 | 1.6 | 2.1 | 2.4 | |
| | COM | 0.3 | 1.2 | 1.5 | 1.6 | 67.7 |
| Bran | HP-A | 0.8 | 5.0 | 5.8 | 6.5 | 69.2 |
| | HP-P | 0.6 | 4.6 | 5.2 | 6.3 | |
| | COM | 0.6 | 3.9 | 4.5 | 5.1 | 71.4 |
| Plain | HP-A | 0.4 | 1.1 | 1.5 | 2.2 | 64.5 |
| | HP-P | 0.5 | 1.0 | 1.5 | 1.7 | |
| Pies | | | | | | |
| Apple | HP-A[j] | 0.4 | 0.8 | 1.2 | 1.4 | 48.8 |
| | HP-P | 0.3 | 0.8 | 1.1 | 1.3 | |
| Cherry | HP-A[j] | 0.5 | 0.4 | 0.9 | 0.9 | 44.4 |
| | HP-P | 0.5 | 0.6 | 1.1 | 0.9 | |
| | COM[k] | 0.4 | 0.6 | 1.0 | 1.1 | 49.9 |
| Rolls, yeast | | | | | | |
| Plain | HP-A | 0.9 | 1.3 | 2.2 | 2.7 | 63.9[h] |
| | HP-P | 0.6 | 1.3 | 1.9 | 2.2 | |
| Sweet | HP-A | 0.9 | 1.4 | 2.3 | 3.2 | 76.1[h] |
| | HP-P | 0.6 | 1.1 | 1.7 | 2.1 | |
| Sweet, with cinnamon | HP-A | 0.6 | 1.3 | 1.9 | 2.6 | 79.1 |
| | HP-P | 0.5 | 0.9 | 1.4 | 1.7 | |
| Sweet, with cinnamon and pecans | HP-A | 0.6 | 1.4 | 2.0 | 2.7 | 79.9 |
| | HP-P | 0.5 | 1.5 | 2.0 | 2.6 | |
| | COM[l] | 0.4 | 1.5 | 1.9 | 2.3 | 86.4 |
| Miscellaneous | | | | | | |
| Doughnut, plain | HP-A | 0.6 | 1.2 | 1.8 | 2.1 | 82.8 |
| | HP-P | 0.5 | 1.0 | 1.5 | 1.7 | |
| | COM | 0.4 | 1.0 | 1.4 | 1.5 | 79.8 |
| Pancake | HP-A | 0.3 | 1.3 | 1.6 | 1.9 | 57.6 |
| | HP-P | 0.3 | 0.7 | 1.0 | 1.3 | |
| Piecrust | HP-A | 0.8 | 1.7 | 2.5 | 2.1 | 91.0 |
| | HP-P | 0.6 | 1.4 | 2.0 | 2.3 | |
| Waffle | HP-A | 0.5 | 0.8 | 1.3 | 1.8 | 64.7 |
| | HP-P | 0.4 | 0.8 | 1.2 | 1.4 | |
| | COM[k] | 0.4 | 1.3 | 1.7 | 2.0 | 69.7 |

[a] Means of two measurements.
[b] Means of four measurements.
[c] HP-A = analyzed values for HP products, HP-P = predicted values for HP products, COM = analyzed values for commercial products.
[d] Sum of soluble fiber components × dry weight.
[e] Sum of insoluble fiber components × dry weight.
[f] Soluble + insoluble fiber.
[g] Determined by lyophilization, except for marked values.
[h] Determined by vacuum oven drying.
[i] From mix.
[j] From frozen pie crust and canned pie filling.
[k] Frozen.
[l] Sweet, with walnuts.

fit the regression equation, as did the products made from them. Apple and cherry pie fillings had Uppsala total fiber values that were 0.3 and 0.5 g/100 g of sample greater than those predicted by the AOAC values and the regression equation. In the pies, these deviations were offset by the frozen piecrust, which had an Uppsala value 0.2 g/100 g of sample less than that predicted by the AOAC value. Apple pie fit the regression equation perfectly, while the Uppsala value for cherry pie was 0.2 g/100 g of sample greater than predicted. These data suggest that dietary fiber values for baked products obtained by either of these two methods can be interrelated by the regression equation, at least as long as the major fiber-containing ingredients come close to fitting the equation. It is unclear why the HP piecrust and one of four rolls deviated from the regression equation.

