Status of Carbohydrates and Dietary Fiber in Gluten-free Diets

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- Studies show dietary fiber intake, an important part of a healthy diet, is especially low for those following a gluten-free diet.
- Alternatives to common gluten-containing grains include pseudocereals, which have excellent nutrient profiles that could be used to help ensure an adequate intake of nutrients and fiber by people with celiac disease.
- Evaluation of the nutritive value of available gluten-free breads suggests consumers have good sources of fiber to choose from.

Celiac disease is an immune-mediated enteropathy triggered by the ingestion of the cereal protein gluten, which is present in wheat, rye, and barley. Since lifelong avoidance of gluten is currently the only treatment for celiac disease, it is important to consider the effect of a gluten-free diet on nutrient intake and the nutritional status of patients adhering to this restricted diet. Concerns have been raised about the long-term dietary habits and food choices of individuals following a strict gluten-free diet, because a number of studies indicate there is an unbalanced intake of carbohydrates, proteins, and fat, as well as a limited intake of certain essential nutrients, by celiac patients (18,29). One very important nutrient that studies have repeatedly shown is not consumed in sufficient amounts is dietary fiber. Even though adherence to a gluten-free diet may also lead to insufficient consumption of other nutrients, such as calcium and certain vitamins, this review focuses on carbohydrate, sugar, and fiber consumption in celiac patients, as well as on the content of these macronutrients in commercially available products. According to the European Food Safety Authority (EFSA), the intake of total carbohydrates, including starch and simple carbohydrates such as sugars, should range from 45 to 60% of total energy intake for both adults and children. Insufficient evidence has been found to set an upper limit for sugars. This is because the possible health effects are mainly related to patterns of food consumption, i.e., the types of foods consumed and how often they are consumed, rather than to the total intake of sugars (4,23).

Although dietary fibers are also carbohydrates based on their chemical structure, per definition they are not included in this macronutrient group and are stated separately on nutrition labels. AACC International has defined dietary fiber as the edible components of plants or plant-like carbohydrates that resist digestion in the small intestine and are partially or wholly fermented in the large intestine; it includes polysaccharides, oligosaccharides, lignin, and associated plant substances (1). Dietary fiber generally falls into two categories: soluble and insoluble. The most soluble dietary fibers are more rapidly fermented in the colon, and they are more accessible to hydrolytic enzymes, whereas less soluble fibers are excreted in the stool and, thus, have the effect of increasing fecal bulk. EFSA, as well as the U.S. Food and Drug Administration (FDA), recommend a daily total dietary fiber intake of 25 g/day, of which 6 g should be soluble fiber. The role of dietary fiber in contributing to a healthy intestine has long been recognized. Potential health benefits of dietary fiber include reduction of bowel transit time, prevention of constipation, reduction in risk of colorectal cancer, lowering of blood cholesterol, production of short-chain fatty acids, and promotion of the growth of beneficial gut microflora (5). From a technological point of view, addition of fiber can modify texture and sensory characteristics, as well as prolong shelf life, due to its water-binding capacity, gel-forming potential, fat mimetic properties, and thickening effects (24,26).

One important source of dietary fiber is cereals, which contribute to ≈50% of the fiber intake in Western countries (20). In a gluten-free diet, the cereal products consumed are considerably different from the gluten-containing foods in this category, which may influence their nutritional quality. Several studies show that the dietary fiber intake of celiac patients is too low (13,17–19,21,29). It has been proposed that this is due to the fact that gluten-free breads are often made from starches and/or refined flours and that these products are rarely enriched with fiber (28). Therefore, they may contain less fiber than their gluten-containing counterparts.

The purpose of this study was to evaluate the gluten-free breads currently available on the market. For this purpose, 95 gluten-free breads were purchased in supermarkets and health shops in seven European countries (France, Ireland, Italy, Finland, Germany, Austria, and Sweden), as well as the United States. Their nutritional value with regard to intake of calories, carbohydrates, sugar, and dietary fiber, as stated on their packaging, is summarized and compared.

Dietary Fiber Intake by Celiac Patients and Nonceliac Subjects

The results of several studies on the consumption of carbohydrates, sugar, and dietary fiber by celiac disease patients are summarized and compared in Table I. Table II summarizes studies on the intake of these nutrients by nonceliac subjects.

