

Article

Exploring the Nutritional Content of Gluten-Free Products in the Greek Market: Implications of a Gluten-Free Diet for the Adult Population

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Featured Application

The findings of this study may support informed food choices among individuals following a gluten-free diet and provide practical guidance for patients, caregivers, and healthcare professionals.

Abstract

Celiac disease is a chronic autoimmune enteropathy triggered by gluten consumption in genetically predisposed individuals. Given that lifelong adherence to a gluten-free diet (GFD) is the only effective treatment, the nutritional quality of commercially available gluten-free (GF) products is of particular importance. The aim of this study was to determine the nutritional content of selected GF products across multiple food categories available in the Greek market and compare them with their gluten-containing (GC) counterparts. In addition, the nutritional adequacy of a GFD for adults was assessed through an indicative 7-day dietary meal plan. A total of 228 food products (114 GF and 114 GC), categorized as charcuterie, starchy, bakery, confectionery, miscellaneous, meat-based, and plant-based, were included. Analysis of food label information revealed broadly comparable nutritional profiles with respect to energy, fat, saturated fat, carbohydrate, sugar, and sodium between GF and GC products. However, GF products contained less protein (7.31 ± 4.94 g vs. 9.86 ± 4.79 g, $p < 0.001$) and more dietary fibre (4.55 ± 3.05 g vs. 3.23 ± 2.21 g, $p = 0.001$). Analysis of the meal plan demonstrated that recommended intakes for all evaluated macronutrients and most micronutrients can be achieved while following a GFD with careful dietary planning. However, iron intake fell slightly below the recommended level for premenopausal women, while meeting vitamin D requirements remained challenging.

Keywords: celiac disease; gluten-free diet; gluten-free products; nutrient content; dietary fibre; nutritional adequacy



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1. Introduction

Celiac disease (CD) is an immune-mediated disorder that occurs in individuals who have a genetic predisposition [1]. It is a systemic autoimmune syndrome that includes chronic inflammation of the mucosa of the small intestine, caused by the consumption of gluten [2]. According to the most recent epidemiological data available for Europe over the past decade, the histology-based prevalence of CD is estimated to range from 0.10% to 3.03% (median: 0.70%) [3]. However, there are significant variations among different

European countries. Finland has reported a prevalence of approximately 2%, while Greece shows rates of about 0.2% in adults [2,4].

The treatment of CD relies exclusively on a strict, lifelong gluten-free diet (GFD) [5]. Although adherence to a GFD improves symptoms and health outcomes in patients with CD, maintaining a lifelong GFD remains highly restrictive and may result in significant psychological and social burden for patients [1,6]. Patients with CD experience difficulties when travelling, eating out, searching for high-quality gluten-free (GF) foods, and identifying foods that are safe for consumption [6]. Studies in Greece have shown that the most significant challenges faced by patients include the high cost of GF foods relative to the quantities provided and the limited availability of GF foods and meals in markets and restaurants [7], as well as low levels of public awareness and reduced access to safe GF foods [8]. Similar barriers to GFD adherence have been documented across Europe and worldwide [9–11].

Inadequate adherence to a GFD may lead to complications such as malnutrition, osteoporosis, autoimmune diseases, refractory CD, and malignancies [12]. Professional dietetic support is crucial for promoting adherence to a GFD in patients with CD [13]. A recent Greek study of 272 adults demonstrated that only 44.9% achieved good adherence to the GFD, as assessed by the Hellenic Celiac Dietary Adherence Test (H-CDAT), while dietetic support was alarmingly limited, as 61.5% were not referred to a dietitian at diagnosis and 75.4% lacked regular follow-up [14]. Similarly, 42.8% of patients with CD from five Central European countries reported not being referred to a dietitian following diagnosis, while 60% of adults with CD in the United Kingdom reported not receiving the recommended annual dietetic review [15,16]. Furthermore, suboptimal adherence rates have been reported across Europe, with 68.7% of adults in Spain demonstrating good or excellent adherence to a GFD and 65.8% of adults in Poland reporting strict adherence to the diet [17,18]. Consistent with these findings, a recent global systematic review and meta-analysis reported that approximately one in three patients with CD is unable to maintain good adherence to a GFD [19].