Mongeau and Brassard (1989) compared three methods for dietary fiber analysis: the AOAC gravimetric method, their own rapid gravimetric method, and the Englyst chemical method for nonstarch polysaccharides (NSP). They found that the NSP values for cereal products and legumes were lower than values from the gravimetric methods. Addition of lignin values (not normally measured by Englyst) to the NSP values reduced, but did not eliminate, the differences. Linear regression of data for a mixture of foods gave:

$$\text{NSP} + \text{lignin} = 0.95\ (\text{AOAC}) - 0.41, \text{ and}$$
$$\text{NSP} + \text{lignin} = 0.93\ (\text{Rapid}) - 0.29$$

The slopes of these regression equations are very similar to that for the Uppsala-AOAC relationship reported here for baked products; however, the intercepts are even further from zero. We recently correlated the results of a comparison of the Uppsala and AOAC methods for 58 foods representing all fiber-containing food groups (Vollendorf and Marlett 1993). The regression equation for all foods was similar to the equation generated from the HP and commercial products (Uppsala = 0.87 [AOAC] + 0.16). However, the regression analysis for each group of foods within the 58 foods produced different equations; the equation for the grain products ($n = 8$) was very different from what we obtained using baked product data in the present study (Uppsala = 0.79 [AOAC] + 0.78). This small subset of eight samples in-

**TABLE III**
**Distribution of Neutral Sugars (%) in the Soluble and Insoluble Fractions of Dietary Fiber from Ingredients and Baked Products**

