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Dietary fibre and available carbohydrates in Finnish cereal products

PERTTI VARO, RAILI LAINE, KIRSTI VEIJALAINEN, KRISTIINA PERO and PEKKA KOIVISTOINEN

Department of Food Chemistry and Technology, University of Helsinki, SF-00710 HELSINKI, Finland

Abstract. The contents of dietary fibre and available carbohydrates in Finnish cereal products were analysed using the Englyst total carbohydrate method. The tabulation gives the carbohydrate compositions of 44 cereal foods. The cereal-based estimated daily intakes were: total soluble sugars 14.8 g, starch 103 g and dietary fibre 11.6 g (energy level 10 MJ).

Introduction

Cereal products are the major source of most carbohydrates. They are the most important source of starch, and usually of dietary fibre. Certain bakery products contain considerable amounts of sugars, added as sucrose or syrups or as lactose from powdered milk.

The functions of carbohydrates in foods and nutrition are various. Although chemically related, the carbohydrates are difficult to analyse simultaneously. SOUTHGATE (1969), SOUTHGATE et al. (1978), ENGLYST (1981), and THEANDER & ÅMAN (1982) have developed methods that allow available carbohydrates and dietary fibre to be determined within a single analytical procedure. The method chosen in this study was the analytical scheme of ENGLYST (1981).

The present study is part of a research project determining the carbohydrate composition of Finnish foods. The project, in turn, is part of a larger attempt to gather new and dependable data on Finnish foods and diet, of which the studies on mineral composition have been completed (KOIVISTOINEN 1980, VARO 1981). The need for such data has become increasingly evident along with the sophistication of our daily lives: the information is required by nutritionists, dietitians and food inspectors, in the industry, and for medical research, to mention but a few.

Material and methods

The samples used in this study were collected for a previous study on the mineral element composition of Finnish foods (KOI-

Index words: food composition, dietary intake, sugars, starch, dietary fibre

VISTOINEN 1980). The original study comprised an average of 4—6 samples per food item, representing large amounts of the product. In the present study, only one sample, pooled from two samples chosen at random, was analysed per item. This is a reflection of the complexity of the analytical procedure, which allowed only a very limited number of samples to be analysed within the context of the present study. For the principles of sampling and the details of sampling procedures, refer to the reports of the mineral study (KOIVISTOINEN 1980).

The analytical scheme used was that developed by ENGLYST (1981) and slightly modified by LAINE et al. (1981). The method measures the total carbohydrate composition as the following fractions: soluble sugars, starch, and dietary fibre as cellulose, water-soluble and water-insoluble non-cellulosic polysaccharides (w.s. and w.i.s. NCP, respectively), and lignin. The detailed sugar compositions of soluble sugars, w.s. NCP and w.i.s. NCP are determined by gas chromatography (GLC).

The dry sample (200 mg) is incubated in an acetate buffer (pH 6, 48°C), first on its own for 5 h (aliquot 1) and then with amyloglucosidase (16 h), after which it is separated by centrifugation into aliquot 2 and residue. The supernatants are analysed for free sugars, starch and w.s. NCP. Free sugars (aliquot 1), and free sugars and glucose from starch together (aliquot 2) are freeze-dried, formed into aldonitrilo acetates (MORRISON 1975) and analysed by GLC. W.s. NCP are precipitated with 4 volumes of ethanol from aliquot 2, hydrolysed with 1 M H_2SO_4 and analysed for neutral sugars as aldonitrilo acetates by GLC and for uronic acids colorimetrically after the carbazole reaction (BITTER & MUIR 1962). The residue is sequentially hydrolysed with 1 M H_2SO_4 and 72 % H_2SO_4, and analysed by GLC and colorimetry for w.i.s. NCP constituents, by colorimetry for cellulose (ROE 1955), and gravimetrically for lignin.

The chromatography of the sugars was performed using an equimolar mixture of different sugars as an external standard, and inositol as an internal standard.

The overall analytical feasibility of the method was tested in two interlaboratory comparisons made during the present study (THEANDER 1981, VARO et al. 1983). Whole meal wheat flour, which was used as a standard, was analysed several times during the study. As seen in Table 1, the variation in some fractions may be considerable. This may be due at least partly to the initial small sample size (200 mg). All samples were analysed as six replicates, and the fractions with over 10 % variation were re-analysed. The analysis of starch tended to be especially problematic, and so it was also analysed on a macroscale from all samples using enzymatic hydrolysis and colorimetry. Free sugars and, less often, lignin also entailed rechecks.