In addition, another important aspect of the GFD concerns the nutritional quality of GF foods. A review conducted in 2019 highlighted that the GF foods available on the market at that time presented major issues in terms of nutritional adequacy and quality, most notably low protein content and high fat and salt content compared with equivalent GC foods [20]. These differences may explain the imbalances in nutrient and energy intake, as well as the increased fat consumption, which have been documented among individuals following a GFD. More specifically, higher fat intake seems to replace dietary fibre and the intake of complex carbohydrates [21,22]. These dietary patterns may contribute to significant nutritional deficiencies and metabolic disorders among patients [23]. Furthermore, their glycaemic index was found to be elevated, which may be attributed to the use of starch, maize, and rice in their production, ingredients that have a high glycaemic index [23–25]. More recently, a comprehensive review highlighted that, despite growing interest in reformulation and enrichment strategies aimed at improving the nutritional quality of GF foods, important nutritional shortcomings remain, including low protein content, high fat content, and variation in dietary fibre content [26]. Consequently, recent research has not yet reached a clear consensus regarding a global nutritional profile for GF foods, and considerable variation exists in the characteristics of these foods depending on their country of origin, the manufacturer's brand, and the type of product.

To our knowledge, only one previous study has examined the nutritional quality of GF products in Greece. The study focused on cereal-based products and reported that approximately one quarter of the GF products presented an unhealthy nutritional profile, although the overall nutritional quality was generally comparable to that of their GC

counterparts [27]. The aim of the present study was to evaluate the nutritional content of commercially available GF products across multiple food categories in the Greek market and compare them with their GC counterparts, in order to evaluate the nutritional adequacy and potential nutritional imbalances associated with a GFD and provide comprehensive information for patients, caregivers, and healthcare professionals.

2. Materials and Methods

2.1. GF Food Products Data Collection

Samples were selected based on predefined criteria with the aim of ensuring comparability and representativeness of the selected foods. First, priority was given to food categories in which the presence of gluten is intrinsic, that is, where it constitutes a fundamental ingredient of the product's formulation or raw material. This category includes foods such as bread, pasta and breakfast cereals, in which the use of wheat, barley or rye is typical and self-evident. Secondly, foods in which gluten is not an essential ingredient but is frequently added during industrial processing for technological purposes (e.g., improvement of texture, shelf life, or flavour enhancement) were also included. This category comprises products such as processed meats and snacks, where the need for substitution or removal of gluten is necessary to develop a safe gluten-free version. In addition, foods for which, according to European Union (EU) Regulation No 828/2014 [28], the labelling "gluten-free" is essential for the protection of the health of consumers with CD were selected. According to the above, charcuterie was separately categorized from meat-based products as they usually contain gluten as filler or binder, or contain flavourings and sauces that may include wheat or barley derivatives, while meat products are naturally gluten-free but may be contaminated through packaging. The "Miscellaneous" category includes foods like potato chips or beer and sauces that do not fit into any of the other categories. For the categories with the largest number of food products, namely sweets and bakery products, further sub-categorization was carried out. Food products were recorded in each group (GF and GC) and were distributed across 8 categories (Table 1).

Table 1. Food product distribution into categories and sub-categories.

Categories	Sub-Category	N (Number)
Charcuterie	-	10
Starchy	-	15
Bakery, Total	-	43
	Bread	15
	Flour	2
	Pizza	7
	Breadstick/Rusk/Cracker	8
	Other Products	11
Confectionery, Total	-	32
	Biscuit/Cookie	15
	Chocolate/Wafer	5
	Other Products	12
Miscellaneous	-	15
Meat-based	-	3
Plant-based	-	5

The selection was limited to products available in the Greek market. The criteria for selecting a GC counterpart product were as follows: (1) the product's labelling and description closely resembled those of the GF product, and (2) when multiple GC alternatives were available, a well-known brand was chosen, and a comparable GC product was selected to correspond to the different GF products. Data was collected exclusively from the websites of major Greek online retailers, including Sklavenitis, AB Vassilopoulos, Masoutis, and other online supermarkets operating in Greece. Data was extracted from food labels and compiled into a comprehensive database (Microsoft Office Excel 2019) between January 2025 and March 2025. For each product, the following data was recorded from the label: energy (kcal), protein (g), carbohydrate (g), sugar (g), sodium (mg), fat (g), saturated fat (g), and fibre (g) content. Because the serving size of products varied, data was recorded per 100 g.

2.2. Development of 7-Day GF Dietary Meal Plan

Table 2 presents an indicative weekly meal plan for adults aged 19–59 years. The dietary plan was developed according to the principles of the Mediterranean dietary pattern, as recommended by the Dietary Guidelines for Americans [29]. Energy requirements for adults aged 19–59 years were estimated based on median height and body weight values corresponding to a healthy body mass index (BMI), ranging from 1600 to 3000 kcal/day for females and males. The mean value of these energy requirements, 2300 kcal/day, was set as the energy content of the dietary plan. The meal plan was designed to provide approximately 17% of total energy from protein (97.8 g/day), 47% from carbohydrates (270 g/day), and 36% from fat (92 g/day). The mean daily food group equivalents based on the DGA were as follows: dairy, 2 cups/day; fruit, 2.5 cups/day; vegetables, 3 cups/day; grains, 7 oz/day; protein foods, 8 oz/day (including lean foods and legumes); and oils, 29 g/day.