Wild et al. (31) analyzed data from 93 validated 5-day food diaries, observing that only 42% of men and women obtained >47% of their total energy intake from carbohydrate sources. These researchers reported a nonstarch polysaccharide intake of 13.7 g/day. Ohlund et al. (21) performed a study of 25 children (aged 4–17 years) with confirmed celiac disease who were adhering to a gluten-free diet. Five-day food records showed that dietary fiber intakes were lower than recommended levels. The mean intake of carbohydrates met recommendations; however, the quality of carbohydrates was characterized by a high intake of sucrose and a low intake of dietary fiber. After recording the 3-day usual nutritional intakes of 50 randomly selected celiac patients, Lee et al. (17) reported that the standard gluten-free diet did not meet the recommended intake for fiber. Hopman

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et al. (14) evaluated the 3-day food records of 111 adolescent members of the Dutch Coeliac Disease Society. They showed that the celiac patients had an intake of fiber significantly lower than the recommended daily allowance (RDA). Thompson et al. (29) concluded from a study employing 3-day estimated self-reported food records that 7 of 8 men (88%) and 18 of 39 women (46%) had estimated dietary fiber intakes that met or exceeded recommended daily intakes of 20–35 g/day, while 7 of 8 men (88%) and 34 of 39 women (87%) had estimated carbohydrate intakes within the acceptable range of 45–60% of total calories. There is no information available on how much of the total carbohydrate intake was as sugars.

A study examining 47 adolescents (aged 10–20 years) with celiac disease and 47 healthy age-matched control subjects used 3-day alimentary records. Researchers concluded that the diets for both groups contained low amounts of carbohydrates and fiber. Fiber consumption was significantly reduced in subjects consuming a gluten-free diet compared with the healthy control subjects (19). Grehn et al. (13) published a study assessing the dietary habits of 49 Swedish adult celiac patients, as well as those of a control group. Four-day dietary records showed that both celiac patients and control subjects had an intake of fiber that was below recommended levels. Comparing the two groups, fiber intake was significantly lower for celiac patients. The relative contribution of dietary fiber from bread was generally lower for celiac patients (28%) than for the control subjects (38%). The energy intakes, as well as the relative contributions of protein, fat, and carbohydrate, were in the same range for both celiac patients and control subjects. Lohiniemi et al. (18) used 4-day food records for 58 adult celiac patients, concluding that the daily fiber intake (13 g) was lower than the average consumption level in Finland (24 g).

All of the abovementioned studies showed an insufficient intake of dietary fiber among celiac patients. This suggests more emphasis should be placed on the nutritional quality of gluten-free diets. However, the dietary fiber intake of nonceliac subjects was commonly lower than recommended as well (Table II), although it was higher than for celiac patients.

Fukuda et al. (10) used 1-day food records to evaluate dietary fiber intake among the Japanese general population. The records revealed an average consumption of 18.4 g/day. Castetbon et al. (6) used three 24-hr recalls to describe the dietary intake of 2,734 adults in France and concluded that compared with current recommendations the intake of carbohydrates and total fiber was frequently unsatisfactory. Galvin et al. (11) used 7-day food diaries to collect food intake data for 1,379 respondents. The resulting average fiber consumption was 20.2 g/day. Elmadfa and Freisling (8) evaluated the macronutrient intake of the Austrian general population and concluded that fiber intake among all population groups was too low. As a result of a too high intake of protein and fat, the average consumption of carbohydrates was too low. Among children and adolescents, the intake of carbohydrates was sufficient. However, 12–19% of carbohydrates consumed were sugars.

Only in one study, which included 4,237 subjects and used food-frequency questionnaires, did the subjects meet the recommendations for dietary fiber intake, with an average fiber consumption of 26.8 g/day. The average intake of carbohydrates was 41.3%, with 19.1% from mono- and disaccharides (30).

Overall, it must be concluded that dietary fiber intake is too low in a substantial portion of the population. This is likely to contribute to impaired bowel function and constipation and an increased risk of chronic gastrointestinal diseases, as well as coronary heart disease and diabetes. The intake of carbohydrates as a percentage of total energy consumed was within the acceptable range in most studies. However, the intake of sugars was frequently very high, especially in children and adolescents.