| Sample[a] | Source of Product Data[b] | Soluble Fiber Fraction | | | | | Insoluble Fiber Fraction | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Glc | Xyl | Gal/Rha | Ara | Man[c] | Glc | Xyl | Gal/Rha | Ara | Man |
| Ingredients | | | | | | | | | | | |
| Apple pie filling | ... | 68 | 8 | 12 | 12 | tr | 63 | 12 | 9 | 13 | 3 |
| Blueberries | ... | 13 | 7 | 39 | 39 | 2 | 44 | 43 | 7 | 3 | 3 |
| Cereal, ALL BRAN | ... | 12 | 53 | 5 | 29 | 1 | 31 | 44 | 2 | 22 | 1 |
| Cereal, oatmeal | ... | 93 | 1 | 2 | 4 | tr | 39 | 37 | tr | 20 | 4 |
| Cherry pie filling | ... | 67 | 10 | 9 | 13 | 1 | 53 | 7 | 12 | 23 | 5 |
| Flour | ... | 16 | 34 | 16 | 28 | 6 | 33 | 40 | tr | 22 | 5 |
| Piecrust | ... | 6 | 46 | 15 | 28 | 5 | 27 | 38 | 3 | 25 | 7 |
| Pecans | ... | 7 | 7 | 45 | 35 | 6 | 45 | 14 | 14 | 23 | 4 |
| Raisins | ... | 15 | 9 | 35 | 32 | 9 | 64 | 10 | 9 | 10 | 7 |
| Cakes | | | | | | | | | | | |
| Pound | HP | 3 | 52 | 11 | 32 | 2 | 53 | 16 | 3 | 12 | 16 |
| | COM | 6 | 42 | 14 | 33 | 5 | 34 | 16 | 6 | 16 | 28 |
| Sponge | HP | 6 | 48 | 12 | 31 | 3 | 46 | 12 | 3 | 11 | 28 |
| White | HP | 7 | 49 | 12 | 30 | 2 | 45 | 18 | 7 | 15 | 15 |
| | COM | 7 | 37 | 16 | 28 | 12 | 41 | 16 | 4 | 15 | 24 |
| Cookies | | | | | | | | | | | |
| Oatmeal | HP | 70 | 12 | 6 | 9 | 3 | 44 | 29 | tr | 19 | 8 |
| | COM | 52 | 18 | 11 | 17 | 2 | 37 | 28 | 4 | 23 | 8 |
| Oatmeal raisin | HP | 73 | 11 | 5 | 9 | 2 | 40 | 32 | 2 | 19 | 7 |
| | COM | 76 | 9 | 4 | 10 | 1 | 45 | 27 | 3 | 19 | 6 |
| Shortbread | HP | 3 | 51 | 12 | 32 | 2 | 39 | 27 | 2 | 19 | 13 |
| | COM | 10 | 39 | 18 | 30 | 3 | 36 | 31 | 4 | 20 | 9 |
| Muffins | | | | | | | | | | | |
| Blueberry | HP | 3 | 51 | 12 | 31 | 3 | 50 | 26 | 6 | 10 | 8 |
| | COM | 8 | 35 | 21 | 30 | 6 | 39 | 31 | 8 | 12 | 10 |
| Bran | HP | 8 | 53 | 8 | 30 | 1 | 34 | 40 | 2 | 22 | 2 |
| | COM | 19 | 37 | 13 | 29 | 2 | 37 | 36 | 2 | 23 | 2 |
| Plain | HP | 8 | 42 | 15 | 31 | 4 | 46 | 23 | 4 | 18 | 9 |
| Pies | | | | | | | | | | | |
| Apple | HP | 35 | 27 | 13 | 23 | 2 | 47 | 23 | 4 | 20 | 6 |
| Cherry | HP | 47 | 20 | 10 | 22 | 1 | 44 | 25 | 3 | 19 | 9 |
| | COM | 43 | 21 | 11 | 22 | 3 | 44 | 23 | 3 | 21 | 9 |
| Rolls, yeast | | | | | | | | | | | |
| Plain | HP | 6 | 48 | 12 | 31 | 3 | 54 | 16 | tr | 14 | 16 |
| Sweet | HP | 5 | 48 | 13 | 31 | 3 | 51 | 20 | 2 | 14 | 13 |
| Sweet with cinnamon | HP | 3 | 51 | 11 | 32 | 4 | 53 | 18 | 1 | 13 | 15 |
| Sweet with cinnamon and pecans | HP | 4 | 49 | 13 | 31 | 3 | 56 | 17 | 2 | 13 | 12 |
| | COM | 10 | 39 | 16 | 30 | 5 | 45 | 20 | 9 | 15 | 11 |
| Miscellaneous | | | | | | | | | | | |
| Doughnut | HP | 4 | 51 | 11 | 32 | 2 | 41 | 23 | 4 | 17 | 15 |
| | COM | 8 | 36 | 19 | 37 | tr | 40 | 25 | 11 | 17 | 7 |
| Pancakes | HP | 9 | 40 | 10 | 29 | 12 | 48 | 25 | 3 | 13 | 11 |
| Piecrust | HP | 10 | 40 | 15 | 30 | 5 | 31 | 37 | 2 | 24 | 6 |
| Waffles | HP | 3 | 53 | 10 | 31 | 3 | 43 | 16 | 8 | 14 | 19 |

[a] See Table II for more complete description of samples.
[b] HP = analyzed values for home-prepared products, COM = analyzed values for commercial products.
[c] Glc = glucose, xyl = xylose, gal = galactose, rha = rhamnose, ara = arabinose, and man = mannose; gal and rha coelute on the high-performance liquid chromatography column that was used.

cluded several grain sources, as well as several processing and preparation methods, which suggests that these factors may be important in influencing how values from the two methods relate.

In general, all of these comparisons suggest that the gravimetric methods measure some materials as dietary fiber that the chemical methods do not. The presence of starch and simple sugars in AOAC fiber residues was the source of inflated fiber values for some foods (Marlett and Navis 1988, Vollendorf and Marlett 1993). Mongeau and Brassard (1989) detected no starch in the insoluble fiber residues from their procedure when they used the iodine test. They apparently did not test the soluble fiber residue for starch. It is not uncommon for soluble fiber residues from the Uppsala method to contain as much, or more, residual starch as the insoluble fiber residue (J. Marlett and N. Vollendorf, *unpublished*). Whatever their source, the discrepancies between methods seem to be reproducible and predictable enough to enable data from different methods to be compared using the appropriate regression equations.