Table 1. Carbohydrate composition of wheat flour (standard), g/100 g dry matter.

	Sample no.							
	1	2	3	4	5	$\bar{X}$[1]	s	V%
Free sugars	3.1	2.4	3.1	2.5	3.2	2.9	0.4	14
Starch	58.3	61.8	62.4	61.9	63.2	61.5	1.9	3
Dietary fibre	13.3	11.3	11.9	12.8	12.5	12.4	0.8	7
w.s. NCP	1.7	1.2	1.2	1.8	1.4	1.5	0.3	20
w.i.s. NCP	8.0	7.0	7.5	7.7	8.1	7.7	0.4	5
cellulose	2.3	1.9	2.0	2.2	2.0	2.1	0.2	10
lignin	1.4	1.3	1.2	1.1	1.0	1.2	0.2	17

[1] $\bar{X}$ = mean, s = standard deviation, V% = coefficient of variation.

Table 2. Carbohydrate composition of Finnish cereal-based foods.

Content in 100 g of food (edible portion)		1.01 Wheat flour, whole-meal	1.02 Wheat flour, c. 1.3 % ash	1.03 Wheat flour, c. 0.7 % ash	1.04 Wheat flour, c. 0.5 % ash	1.05 Wheat bran	1.06 Wheat germ	1.07 Rye flour, whole-meal	1.08 Rye flour, c. 0.5 % ash	1.09 Barley flour, whole-meal	1.10 Rolled oats
Water	g	14	14	14	14	14	13	14	14	14	12
Available carbo-hydrates	g	54.5	59.4	63.5	63.6	15.4	31.0	52.0	66.3	58.9	57.0
Free sugars	g	0.7	0.5	0.5	0.4	1.3	16.4	2.4	0.5	0.9	1.3
fructose	g	0.1	0.1	0.2	0.2	0.2	0.6	0.3	0.1	0.2	0.2
glucose	g	0.1	0.1	0.1	0.1	0.2	0.6	0.2	0.2	0.2	0.2
sucrose	g	0.5	0.3	0.2	0.1	0.9	15.2	1.0	0.2	0.5	0.9
maltose	g	—	—	—	—	—	—	0.9	—	tr	—
lactose	g	—	—	—	—	—	—	—	—	—	—
Starch	g	53.8	58.9	63.0	63.2	14.1	14.6	49.6	65.8	58.0	55.7
Dietary fibre	g	9.9	5.5	3.6	3.5	37.5	14.0	13.6	4.5	7.6	5.7
W.s. NCP	g	1.0	1.0	1.0	0.9	1.2	1.3	2.2	1.5	1.0	1.1
W.i.s. NCP	g	6.5	3.2	1.7	1.7	24.2	8.9	6.9	1.9	4.0	3.1
Cellulose	g	1.5	0.6	0.5	0.4	7.5	2.3	1.9	0.9	1.3	0.7
Lignin	g	0.9	0.7	0.4	0.5	4.6	1.5	2.6	0.2	1.3	0.8

Content in 100 g of food (edible portion)		1.11 Rice, polished	1.12 Rice, par-boiled	1.13 Rye bread, sour	1.14 Wheat bread	1.15 Wheat bread, dark	1.16 Oat bread	1.17 Brown bread, sweetened	1.18 Crisp bread	1.19 Crisp bread, wholerye	1.20 Whole-wheat rusk
Water	g	14	12	38	33	36	36	35	8	5	4
Available carbo-hydrates	g	75.5	70.9	36.9	41.3	40.0	41.2	40.0	56.1	57.8	63.9
Free sugars	g	0.3	0.7	3.5	3.2	2.6	3.5	7.8	1.6	2.4	2.1
fructose	g	tr	tr	0.8	0.3	0.2	0.8	2.8	0.3	1.2	0.3
glucose	g	tr	0.1	0.8	0.2	0.2	0.5	2.4	0.2	1.0	0.3
sucrose	g	0.3	0.6	—	tr	0.1	tr	0.1	tr	tr	—
maltose	g	—	—	1.9	2.5	2.1	2.2	2.5	1.1	0.2	1.5
lactose	g	—	—	—	0.2	—	—	—	—	—	—
Starch	g	75.2	70.2	33.4	38.1	37.4	37.7	32.2	55.5	55.4	61.8
Dietary fibre	g	2.3	4.8	9.9	3.5	5.0	6.4	4.7	12.9	14.9	8.5
W.s. NCP	g	0.2	0.6	1.7	0.8	1.0	1.2	1.1	2.9	2.7	1.4
W.i.s. NCP	g	1.6	3.1	6.1	1.7	2.7	3.9	2.5	6.6	8.0	4.9
Cellulose	g	0.2	0.7	0.9	0.6	0.7	0.8	0.8	1.9	2.2	1.3
Lignin	g	0.3	0.4	1.2	0.4	0.6	0.6	0.3	1.5	2.0	0.9