Table I. Results of several studies on the dietary fiber intake of celiac disease patients[a]

	Study							
Nutrient Recommendation[b]	**Mariani et al. (19)**	**Lohiniemi et al. (18)**	**Grehn et al. (13)**	**Thompson et al. (29)**	**Hopman et al. (14)**	**Lee et al. (17)**	**Ohlund et al. (21)**	**Wild et al. (31)**
Carbohydrates/sucrose (%E)								
Children and adolescents: 45–65%	43.2/NIA				54.0/NIA		54.2/14.7	
Adults: 45–65%		NIA	49/NIA	53.5/NIA		NIA		58.5/NIA
Fiber (g/day)								
Children and adolescents: 19–26 g	8.5				17.0		9.9	
Adults: 25–38 g		13.0	10.8	22.3		5.0		13.7

[a] NIA = no information available.

[b] Source: Dietary Reference Intakes: Macronutrients, U.S. Department of Agriculture (http://fnic.nal.usda.gov/nal_display/index.php?info_center=4&tax_level=3&tax_subject=256&topic_id=1342&level3_id=5140).

Table II. Results of several studies on the dietary fiber intake of nonceliac subjects[a]

	Study						
Nutrient Recommendation[b]	**Mariani et al. (19)**	**Grehn et al. (13)**	**Galvin et al. (11)**	**Elmadfa and Freisling (8)**	**Fukuda et al. (10)**	**Castetbon et al. (6)**	**Van de Vijver et al. (30)**
Carbohydrates/sucrose (%E)							
Children and adolescents: 45–65%	48.4/NIA			52.0/13.5			
Adults: 45–65%		46.5/NIA	NIA	43.5/9.6	NIA	45.7/20.1	41.9/19.1
Fiber (g/day)							
Children and adolescents: 19–26 g	11.2			13.7			
Adults: 25–38 g		16.7	20.2	19.3	18.4	17.5	26.8

[a] NIA = no information available.

[b] Source: Dietary Reference Intakes: Macronutrients, U.S. Department of Agriculture (http://fnic.nal.usda.gov/nal_display/index.php?info_center=4&tax_level=3&tax_subject=256&topic_id=1342&level3_id=5140).

Nutritive Value of Gluten-free Breads Currently on the Market

Cereal grains provide significant amounts of many nutrients and play a major role in human nutrition. Carbohydrates have particular significance in cereal products such as breads. In the course of this study, 95 gluten-free bread products were purchased, and their nutritive value with respect to calorie, carbohydrate, and dietary fiber content was evaluated. The products were grouped into white, brown, multiseed, and pumpernickel-style breads. The average values for provided energy, as well as carbohydrate and fiber contents, were calculated for each bread group and compared with the values for a standard wheat bread from the same category. The data for the reference wheat breads were sourced from the U.S. Department of Agriculture (USDA) National Nutrient Database for Standard Reference.

Energy is required to sustain the body's various functions, including respiration, circulation, physical movement, and maintenance of core body temperature. In the gluten-free products reviewed, the number of kilocalories varied from 178 kcal for a multiseed gluten-free bread to 311 kcal for white rolls, as well as a bread containing sunflower seeds. In this respect, the origin of the calories is interesting. Table III shows the calorie content, as well as the carbohydrate and sugar contents of the gluten-free products.

The primary role of carbohydrates (sugars and starches) is to provide energy to cells in the body. They can be classified into two broad categories: available and unavailable. Available carbohydrates are those digested and absorbed by humans, and they include starch and soluble sugar. Unavailable carbohydrates, or dietary fibers, are not digested by the endogenous secretion of the human digestive tract (25). Starch is the most abundant cereal polysaccharide, and it is a major food reserve that provides a bulk nutrient and energy source in the human diet (7). The carbohydrate content of most gluten-free products is lower than that of standard products containing gluten. This is probably due to the fact that in addition to flour or starch, nearly all gluten-free formulations contain oil and a protein source such as milk or whey powder, soy protein concentrate, egg albumin, or rice or lupine protein.