The requirements for micronutrients (iron, folic acid, calcium, vitamin D, vitamin B12, vitamin C, vitamin A, magnesium, and zinc) were determined in accordance with the Dietary Reference Intakes (DRIs) issued by the Institute of Medicine (IOM) for adults aged 19–59 years [30]. Dietary analysis was performed using the specialized software Athlisis Pro (version 9.8; Nutrilogic–Nutrition & IT Consultants, latest update: July 2025). For each seven-day dietary plan, calories, carbohydrates, protein, fats, dietary fibre, iron, folic acid, calcium, vitamin D, vitamin B12, vitamin C, vitamin A, magnesium, and zinc were calculated in detail based on the USDA food database [31] and nutritional information obtained from GF product labels, and then the averages for each nutrient category were determined across all days.

Table 2. Representative 7-day GF meal plan for adults aged 19–59 years (2300 Kcal/per day).

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Breakfast	Low-fat yoghurt 200 g Raisins 20 g Oats, raw 40 g * Tahini 15 g	Gluten-free bread 60 g Peanut butter 15 g Banana, raw 120 g	Low-fat milk 250 g Gluten-free granola 60 g Apple, raw 120 g	Low-fat yoghurt 200 g Raisins 20 g Oats, raw 40 g * Tahini 15 g	Gluten-free bread 60 g Peanut butter 15 g Banana, raw 120 g	Low-fat milk 250 g Gluten-free granola 60 g Apple, raw 120 g	Low-fat yoghurt 200 g Raisins 20 g Oats, raw 40 g * Tahini 15 g
Mid-morning snack	Orange 100 g Almonds, raw 20 g Gluten-free breadsticks 60 g	Kefir 150 g Apple 100 g	Low-fat yoghurt 200 g Walnuts 15 g Strawberries, raw 150 g	Orange, raw 100 g Cheese 30 g Gluten-free breadsticks 50 g	Low-fat yoghurt 200 g Walnuts 20 g Strawberries, raw 150 g	Gluten-free breadsticks 40 g	Orange 100 g Almonds, raw 20 g Gluten-free breadsticks 60 g
Lunch	Beef burger, grilled 120 g Brown rice, cooked 250 g Green leafy vegetables 100 g Sun-dried tomatoes 30 g Olive oil 15 g	Gluten-free pasta 320 g Tomato sauce 50 g Parmesan cheese 45 g Green leafy vegetables 100 g Olive oil 25 g	Chicken breast, cooked 160 g Potato, boiled 250 g Broccoli, boiled 150 g Olive oil 15 g	Cooked beans 250 g Gluten-free bread 60 g Green leafy vegetables 100 g Olive oil 20 g	Salmon, steamed 180 g Asparagus, cooked 200 g Sweet potato, boiled 250 g Sweetcorn 100 g Olive oil 20 g	Lentils, boiled 250 g Cabbage 100 g Carrot 100 g Olive oil 25 g	Spinach rice 300 g Cucumber 100 g Tomatoes 100 g Feta cheese 50 g Gluten-free toasted bread 60 g
Afternoon snack	Kefir 150 g Apple 100 g	Low-fat yoghurt 200 g Hazelnuts 15 g Strawberries, raw 150 g	Chocolate 30 g Dried plums (prunes) 50 g	Kefir 150 g Apple 100 g Linseed 10 g	Kefir 150 g Apple 100 g Linseed 10 g Oats, raw 50 g *	Chocolate 30 g Dried plums (prunes) 50 g	Kefir 150 g Apple 100 g
Dinner	Boiled eggs (2 pcs) 100 g Broccoli, boiled 100 g Gluten-free bread 60 g Sweetcorn 100 g Black olives 35 g	Gluten-free tortilla 80 g Tuna in water 160 g Carrot, grated 100 g Mayonnaise (regular) 15 g	Gluten-free bread 60 g Graviera cheese 30 g Olive paste 30 g Tomato 100 g	Quinoa, cooked 250 g Tomato 100 g Egg, boiled 50 g Avocado, raw 50 g Cucumber 100 g Olive oil 15 g	Gluten-free tortilla 80 g Cottage cheese 40 g Turkey, boiled 30 g Spinach 40 g Tomatoes 100 g	Chicken breast, grilled 160 g Brown rice, cooked 200 g Broccoli, boiled 150 g Olive oil 15 g	Sardines, canned 100 g Gluten-free toasted bread 60 g Sweetcorn 100 g

* Certified gluten-free oats were assumed in the meal plan.