Content in 100 g of food (edible portion)		1.21 Sweet wheat bread, 5 % fat	1.22 Sweet wheat bread, 10 % fat	1.23 Doughnut	1.24 Swiss roll	1.25 Biscuit	1.26 Cream cracker	1.27 »Mämmi» Easter dessert	1.28 Macaroni	1.29 Corn flakes	1.30 Rice, puffed
Water	g	20	16	22	25	2	5	59	12	4	3
Available carbohydrates	g	49.7	43.2	44.4	40.9	69.9	57.4	27.6	66.4	80.2	78.6
Free sugars	g	10.5	8.6	13.3	25.3	19.6	1.6	13.2	0.5	6.1	5.2
fructose	g	3.8	3.0	1.6	1.0	2.4	0.3	6.4	0.1	0.9	0.4
glucose	g	3.0	2.2	1.9	1.9	2.1	0.3	4.5	0.2	1.5	0.4
sucrose	g	0.7	0.4	8.3	22.1	14.4	—	2.2	0.2	3.6	4.4
maltose	g	2.3	2.2	1.5	tr	0.7	1.0	—	—	—	—
lactose	g	0.7	0.8	—	0.3	—	—	—	—	—	—
Starch	g	39.2	35.6	31.1	15.6	50.3	55.8	14.4	65.9	74.1	73.6
Dietary fibre	g	3.6	2.8	2.5	1.5	2.0	4.3	4.9	3.1	5.4	5.0
W.s. NCP	g	0.8	0.9	0.7	0.8	0.4	1.3	1.2	1.0	0.4	0.5
W.i.s. NCP	g	2.1	1.5	1.2	0.4	0.8	2.3	1.9	1.6	3.1	3.4
Cellulose	g	0.5	0.3	0.3	0.1	0.4	0.4	0.7	0.3	0.7	0.3
Lignin	g	0.2	0.1	0.3	0.2	0.4	0.3	1.1	0.1	1.2	0.8

Content in 100 g of food (edible portion)		1.31 Oats, puffed	1.32 Roasted oatmeal, »Talk-kuna»	1.33 Buckwheat whole grain	1.34 Millet, whole grain	1.35 Spring wheat, whole grain	1.36 Rye, whole grain	1.37 Barley, whole grain	1.38 Oats, whole grain	1.39 Rice whole grain	1.40 Maize, whole grain
Water	g	3	14	14	14	14	14	14	14	13	13
Available carbo-hydrates	g	70.6	57.6	60.4	55.3	52.9	52.9	48.2	47.3	65.4	63.6
Free sugars	g	9.8	0.7	0.4	0.6	2.6	2.4	1.3	0.3	0.8	1.0
fructose	g	0.3	tr	tr	0.2	0.2	0.4	0.2	0.1	tr	0.1
glucose	g	0.3	0.1	0.2	0.3	0.3	0.6	0.3	0.2	0.3	0.5
sucrose	g	9.2	0.6	0.2	0.1	0.8	1.0	0.6	tr	0.5	0.4
maltose	g	—	—	—	—	1.3	0.4	0.2	—	—	—
lactose	g	—	—	—	—	—	—	—	—	—	—
Starch	g	60.8	56.9	60.0	54.7	50.3	50.5	46.9	47.0	64.6	62.6
Dietary fibre	g	4.9	9.9	5.8	3.2	10.8	12.7	16.5	18.5	7.4	9.2
W.s. NCP	g	0.7	1.6	0.8	0.6	1.3	2.4	2.2	1.8	1.1	0.8
W.i.s. NCP	g	3.4	3.6	2.8	1.6	6.6	6.8	8.0	7.1	3.6	5.9
Cellulose	g	0.4	2.4	1.5	0.4	1.8	2.2	3.7	6.2	1.7	2.0
Lignin	g	0.4	2.3	0.7	0.6	1.1	1.3	2.6	3.4	1.0	0.5