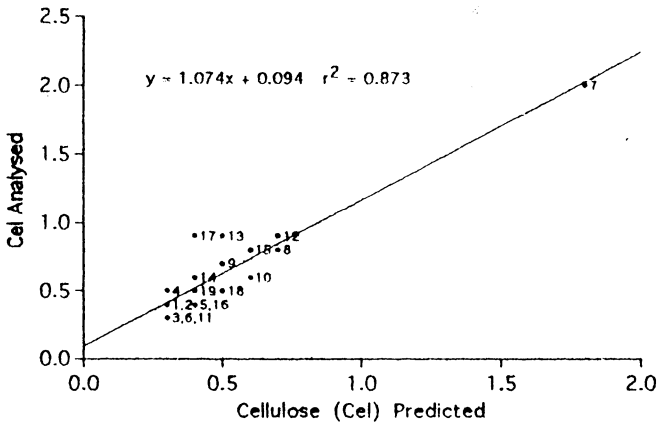


**Fig. 1.** Relationship between predicted and analyzed cellulose content (g/100 g [dry weight] of sample) of 19 home-prepared products. Numbers on data points correspond to product numbers in Table I.

### Prediction of Dietary Fiber Content and Composition

The predicted total dietary fiber values were low compared to the values obtained by analysis for 11 of the 19 HP products using the Uppsala method and for 12 of the HP products using the AOAC method (Table II). Regression analysis showed linear relationships for both sets of data:

$$\text{Analyzed} = 1.09\ (\text{predicted}) + 0.08$$
$$r^2 = 0.96 \text{ for the Uppsala method}$$

$$\text{Analyzed} = 0.94\ (\text{predicted}) + 0.49$$
$$r^2 = 0.94 \text{ for the AOAC method}$$

The Uppsala data for soluble and insoluble fiber suggest that these underpredictions were primarily due to low predicted values for the insoluble fiber fraction (Table II). Each of the four components in the insoluble fiber fraction was examined for its role in these underpredictions.

Cellulose content in the insoluble fraction was predicted well (Fig. 1). The slope and intercept of the regression equation show that analyzed values for cellulose were slightly higher than predicted. Only two foods, sweet rolls and pancakes (Figs. 1, 13 and 17, respectively), had cellulose values that were more than 0.2 g/100 g of sample greater than the predicted values. Klason lignin was the least accurately predicted component of the insoluble fiber fraction (Fig. 2). The slope (1.27) and the intercept (0.2) from the linear regression show that analyzed lignin values tended to be greater than predicted values. This suggests some sort of artifact lignin was generated during the baking process—possibly Maillard reaction products, which have analyzed as Klason lignin (Theander 1983, Marlett and Navis 1988). Mongeau and Brassard (1989) used permanganate lignin values to add to their NSP values. The authors reported that that method was more accurate and did not include Maillard reaction products.