2.3. Statistical Analysis

Statistical analysis was carried out using the statistical software packages Statistical Package for the Social Sciences (SPSS) Version 25.0 and MINITAB 19 Version 22.0. The normality of the variables was assessed using the Kolmogorov–Smirnov and Shapiro–Wilk tests. Data variables that were not normally distributed were subjected to a Box–Cox transformation; where this was not feasible based on the outputs of the statistical software, a Johnson transformation was applied. To compare the mean values of the variables between the two food groups, a one-way analysis of variance (One-Way ANOVA) was performed. Mean values (mean) and standard deviations (standard deviation) were used to describe the variables. For dietary fibre, mean values were calculated based only on products for which fibre information was available on the nutrition label ($n = 93$ GF products and $n = 83$ GC products). The level of statistical significance was set at $p < 0.05$ (*). To investigate potential additional differences within the two main groups (sweets and bakery products), multiple pairwise comparison analyses of subgroups were conducted.

3. Results

3.1. Nutritional Content of GF Foods

A total of 228 products were assessed in the present study, including 114 GF and 114 GC products. Table 3 presents the descriptive statistical data for the variables analysed in the GF and GC food groups. Overall, no significant differences were observed between GF and GC products regarding energy, fat, saturated fat, carbohydrate, sugar, or sodium content. However, GC products contained significantly higher levels of protein, whereas GF products contained significantly higher levels of fibre.

Table 3. Differences in energy, macronutrient and sodium contents of gluten-free (GF) and gluten-containing (GC) products per 100 g of product as consumed. Data are expressed as mean $\pm$ SD.

Nutritional Variable	GF Product (n = 114)	GC Product (n = 114)	<i>p</i> -Value
Energy (Kcal)	332.97 $\pm$ 120.25	337.45 $\pm$ 122.83	0.781
Fat (g)	12.12 $\pm$ 9.06	12.16 $\pm$ 10.04	0.977
Saturated fat (g)	4.65 $\pm$ 5.17	6.28 $\pm$ 12.47	0.197
Carbohydrates (g)	46.47 $\pm$ 25.26	46.69 $\pm$ 23.47	0.945
Sugar (g)	9.32 $\pm$ 11.58	11.79 $\pm$ 14.16	0.151
Protein (g)	7.25 $\pm$ 4.92	9.82 $\pm$ 4.79	<0.001
Fibre (g) [†]	4.53 $\pm$ 3.06	3.16 $\pm$ 2.14	0.001
Sodium (mg)	454.80 $\pm$ 589.51	456.04 $\pm$ 551.89	0.987

[†] Fibre values represent means calculated from $n = 93$ GF and $n = 83$ GC products.

Table 4 presents the nutritional variables for the seven categories of GF and GC food products. Statistically significant differences in protein content were observed between starchy products with and without gluten. Specifically, GF starchy products exhibited a markedly lower protein content compared with their GC counterparts ($p = 0.003$). Within the bakery products category, GF products showed significantly lower protein content compared with equivalent GC products ($p < 0.001$). Furthermore, GF bakery products were found to have significantly higher fibre content compared with their GC equivalents ($p < 0.001$). Similarly, GF confectionery contained significantly lower protein levels compared with corresponding GC products ($p = 0.045$).

Table 4. Differences in energy, macronutrient, and sodium contents of GF and GC products (per 100 g of product as consumed) based on product type. Data are expressed as mean $\pm$ SD.