Another parameter to be considered is the simple carbohydrate or "sugar" content. On food labels, "sugar" is defined as all monosaccharides and disaccharides present, excluding polyols. The intake of mono- and disaccharides should be limited as much as possible because they increase the caloric value of a product without providing vitamins or minerals. Several products (21 of 95) did not provide information on sugar content. In the other products, sugar content varied widely from trace amounts to substantial amounts for white rolls (8.8 g of 46.7 g of carbohydrates) and a sweet white bread (12.4 g of 52.2 g of carbohydrates). The standard white wheat bread contained 4.3 g of sugar.

The importance of a sufficient intake of dietary fiber has long been recognized. The dietary fiber group includes resistant starch, cellulose, and other complex polysaccharides, such as arabinoxylans, β-glucans, pectins, arabinogalactans, and lignin. Dietary fibers can be divided into soluble and insoluble portions. Soluble dietary fiber slows down glucose absorption, reduces plasma cholesterol concentrations, and is useful in the management of diabetes and heart disease. Insoluble fiber increases fecal weight, bulk, and softness, as well as the frequency of defecation, and reduces intestinal transit times. These effects are thought to play a role in preventing colon cancer and other bowel disorders (7).

The analysis of ingredients in gluten-free breads showed that a large number were enriched with fiber. Substances used for this purpose include sugar beet fiber, psyllium husk, citrus fiber, pea fiber, cellulose and derivatives (e.g., hydroxypropylmethylcellulose), vegetable fiber (inulin), apple fiber, and bamboo fiber. Table IV shows the amounts of total, soluble, and insoluble fibers, as well as the color and water-holding capacity of some commercially available fibers. Regarding dietary fiber content, only 74 of 95 products stated the levels on their packaging. As shown in Table III, there were large variations in this value. As expected, the white breads had the lowest fiber contents, ranging from 0.1 to 9.7 g/100 g, with an average of 4.0 g/100 g. However, compared with its gluten-containing counterparts, the majority of gluten-free white breads contained higher amounts of fiber (25 of 32). The brown breads showed an average fiber content similar to the white bread category, with an average of 4.8 (1.3-g minimum and 9.3-g maximum). This was probably due to the fact that several brands market the same product formulation twice. In many cases white bread is transformed into brown bread simply by adding food coloring, i.e., molasses or caramel: 17 of 54 products (brown, multiseed, or pumpernickel-style breads) listed caramel, dark syrup, or treacle among their ingredients. The pumpernickel-style breads had a higher fiber content, ranging between 4.0 and 7.0 g/100 g, with an average of 5.3 g/100 g. These breads ranked only slightly below the average for gluten-containing pumpernickel-style breads (6.5 g). The highest fiber content was found in breads containing multiseeds, with values ranging from 3.9 to 14.2 g/100 g, with an average of 7.7 g/100 g. The standard reference for this type of bread containing gluten is 7.4 g/100 g. When summarizing this data, it can be seen that the dietary fiber contents of the white and multiseed gluten-free breads was generally higher than that of their gluten-containing counterparts, while the reverse was found for brown and pumpernickel-style breads. However, there was some uncertainty in the data, since there was a substantial number of samples (22%) that did not provide any information on fiber content. It is possible that these samples were very low in dietary fiber.

Possible Ways of Improving Fiber Uptake by Celiac Patients

As discussed above, dietary fiber intake is too low for a substantial portion of the population, especially celiac patients. Therefore, possible ways of increasing the uptake of this highly important nutrient need to be considered. Lee et al. (17) suggest that grains with high nutritional value could be used in a gluten-free diet and have the potential to improve the nutritional profile of gluten-free diets for individuals with celiac disease. Many alternatives to common gluten-containing grains exist, such as the pseudocereals amaranth, quinoa, and buckwheat (16). These grains are characterized by an excellent nutrient profile, and the availability of palatable pseudocereal-containing gluten-free products would represent a significant advance toward ensuring an adequate intake of nutrients for people with celiac disease (3). In particular, dietary fiber content is significantly higher in buckwheat seeds compared with common cereals. Therefore, the incorporation of these seeds in the diets of celiac patients should help alleviate, at least in part, the deficit in fiber intake found in this sector of the population (2).