**TABLE IV**
**Dietary Fiber Composition (g/100 g dry weight) of Ingredients and Commercial Products**

| | Soluble Fiber | | Insoluble Fiber | | | |
|---|---|---|---|---|---|---|
| **Food Sample**[a] | **Hemicelluloses** | **Pectin** | **Hemicelluloses** | **Cellulose** | **Pectin** | **Klason Lignin** |
| Ingredients | | | | | | |
| Apple pie filling | 0.8[b] | 0.3 | 0.8 | 1.3 | 0.5 | 0.1 |
| Blueberries | 0.7 | 1.0 | 4.4 | 3.5 | 1.7 | 6.4 |
| Cereal, ALL BRAN | 2.4 | 0.1 | 16.3 | 7.3 | 0.6 | 2.8 |
| Cereal, oatmeal[c] | 4.7 | 0.1 | 2.6 | 0.6 | 0.2 | 2.2 |
| Cherry pie filling | 1.7 | 0.1 | 0.2 | 0.2 | 0.3 | 0.3 |
| Flour | 1.0 | 0.0 | 1.4 | 0.7 | 0.0 | 0.1 |
| Piecrust, frozen | 0.5 | 0.0 | 0.7 | 0.3 | 0.0 | 0.3 |
| Pecans | 0.2 | 0.0 | 1.9 | 1.5 | 1.1 | 1.4 |
| Raisins | 0.3 | 0.3 | 0.5 | 0.9 | 0.7 | 2.0 |
| Cakes | | | | | | |
| Pound | 0.3 | 0.0 | 0.3 | 0.1 | 0.0 | 0.0 |
| White, from mix | 0.5 | 0.0 | 0.3 | 0.2 | 0.0 | 0.1 |
| Cookies | | | | | | |
| Oatmeal[d] | 1.0 | 0.1 | 0.9 | 0.2 | 0.1 | 0.8 |
| Oatmeal raisin[e] | 1.3 | 0.0 | 0.6 | 0.3 | 0.1 | 0.6 |
| Shortbread | 0.5 | 0.0 | 0.7 | 0.4 | 0.0 | 0.0 |
| Muffins | | | | | | |
| Blueberry | 0.4 | 0.1 | 0.7 | 0.5 | 0.1 | 0.5 |
| Bran | 0.7 | 0.1 | 2.8 | 1.6 | 0.2 | 0.9 |
| Pie, cherry | 0.9 | 0.0 | 0.4 | 0.3 | 0.2 | 0.4 |
| Roll, sweetened, with nuts | 0.5 | 0.0 | 0.7 | 0.6 | 0.1 | 0.3 |
| Miscellaneous | | | | | | |
| Doughnut, plain | 0.5 | 0.0 | 0.6 | 0.4 | 0.1 | 0.1 |
| Waffles, frozen | 0.6 | 0.0 | 0.7 | 0.3 | 0.0 | 0.8 |

[a] See Table II for more complete description of samples.
[b] All values are means of two measurements.
[c] Hemicellulose values include 3.9 and 0.7 g/100 g dry weight β-glucans in the soluble and insoluble fractions, respectively.
[d] Hemicellulose values include 0.5 and 0.3 g/100 g dry weight β-glucans in the soluble and insoluble fractions, respectively.
[e] Hemicellulose values include 0.7 and 0.1 g/100 g dry weight β-glucans in the soluble and insoluble fractions, respectively.

Predicted values for hemicellulose content in the insoluble fraction tended to be higher than analyzed. The regression equation was:

$$\text{Analyzed} = 0.96\ (\text{predicted}) - 0.12,\ r^2 = 0.94$$

This was due to solubilization of large percentages of the insoluble hemicelluloses in 11 of the 19 HP products (Fig. 3). Total hemicellulose content was predicted very well. The linear regression equation was:

$$\text{Analyzed} = 0.99\ (\text{predicted}) - 0.002,\ r^2 = 0.97$$

This shift of hemicellulose from the insoluble fraction to the soluble fraction should have produced an overprediction of insoluble fiber content and an underprediction of soluble fiber content. In the insoluble fraction, this trend probably modulated the overall underprediction that occurred. Predicted soluble fiber content did, in fact, tend to be slightly lower than analyzed. There was no apparent explanation for why some foods exhibited an increase in hemicellulose solubility and others did not. For example, the two oatmeal cookies with large amounts of soluble $\beta$-glucans did not show much change in solubility. Shortbread cookies, containing hemicelluloses from only white flour, did show an increase in hemicellulose solubility. Two of the three cakes exhibited shifts in hemicellulose distribution, but only one of the three muffins did.

Pectin was less than 5% of the total dietary fiber present in the HP products, except for the sweet rolls with pecans, apple pies, and cherry pies, in which 5.5, 10.3, and 10.0%, respectively, of the dietary fiber was pectin. For these three products, predicted total pectin agreed with the analyzed values: 0.2 vs. 0.2, 0.3 vs. 0.3, and 0.2 vs. 0.3 g/100 g (dry weight) of sample for the rolls, apple pie, and cherry pie, respectively.