	n		Energy (Kcal)	Fat (g)	Saturated Fat (g)	Protein (g)	Carbohydrates (g)	Sugars (g)	Fibre (g)	Sodium (mg)
charcuterie	10	GC	246.00 $\pm$ 78.91	17.05 $\pm$ 8.69	6.45 $\pm$ 2.81	18.62 $\pm$ 8.40	4.42 $\pm$ 2.43	0.60 $\pm$ 0.49	0.12 $\pm$ 0.25	1064.00 $\pm$ 539.39
		GF	211.67 $\pm$ 68.34	15.00 $\pm$ 9.85	5.07 $\pm$ 3.61	16.80 $\pm$ 7.59	2.00 $\pm$ 3.04	0.10 $\pm$ 0.17	0.23 $\pm$ 0.40	1080.60 $\pm$ 160.00
		<i>p</i> -value	0.977	0.843	0.944	0.747	0.303	0.652	0.677	0.874
starchy	15	GC	353.75 $\pm$ 30.32	3.32 $\pm$ 2.03	1.16 $\pm$ 1.12	12.44 $\pm$ 1.66	67.28 $\pm$ 7.45	3.38 $\pm$ 1.07	3.17 $\pm$ 0.99	148.96 $\pm$ 192.89
		GF	353.33 $\pm$ 35.99	4.31 $\pm$ 3.77	0.97 $\pm$ 0.89	7.77 $\pm$ 4.04	71.10 $\pm$ 12.79	3.88 $\pm$ 10.64	3.52 $\pm$ 2.138	171.31 $\pm$ 264.61
		<i>p</i> -value	0.968	0.557	0.012	0.003 *	0.517	0.363	0.642	0.833
bakery	43	GC	331.43 $\pm$ 90.44	9.64 $\pm$ 8.26	6.65 $\pm$ 19.98	9.65 $\pm$ 2.58	49.59 $\pm$ 15.46	6.25 $\pm$ 6.08	3.54 $\pm$ 2.16	451.81 $\pm$ 174.81
		GF	316.49 $\pm$ 85.26	8.54 $\pm$ 6.24	2.66 $\pm$ 3.58	4.52 $\pm$ 3.06	49.08 $\pm$ 16.72	4.58 $\pm$ 4.45	6.11 $\pm$ 3.09	436.419 $\pm$ 217.95
		<i>p</i> -value	0.355	0.891	0.268	0.000 *	0.914	0.287	0.000 *	0.982
confectionery	32	GC	462.21 $\pm$ 60.15	21.36 $\pm$ 6.86	10.45 $\pm$ 7.05	6.40 $\pm$ 1.43	59.63 $\pm$ 8.57	25.66 $\pm$ 10.43	2.95 $\pm$ 2.40	222.09 $\pm$ 156.31
		GF	444.43 $\pm$ 74.48	20.18 $\pm$ 6.69	9.71 $\pm$ 5.68	5.37 $\pm$ 1.74	58.70 $\pm$ 12.54	25.498 $\pm$ 7.19	3.64 $\pm$ 2.33	230.57 $\pm$ 276.87
		<i>p</i> -value	0.622	0.584	0.420	0.045 *	0.749	0.143	0.312	0.626
miscellaneous	15	GC	226.00 $\pm$ 278.75	13.20 $\pm$ 18.07	2.00 $\pm$ 1.82	3.83 $\pm$ 2.66	22.13 $\pm$ 26.73	2.27 $\pm$ 2.40	2.27 $\pm$ 1.91	408.00 $\pm$ 148.16
		GF	206.00 $\pm$ 251.48	9.87 $\pm$ 13.24	0.93 $\pm$ 0.90	3.43 $\pm$ 2.02	24.93 $\pm$ 31.24	4.00 $\pm$ 1.82	2.30 $\pm$ 1.97	546.67 $\pm$ 61.65
		<i>p</i> -value	0.551	0.948	0.819	0.584	0.298	0.697	0.984	0.961
meat-based	3	GC	192.67 $\pm$ 41.76	8.23 $\pm$ 5.43	3.70 $\pm$ 5.29	14.60 $\pm$ 7.15	14.67 $\pm$ 12.89	2.00 $\pm$ 2.25	4.97 $\pm$ 0.90	520.00 $\pm$ 105.83
		GF	215.00 $\pm$ 19.03	13.07 $\pm$ 0.95	4.13 $\pm$ 2.26	12.70 $\pm$ 3.66	10.67 $\pm$ 4.21	1.73 $\pm$ 0.84	-	473.33 $\pm$ 176.91
		<i>p</i> -value	0.672	0.798	0.739	0.584	0.564	0.370	-	0.530
plant-based	5	GC	216.40 $\pm$ 48.80	12.52 $\pm$ 6.26	4.72 $\pm$ 2.69	19.88 $\pm$ 3.13	6.02 $\pm$ 4.29	0.90 $\pm$ 1.12	-	602.40 $\pm$ 167.11
		GF	231.00 $\pm$ 43.65	13.64 $\pm$ 5.70	4.02 $\pm$ 3.03	18.28 $\pm$ 4.66	8.66 $\pm$ 7.64	0.36 $\pm$ 0.29	2.10 $\pm$ 0.00	524.80 $\pm$ 167.24
		<i>p</i> -value	0.464	0.206	0.906	0.716	0.644	0.861	-	0.731

Statistically significant differences between variables of GF and GC groups for each category are marked in bold with an asterisk (*).