Thompson (27) suggests that a further measure to increase fiber intake would be to encourage patients to consume enriched or fortified gluten-free flours, breads, and pastas whenever possible. Hopman et al. (14) compared the intake of celiac patients consuming nonenriched gluten-free products and patients who consumed enriched gluten-free foods. The latter had a significantly higher intake of fiber. However, these patients still did not reach the RDA for fiber. Hence, celiac patients should also increase their consumption of noncereal, naturally gluten-free fiber sources such as fruits, vegetables, legumes, nuts, and seeds.

Table III. Nutritional characterization of gluten-free bread products from different bread categories[a]

Category Product	Country	Energy kJ/100 g	Energy kcal/100 g	Carbohydrate (g/100 g)	Sugar (g/100 g)	Fiber (g/100 g)
Brown bread						
Meingast Krustenbroetchen	Austria	1,092	261	54.4	3.7	2.3
Minderleinsmuehle rolls	Austria	1,167	279	43.8	NA	NA
Minderleinsmuehle – sunflower bread	Austria	1,301	311	43.3	NA	NA
Tattarileipä – buckwheat bread	Finland	1,059	253	52.8	2.5	2.5
Tumma leipä – dark bread	Finland	1,088	260	56.5	5.5	2.6
Hapan mausteleipä – sourdough bread	Finland	1,096	262	54.2	3.1	2.7
Pirjon Pakari	Finland	841	201	41.9	3.9	4.1
Schnitzer spezial Bio Landbrot	Germany	803	192	36.6	2.0	4.4
Schnitzer spezial Bio Buchweizenbrot	Germany	895	214	30.1	2.8	5.8
3 Pauly Schwarzbrot mit Teff	Germany	933	223	38.2	2.0	3.6
3 Pauly Vollkorn Schnittbrot	Germany	820	196	38.0	1.0	5.0
Schaer Sunna Vollkornbroetchen	Germany	1,088	260	35.6	4.2	8.1
Schaer Landbrot	Germany	937	224	44.7	3.5	5.2
Schaer Ciabatta Rustica	Germany	1,067	255	39.6	3.7	8.9
Schaer Rustico	Germany	958	229	40.8	3.0	5.7
Ener Bio Buchweizenbrot	Germany	895	214	30.1	2.8	5.8
Hammermuehle Bio Landbrot	Germany	933	223	49.0	NA	NA
Kelkin sliced brown bread	Ireland	933	223	47.8	2.6	1.3
Ener-G gluten-free flax loaf	Ireland	1,105	264	41.0	2.9	3.4
Genius gluten-free fresh brown bread	Ireland	1,159	277	42.2	5.1	9.5
Kelkin multiseed brown bread	Ireland	908	217	37.4	2.0	2.3
Marks & Spencer 4 soft brown baps	Ireland	1,046	250	31.6	0.4	9.3
Nutrifree PanFette integrale	Italy	1,184	283	60.0	2.4	5.6
Semper Toasty fiber	Sweden	879	210	41.0	1.0	6.5