Results and discussion

The available carbohydrates and fibre constituents of Finnish cereal products are given in Table 2. The results are largely consistent with those reported previously for cereal foods (PAUL & SOUTHGATE 1978, SOUCI et al. 1981, SALO & KOTILAINEN 1970, FRØLICH & ASP 1981).

Free sugars. Cereal grains and flours are low in sugars, sucrose being the main one. Maltose was usually found only in trace amounts. Sugars other than those tabulated were sometimes detected (e.g. 4 % raffinose in wheat germ). Bakery products with added sucrose and leavened with yeast contained only little sucrose, but more fructose and glucose. Breads commonly contained 1—2 % maltose. Lactose was detected in breads with added milk or powdered milk.

Starch. The starch content of cereal products was generally in the expected range. The starch content was highest in polished rice and lowest in nuts.

Dietary fibre (DF). The fibre content of cereal products follows closely the extraction of flour used as a raw material. The bulk of the fibre constituents are in the bran fraction. Whole meal wheat flour contained about 10 % DF, whereas white flour contained 3.5 % and wheat bran c. 40 %. The fibre concentration of many bakery products was slightly higher than might be expected of their raw materials. This may indicate that bread making causes an increase in the amount of fibre especially while the crust is forming. However, not only lignin but other fibre fractions, too, were slightly increased. Similar increments have been found in heat-treated potato (VARO et al. 1983, VARO et al. 1984).

W.i.s. NCP was generally the main DF fraction in cereal products. The present method shows that the concentrations of cel-

Content in 100 g of food (edible portion)		1.41 Distiller's spent grain	1.42 Pea, dried	1.43 Hazelnut	1.44 Almond
Water	g	12	15	5	5
Available carbohydrates	g	1.1	48.5	3.4	6.6
Free sugars	g	0.0	2.1	3.4	6.6
fructose	g	—	0.1	0.5	0.5
glucose	g	—	0.2	0.4	0.3
sucrose	g	—	1.8	2.5	5.8
maltose	g	—	—	—	—
lactose	g	—	—	—	—
Starch	g	1.1	46.4	0.0	0.0
Dietary fibre	g	21.0	10.7	6.0	7.2
W.s. NCP	g	4.7	0.7	0.3	0.3
W.i.s. NCP	g	8.4	4.1	2.5	3.7
Cellulose	g	3.1	5.7	1.4	1.5
Lignin	g	4.8	0.2	1.8	1.7

lulose and lignin were approximately the same in cereal foods. The concentration of w.s. NCP was fairly constant. As an example, whole meal wheat flour and white wheat flour contained equal amounts of this fraction.

Table 3 gives the relative neutral sugar and uronic acid compositions of w.s. NCP and w.i.s. NCP of some flour and bread samples. The most variable is that of glucose, especially in the w.i.s. NCP fraction, suggesting that traces of starch may have been left in some of the w.i.s. NCP fractions. The relative amounts of other constituents remain fairly constant with increasing extraction.

Since the number of samples was limited to one per item, no information was obtained in the variation within a single food commodity. The main purpose of the study, to obtain average carbohydrate values for as many of the principal cereal foods as possible, was probably covered reasonably well considering the sampling procedure, which was planned to produce samples representing high volumes of production.

The analytical procedure chosen for the present study is too laborious for routine fibre determinations. The actual rate was only 2—4 samples/week/2 technicians. The need for rechecks of results was also undesirably high despite careful standardization of the procedures. One major problem was the difficulty of obtaining exactly reproducible fractionation of the small quantity of starting material. For instance, the gravimetric determination of a few milligrams of lignin necessarily caused high variation, which was greatly enhanced by small differences in fractionation.