The neutral sugar distributions (Table III) of the HP products reflected their ingredients. Glucose from cellulose was usually the dominant sugar in the insoluble fractions. Glucose was a larger proportion of the insoluble sugars for products that contained only white flour than it was for the flour itself. This corresponds with the solubilization of hemicelluloses observed for most of these products. The percentage of mannose in the insoluble fractions also increased. In the soluble fraction of the prepared products, the shift of hemicellulose resulted in a larger proportion of xylose and, to a lesser extent, arabinose than it did for white flour. The oat products contained large amounts of soluble glucose

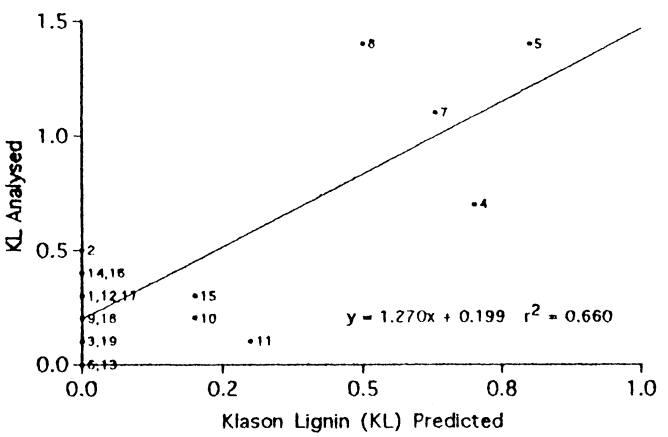


**Fig. 2.** Relationship between predicted and analyzed Klason lignin content (g/100 g [dry weight] of sample) of 19 home-prepared products. Numbers on data points correspond to product numbers in Table I.