Semper Toasty pure oats	Sweden	920	220	45.0	0.8	5.5
Semper Minibaguette fiber	Sweden	920	220	46.0	6.0	4.0
Glutino whole-grain brown rice bread	United States	1,046	250	49.9	4.5	4.0
Ener-G brown rice loaf	United States	1,100	263	42.1	5.3	2.6
Ener-G brown rice yeast-free loaf	United States	929	222	37.7	0.0	4.4
Food for Life brown fruit juice rice bread	United States	1,071	256	48.9	7.0	4.7
Average gluten-free brown bread		1,006	240	43.3	3.1	4.8
Standard brown bread (whole wheat)[b]		1,033	247	41.3	5.6	6.8
Pumpernickel-style bread						
Brotmix – sunflower bread	Austria	782	187	33.0	1.0	4.0
Brotmix – linseed bread	Austria	866	207	36.0	2.0	6.0
PEMA Reisbrot mit Sonnenblumenkernen	Germany	757	181	33.0	1.0	4.0
Schnitzer spezial Bio Inkabrot mit Amaranth	Germany	900	215	30.8	2.9	6.9
Solena whole-meal bread with buckwheat	Germany	874	209	31.0	1.0	7.0
Hammer Muehle Vitalbrot-Mix – sunflower seeds	Germany	757	181	33.0	1.0	4.0
Glutano Dreikornbrot	Germany	812	194	38.0	NA	NA
Sibylle-Diat buckwheat-linseed bread	Germany	799	191	26.0	NA	NA
Sibylle-Diat sunflower bread	Germany	1,017	243	35.0	NA	NA
Hammer Muehle Bio-Hirsebrot	Germany	1,105	264	47.2	NA	NA
Hammer Muehle Bio-Inkabrot	Germany	1,008	241	37.0	NA	NA
Hammer Muehle Bio-Lupinenbrot	Germany	1,029	246	38.3	NA	NA
Hammer Muehle Vitalbrot-Mix linseeds	Germany	824	197	36.0	2.0	5.0
Average gluten-free pumpernickel-style bread		887	212	34.9	1.6	5.3
Standard pumpernickel-style bread[b]		1,046	250	47.5	0.5	6.5
Multiseed bread						
Revola GlutaBye Savoureux aux cereales	France	1,050	251	30.5	NA	10.1
Revola GlutaBye Baguette sesame pavot	France	891	213	45.2	NA	NA
Schaer Ertha Unser Koernerbrot	Germany	745	178	33.0	1.8	11.6
Ener Bio Sesambrot	Germany	1,013	242	26.3	1.6	5.0
3 Pauly Winzerbrot mit Teff	Germany	891	213	39.2	NA	NA
Livwell sliced multiseeded bread	Ireland	1,151	275	44.9	2.1	3.9
Marks & Spencer brown seeded loaf	Ireland	1,025	245	19.3	0.5	14.2
Ds Dietary Specials multigrain sliced loaf	Ireland	987	236	42.6	2.3	5.4
Semper Toasty Trio	Sweden	962	230	40.0	1.1	6.5
Semper Trio rolls	Sweden	1,172	280	45.0	4.0	5.0
Average gluten-free multiseed bread		989	236	36.6	1.9	7.7
Standard multiseed wheat bread[b]		1,109	265	43.3	6.4	7.4