Table 5 presents the nutritional variables and sample distribution of the sub-categories within the “Bakery Products” category. Within the “Bakery Products” group, statistically significant differences were observed in protein and dietary fibre content among products in the “Bread” sub-group. Specifically, GF bread products exhibited significantly lower protein content ($p = 0.003$) and significantly lower dietary fibre content ($p = 0.036$) compared with their GC counterparts. In addition, within the “Pizza” sub-group, GF products were found to have significantly lower protein content compared with equivalent GC products ($p = 0.004$), while sodium content was also significantly lower ($p = 0.036$). Conversely, this sub-group demonstrated significantly higher dietary fibre content relative to GC equivalents ($p = 0.005$). In the “Breadstick/rusk/cracker” sub-group, GF products exhibited significantly lower protein content compared with their GC counterparts ($p = 0.011$). In the “Other” sub-group, GF products showed significantly lower protein content compared with equivalent GC products ($p = 0.009$), alongside significantly higher dietary fibre content ($p = 0.029$).

Table 6 presents the numerical sample distribution of sub-categories within the “Confectionery” category. Within the “Confectionery” group, a statistically significant difference in protein content was observed among products in the “Chocolate/Wafer” sub-group. Specifically, GF chocolate/wafer products exhibited a significantly lower protein content compared with their GC equivalents ($p = 0.021$). In addition, GF biscuit/cookie products exhibited lower sugar content compared with GC products, GF chocolate/wafer products exhibited higher carbohydrate content, and GF products in the “Other” sub-category exhibited higher sodium content; however, these differences did not reach statistical significance.

3.2. Dietary Assessment of 7-Day GF Dietary Meal Plan

The mean daily food exchange equivalents based on the DGA were as follows [16]: dairy (cups/day): 2; fruit (cups/day): 2.5; vegetables (cups/day): 3; grains (ounces/day): 7; protein foods (ounces/day): 8 (lean foods and legumes were included); oils (g/day): 29 g. Dietary analysis based on the mean values of the seven-day meal plan yielded the following results: energy: 2287 kcal; protein (PRO): 101 g; carbohydrates (CHO): 272 g; fat (FAT): 89.5 g; dietary fibre: 39.2 g (RDA: 30 g). Micronutrient analysis based on the mean values of the seven-day meal plan indicated the following intakes: iron: 16.9 mg (RDA: 8 mg); folate: 467 µg (RDA: 400 µg); calcium: 1256 mg (RDA: 1000 mg); magnesium: 489 mg (RDA: 400 mg); zinc: 12.2 mg (RDA: 11 mg); vitamin D: 10 µg (RDA: 15 µg); vitamin A (provitamin A plus vitamin A): 1400 µg (RDA: 900 µg); vitamin C: 172 mg (RDA: 90 mg); and vitamin B12: 5.6 µg (RDA: 2.4 µg). The recommended dietary allowance (RDA) values were based on the Dietary Reference Intakes published by the Institute of Medicine [17].

Table 7 presents the nutritional analysis of the indicative 7-day gluten-free meal plan in comparison with the Dietary Reference Intakes (DRIs), Dietary Guidelines for Americans (DGA) energy recommendations, and Acceptable Macronutrient Distribution Ranges (AMDRs) for adult men and women aged 19–59 years. The meal plan provided a mean daily energy intake of 2287 kcal, with protein, carbohydrate, and fat contributing 17.7%, 47.6%, and 35.2% of total energy intake, respectively. The analysed meal plan provided adequate amounts of dietary fibre, calcium, magnesium, zinc, vitamin C, vitamin A, vitamin B12, folate, and, for men, iron. In contrast, iron intake did not meet the recommended intake for women, and vitamin D intake remained below the recommended level for both sexes.

Table 5. Differences in energy, macronutrient and sodium contents of GF and GC products (per 100 g of product as consumed) for the category bakery. Data are expressed as mean $\pm$ SD.