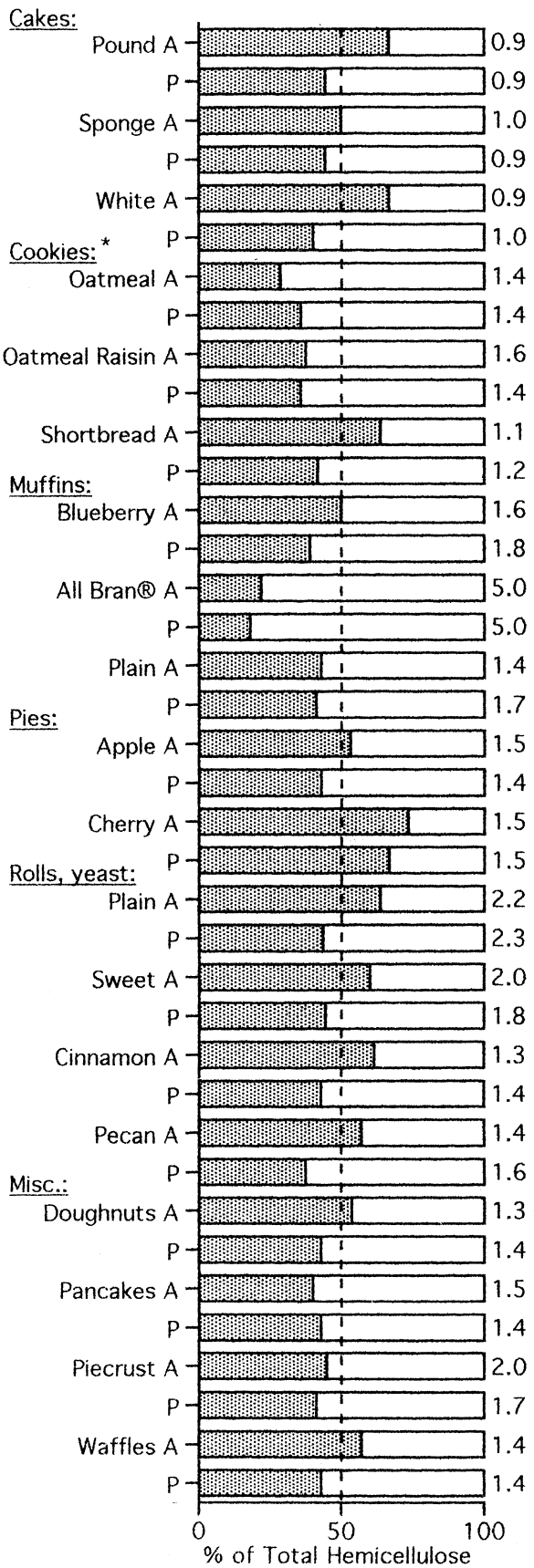


**Fig. 3.** Analyzed (A) and predicted (P) hemicellulose contents and distribution between soluble and insoluble fiber fractions in 19 home-prepared products. Values at the ends of the bars are total hemicellulose values (g/100 g [dry weight] of sample). The left of each bar is soluble hemicellulose and the right of each bar is insoluble hemicellulose. The A and P values for oatmeal cookies (*), both include 1.3 g of $\beta$-glucan per 100 g of sample, of which 75 and 86%, respectively, was soluble. The A and P values for oatmeal raisin cookies both include 1.3 g of $\beta$-glucan per 100 g of sample, of which 80 and 85%, respectively, was soluble.

from the β-glucans. The pies also contained more soluble glucose than most products, possibly reflecting a modified starch-based thickener in the pie fillings.

### Comparison of HP and Commercial Products

Total dietary fiber contents for seven of the 11 commercial products were lower than those for the corresponding HP products (Table II). Three commercial foods had similar values, and only one, waffles, had slightly more fiber than the HP counterpart. In general, both Uppsala and AOAC methods gave similar results. In most cases, both soluble and insoluble dietary fiber content (Table II) reflected the lower dietary fiber values for commercial baked goods compared to those of the HP products. This suggests that the differences are due primarily to lower amounts of fiber-containing ingredients in the commercial recipes. The use of various ratios of soft and hard wheat flours or specialized subfractions (Ranhotra et al 1992) instead of "all purpose" flour also may account for some differences.

The fiber compositions of the commercial products compared to those of the HP products did not provide any insights into the reasons for the differences (Table IV, Figs. 1–3). For example, some commercial products had hemicellulose distributions different from those of the HP product, while others were similar.

Neutral sugar distributions for commercial products (Table III) were qualitatively similar to those of the HP products. Arabinose and xylose were usually the dominant sugars in the soluble fraction; glucose was the primary sugar in the insoluble fraction. Some variations in the sugar ratios of the commercial products are probably caused by additives or minor ingredients. Several of the commercial products listed gums or modified starch as ingredients. The commercial bran muffin contained barley malt. Thus, the larger amount of soluble glucose observed may be from β-glucans.

## CONCLUSIONS

The Uppsala and AOAC methods for measuring dietary fiber do not agree. The AOAC method usually gives larger values for total dietary fiber. The two methods are highly correlated, and data from the two methods can be compared using an appropriate regression equation. This equation probably depends on the method of processing and the types of major fiber-containing ingredients.

Prediction of total dietary fiber content for baked goods from the dietary fiber content of their ingredients is not a viable option using either the AOAC or the Uppsala method. The fiber-composition data from the Uppsala analyses indicate that this is primarily caused by an inability to predict Klason lignin values. Klason lignin values may include materials produced during the baking process, such as Maillard reaction products or precipitated protein. Perhaps a more selective measure of lignin, such as permanganate lignin suggested by Mongeau and Brassard (1989), would solve this problem for the Uppsala method where lignin content is actually measured. The baking process also affects the distribution of dietary fiber components between the soluble and insoluble fractions. Thus, total amounts of all components, except lignin, can be predicted, but their relative analytical solubility cannot.

Dietary fiber content for HP and commercial products were different, probably because of differences in the recipes. Apparently similar commercial products may use different recipes, making approximations of dietary fiber contents unreliable for unknown products from known values.


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