(continued on next page)

[a] NA = not available.

[b] Source: USDA National Nutrient Database for Standard Reference.

Table III. *(continued from previous page)*

Category Product	Country	Energy kJ/100 g	 kcal/100 g	Carbohydrate (g/100 g)	Sugar (g/100 g)	Fiber (g/100 g)
White bread						
Kaisersemmeln – white rolls	Austria	1,075	257	56.0	2.3	1.9
Meingast Landbroetchen	Austria	1,297	310	62.7	5.5	4.1
Meingast Ciabatta	Austria	1,184	283	57.7	0.3	2.4
Porkkanaleipä – carrot bread	Finland	908	217	43.7	2.2	2.3
Kauraleipä – oat bread	Finland	1,046	250	50.4	2.3	6.0
Rouheleipä – white bread with flaxseed	Finland	941	225	48.8	1.6	4.7
Vuokaleipä pieni toast	Finland	NA	NA	NA	NA	NA
Marika-leipä – oat bread	Finland	NA	NA	NA	NA	NA
Les Recettes de Celiane pain campagnard	France	1,130	270	52.4	5.5	4.5
Valpiform pain campagnard	France	1,033	247	50.3	NA	NA
France aglut le grand bio	France	1,025	245	45.9	NA	NA
France aglut pain biologique	France	1,075	257	48.1	NA	NA
Schnitzer spezial Bio feines Reisbrot	Germany	824	197	42.9	7.1	4.2
Schaer Bon matin suesse Broetchen	Germany	1,205	288	52.2	12.4	3.0
Schaer Ciabatta	Germany	820	196	40.9	2.7	8.3
Schaer Pan carré	Germany	900	215	39.7	3.8	6.3
Schaer Panini	Germany	891	213	44.6	3.3	4.5
Schaer Mini-baguette Duo	Germany	908	217	45.3	3.0	6.3
Naturkornmuhle Werz Braunhirse Toast	Germany	1,184	283	43.8	NA	NA
Naturkornmuhle Werz	Germany	1,219	291	56.9	NA	NA
Sibylle-Diat chestnut bread	Germany	1,017	243	35.0	NA	NA
Kelkin gluten-free white rolls	Ireland	1,029	246	53.0	2.9	0.1
Juvela gluten-free white sliced loaf	Ireland	971	232	47.8	5.4	3.3
Juvela gluten-free bread rolls	Ireland	1,301	311	58.0	8.1	1.5
Livwell sliced white bread	Ireland	1,130	270	47.6	Trace	4.0
Genius gluten-free fresh white bread	Ireland	1,238	296	41.1	3.0	9.7
Juvela fibro sliced loaf	Ireland	858	205	42.1	4.4	5.0
Livwell sliced white bread	Ireland	1,130	270	47.6	Trace	4.0
Juvela white rolls	Ireland	1,071	256	46.7	8.8	3.5
Livwell 4 white rolls	Ireland	1,172	280	47.7	3.4	4.1
Ds Dietary Specials white sliced loaf	Ireland	962	230	41.6	3.1	5.6
Kelkin sliced white bread	Ireland	1,029	246	53.0	2.9	0.1
Livwell 4 white pita breads	Ireland	1,096	262	61.7	4.3	3.9
Marks & Spencer white loaf	Ireland	1,088	260	34.9	0.5	8.0
Marks & Spencer 4 soft white baps	Ireland	1,025	245	37.5	0.5	6.7
BiAglut Sforna gusto pancarrè	Italy	1,134	271	50.2	NA	NA
Semper Toasty white	Sweden	837	200	42.0	4.8	4.1
Semper Minibaguette	Sweden	1,130	270	52.0	6.2	2.3
Ener-G white rice loaf	United States	1,100	263	44.7	5.3	2.6
Ener-G tapioca loaf	United States	1,197	286	39.3	3.6	7.1
Udi's Gluten Free Foods sandwich bread	United States	1,025	245	35.0	3.5	1.8
Average gluten-free white bread		1,056	253	47.0	4.0	4.0
Standard wheat white bread[b]		1,113	266	50.6	4.3	2.4

Table IV. Several fibers used commercially and their physiologically and technologically important properties[a]

Fiber	Dietary Fiber (g/100 g) Total	 Soluble	 Insoluble	Color	WHC (g water/g solid)	Source
Apple fiber	60–90	8–15	45–81	Brownish	6.1	Rettenmeier (Germany) product specification sheet
Bamboo fiber	97	0	97	White	4.8	Rossel et al. (22)
Cellulose	98	1	97	White	5.6	Rossel et al. (22)
HPMC	100	100	0	White	NA	Rossel et al. (22)
Citrus fiber	44–68	5–10	38–62	White – light yellow	NA	Figuerola et al. (9)
Inulin	97	97	0	White	11.1	Rossel et al. (22)
Pea fiber	65–75	>0.5	>65	White – beige	6–9	Rettenmeier (Germany) product specification sheet
Psyllium husk	77–80	>75	2–5	Brownish	20	Rettenmeier (Germany) product specification sheet; Goni and Martin-Carron (12)
Sugar beet fiber	67–75	>45	>22	White	26	Javidipour et al. (15); Sabanis et al. (24)

[a] WHC = water-holding capacity; HPMC = hydroxypropylmethylcellulose; NA = not available.

Conclusions

A comparison of several studies on carbohydrate intake shows that this macronutrient is consumed in reasonable amounts. Frequently, however, the intake of simple sugars is high. Regarding dietary fiber uptake, the studies show that the intake of dietary fiber is insufficient among both celiac patients and nonceliac subjects. Dietary fiber uptake by celiac patients, however, is even lower. The link between inadequate dietary fiber consumption and low nutritional quality of gluten-free products cannot be confirmed. In general, it can be said that the necessity of fiber enrichment in gluten-free breads is recognized by the food industry because many products are available that contain a sufficient amount of fiber. Although several products contain high amounts of simple carbohydrates, gluten-free breads with reasonable sugar

contents are available. This leaves the responsibility with the consumer to choose nutritionally valuable products.

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