In 1981 the consumption of cereals in Finland was 209 g/d/person, of which 128 g was wheat, 57 g rye and the rest equal amounts of barley, oats and rice (Agric. Econ. Res. Inst. 1983). Nearly all the rye is consumed as whole grain products, whereas about 80 % of the wheat is used as refined flour (SALOVAARA 1979). About 70 % of all industrial bakery products are unsweetened rye and

Table 3. Sugar and uronic acid composition of w.s. NCP and w.i.s. NCP in some cereal products.

	w.s. NCP								w.i.s. NCP							
	% of total							g/100 g	% of total							g/100 g
	rha	man	glu	gal	ara	xyl	uro	total[a]	rha	man	glu	gal	ara	xyl	uro	total[a]
Whole meal wheat flour	tr	7	11	14	25	40	4	1.2	1	1	10	3	25	53	6	7.6
Wheat flour, 1.3 % ash	4	7	20	21	16	32	tr	1.2	tr	2	13	3	29	43	9	3.7
Wheat flour, 0.7 % ash	tr	4	12	15	25	44	tr	1.2	0	2	41	4	17	28	5	2.0
Wheat bran	tr	4	17	8	24	42	5	1.4	0	1	9	2	29	53	6	28.1
Wheat bread, white	tr	tr	10	10	24	53	2	1.2	0	5	50	4	15	26	1	2.5
Whole rye flour	0	5	10	4	28	49	4	2.6	0	2	21	4	24	42	7	8.0
Rye crisp bread	2	3	7	4	29	50	5	2.8	0	4	19	6	25	43	4	8.4
Rolled oats	5	4	46	8	12	12	13	1.3	2	3	19	9	25	35	7	3.5

[a] In dry product

Abbreviations: rha = rhamnose, man = mannose, glu = glucose, gal = galactose, ara = arabinose, xyl = xylose, uro = uronic acids, tr = traces
w.s. = water soluble, w.i.s. = water insoluble, NCP = non-cellulosic polysaccharides

wheat bread, the remainder being sweetened products. Home baking, however, increases the share of sweetened products to at least 40 % of total bread consumption. It is estimated that homebaked products account for about 13 % of total sugar consumption (PRÄTTÄLÄ 1983). These findings, together with data on the detailed distribution of the production of bakery products (SALOVAARA 1979), and the present analytical data enabled us to estimate roughly the average intake of carbohydrates from cereal products (Table 4).

Table 4. Cereal products as sources of sugars, starch and dietary fibre in 1981 (energy level 10 MJ).

	g/d
Sugars	14.8
sucrose	5.5
glucose	2.5
fructose	2.9
maltose	3.5
lactose	0.4
Starch	103
Dietary fibre	11.6
w.s. NCP	2.3
w.i.s. NCP	5.8
cellulose	1,7
lignin	1.8

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Suomalaisten elintarvikkeiden hiilihydraattitutkimus — viljavalmisteiden ravintokuitu-, tärkkelys- ja sokeripitoisuudet

Pertti Varo, Raili Laine, Kirsti Veijalainen, Kristiina Pero ja Pekka Koivistoinen

Elintarvikekemian ja -teknologian laitos, Helsingin yliopisto, 00710 Helsinki

Suomalaisten viljavalmisteiden hiilihydraattikoostumus määritettiin tässä tutkimuksessa ns. Englystin kokonaishiilihydraattimenetelmällä. Se antaa yksityiskohtaisen kuvan sekä hyväksikäytettävien hiilihydraattien että ravintokuidun määrästä ja laadusta. Tutkimus on osa poikkileikkaustutkimusta, jonka kohteena oli tärkeimpien suomalaisten elintarvikkeiden hiilihydraattikoostumus. Menetelmän työläydestä johtui, että vain yksi kokoomanäyte kutakin nimikettä voitiin analysoida. Tutkimuksen vaikeutena olivat monimutkainen fraktiointikaavio ja pieni näytemäärä (200 mg), ja tarkistusanalyysien määrä kasvoikin ajoittain epätoivottavan suureksi.

Saatujen tulosten ja kulutustietojen perusteella arvioitiin hiilihydraattien keskimääräinen päiväsaanti viljavalmisteista. Liukoisia sokereita arvioitiin saatavan yhteensä 14.8 g/d, tärkkelystä 103 g/d ja ravintokuitua 11.6 g/d (energiataso 10 MJ).