	n		Energy (Kcal)	Fat (g)	Saturated Fat (g)	Protein (g)	Carbohydrates (g)	Sugars (g)	Fibre (g)	Sodium (mg)
Bread	15	GC	266.57 $\pm$ 34.10	5.89 $\pm$ 4.78	1.31 $\pm$ 1.55	8.93 $\pm$ 1.58	41.20 $\pm$ 8.43	4.66 $\pm$ 2.57	4.09 $\pm$ 2.31	439.21 $\pm$ 88.04
		GF	283.50 $\pm$ 60.31	7.20 $\pm$ 4.86	1.60 $\pm$ 2.16	5.92 $\pm$ 3.04	44.16 $\pm$ 11.48	4.59 $\pm$ 2.39	3.63 $\pm$ 3.48	430.57 $\pm$ 171.90
		<i>p</i> -value	0.244	0.416	0.723	0.003 *	0.233	0.759	0.036 *	0.964
Flour	2	GC	341.00	0.50	0.50	11.00	73.00	0.20	-	560.00
		GF	344.00	0.50	0.10	1.00	82.00	1.70	4.70	4.00
		<i>p</i> -value	-	-	-	-	-	-	-	-
Pizza	7	GC	272.00 $\pm$ 82.48	10.78 $\pm$ 7.67	5.68 $\pm$ 3.98	8.54 $\pm$ 2.09	35.34 $\pm$ 10.52	3.72 $\pm$ 1.38	1.86 $\pm$ 0.25	571.20 $\pm$ 130.27
		GF	288.80 $\pm$ 60.35	11.08 $\pm$ 10.17	4.88 $\pm$ 5.14	5.14 $\pm$ 3.00	40.00 $\pm$ 14.54	2.26 $\pm$ 0.36	4.82 $\pm$ 1.19	484.00 $\pm$ 100.40
		<i>p</i> -value	0.771	0.590	0.135	0.004 *	0.209	0.081	0.005 *	0.036 *
Breadstick/ rusk/cracker	8	GC	409.86 $\pm$ 59.91	10.23 $\pm$ 7.04	3.53 $\pm$ 2.98	12.61 $\pm$ 2.14	64.84 $\pm$ 6.79	3.57 $\pm$ 1.30	4.61 $\pm$ 2.60	345.71 $\pm$ 214.78
		GF	337.14 $\pm$ 107.98	10.49 $\pm$ 5.93	2.47 $\pm$ 2.91	6.68 $\pm$ 4.28	50.33 $\pm$ 15.10	3.87 $\pm$ 1.879	7.66 $\pm$ 3.24	482.39 $\pm$ 285.84
		<i>p</i> -value	0.093	0.795	0.681	0.011 *	0.289	0.873	0.111	0.195
Other	11	GC	383.00 $\pm$ 84.57	13.16 $\pm$ 10.40	18.59 $\pm$ 39.44	8.27 $\pm$ 2.27	56.91 $\pm$ 17.34	12.52 $\pm$ 9.68	2.48 $\pm$ 1.43	445.78 $\pm$ 209.54
		GF	377.11 $\pm$ 98.30	10.26 $\pm$ 8.89	4.34 $\pm$ 5.01	5.22 $\pm$ 2.28	54.98 $\pm$ 18.51	7.34 $\pm$ 8.49	4.46 $\pm$ 2.86	423.11 $\pm$ 240.08
		<i>p</i> -value	0.867	0.348	0.270	0.009 *	0.730	0.146	0.029 *	0.458

Statistically significant differences between variables of GF and GC groups for each sub-category are marked in bold with an asterisk (*).

Table 6. Differences in energy, macronutrient and sodium contents of GF and GC products (per 100 g of product as consumed) for the sub-category sweets. Data are expressed as mean $\pm$ SD.

	n		Energy (Kcal)	Fat (g)	Saturated Fat (g)	Protein (g)	Carbohydrates (g)	Sugars (g)	Fibre (g)	Sodium (mg)
Biscuit/cookie	15	GC	485.07 $\pm$ 15.75	22.45 $\pm$ 3.64	11.15 $\pm$ 3.39	6.55 $\pm$ 0.97	63.01 $\pm$ 6.48	26.92 $\pm$ 9.67	2.55 $\pm$ 0.76	267.43 $\pm$ 146.25
		GF	475.93 $\pm$ 36.11	20.97 $\pm$ 6.01	9.78 $\pm$ 5.05	5.75 $\pm$ 1.55	60.19 $\pm$ 6.68	25.00 $\pm$ 6.36	4.00 $\pm$ 1.88	306.57 $\pm$ 345.98
		<i>p</i> -value	0.103	0.629	0.377	0.630	0.330	0.062	0.880	0.341
Chocolate/wafer	5	GC	542.50 $\pm$ 19.09	33.00 $\pm$ 2.83	27.25 $\pm$ 8.84	4.65 $\pm$ 0.21	56.00 $\pm$ 1.41	39.00 $\pm$ 1.41	1.45 $\pm$ 0.92	72.00 $\pm$ 11.32
		GF	527.74 $\pm$ 14.32	27.92 $\pm$ 3.48	17.92 $\pm$ 0.79	3.30 $\pm$ 0.64	66.25 $\pm$ 3.33	35.62 $\pm$ 7.64	0.75 $\pm$ 0.99	59.00 $\pm$ 11.49
		<i>p</i> -value	0.712	0.142	0.126	0.021 *	0.068	0.206	0.500	0.651

Table 6. Cont.

	n		Energy (Kcal)	Fat (g)	Saturated Fat (g)	Protein (g)	Carbohydrates (g)	Sugars (g)	Fibre (g)	Sodium (mg)
Other	12	GC	393.56 ± 61.66	15.87 ± 7.69	4.25 ± 3.88	6.61 ± 2.08	53.90 ± 10.41	19.33 ± 9.28	4.17 ± 4.11	174.28 ± 168.08
		GF	367.00 ± 58.30	15.59 ± 5.98	6.34 ± 4.13	5.66 ± 1.81	48.20 ± 14.64	23.50 ± 5.13	4.29 ± 2.83	192.80 ± 182.66
		<i>p</i> -value	0.224	0.543	0.392	0.125	0.683	0.502	0.944	0.070

Statistically significant differences between variables of GF and GC groups for each sub-category are marked in bold with an asterisk (*).

Table 7. Nutritional analysis of the indicative 7-day meal plan for adults aged 19–59 years in comparison with recommended dietary allowances (RDAs).

Nutritional Values	Mean Values	RDAs * Men, 19–59 Yrs	RDAs * Women, 19–59 Yrs
Energy (Kcal)	2287	DGA ^a : 1600–3000	DGA ^a : 1600–3000
Protein (g, %)	101 (17.7)	56, AMDR ^a : 10–35% of total kcal	46, AMDR ^a : 10–35% of total kcal
Carbohydrates (g, %)	272 (47.57)	AMDR ^b : 45–65% of total kcal	AMDR ^b : 45–65% of total kcal
Sugar, Total (g, %) ^c	83.83 (11.6)	Added sugars: <25% of total energy	Added sugars: <25% of total energy
Fat (g, %)	89.5, 35.2%	AMDR ^a : 20–35% of total kcal	AMDR ^a : 20–35% of total kcal
Saturated fat (g, %)	21.99 (6.86)	As low as possible while consuming a nutritionally adequate diet	As low as possible while consuming a nutritionally adequate diet
Fibre (g) [†]	39.2	30	30
Sodium (mg)	2403.60	1500	1500
Iron (mg)	16.9	8	18
Calcium (mg)	1256	1000	1000
Magnesium (mg)	489	400	310
Zinc (mg)	12.2	11	8
Vitamin C (mg)	172	90	75
Vitamin A (provitamin A plus vitamin A) (µg)	1400	900	700

Table 7. Cont.

Nutritional Values	Mean Values	RDA ^s *	RDA ^s *
		Men, 19–59 Yrs	Women, 19–59 Yrs
Vitamin D (µg)	10	15	15
Vitamin B12 (µg)	5.6	2.4	2.4
Folate (µg)	467	400	400

* Dietary Reference Intakes (DRIs) for Magnesium, and Vitamin D (1997); Dietary Reference Intakes for Folate, and Vitamin B12, (1998); Dietary Reference Intakes for Vitamin C (2000); Dietary Reference Intakes for Vitamin A, and Zinc (2001); Dietary Reference Intakes for Calcium and Vitamin D (2011); and Dietary Reference Intakes for Sodium, added sugars, and saturated fat (2019). These reports may be accessed via www.nationalacademies.org/publications/all. ^a Calorie level ranges: Ages 19 through 30, Females: 1800–2400 calories; Males: 2400–3000 calories. Ages 31 through 59, Females: 1600–2200 calories; Males: 2200–3000 calories. Energy levels are calculated based on median height and body weight for healthy body mass index (BMI) reference individuals. ^b Acceptable Macronutrient Distribution Range (AMDR) ^b is the range of intake for a particular energy source that is associated with reduced risk of chronic disease while providing intakes of essential nutrients. If an individual consumes in excess of the AMDR, there is a potential for increased risk of chronic diseases and insufficient intakes of essential nutrients. ^c Total sugar intake is presented, whereas the DRI recommendations refer to added sugars. [†] Adequate Intake (AI) according to the Dietary Reference Intakes (DRIs).

4. Discussion

The present study compared the nutritional composition of commercially available GF products in the Greek market with that of their GC counterparts and evaluated the nutritional adequacy of an indicative GFD for adults, providing insight into the nutritional quality of GF products and highlighting potential nutritional challenges associated with the substitution of conventional GC foods with GF alternatives in the diet.

Analysis of food label information from GF and GC products representing a wide range of food categories available in major supermarket chains operating in Greece revealed broadly comparable nutritional profiles with respect to energy, fat, saturated fat, carbohydrate, sugar, and sodium between the two product groups (Table 3). Although GF starchy, meat-based, and plant-based products tended to contain higher fat levels than corresponding GC products, and meat-based GF products exhibited higher mean saturated fat contents, none of these differences reached statistical significance (Table 4). These findings are consistent with those reported by Bathrellou and Kontogianni (2024), who observed an overall comparable nutritional profile between cereal-based GF products and their GC counterparts in the Greek market [27].

In contrast, a study conducted in the Norwegian market reported higher carbohydrate, saturated fat, and salt contents in GF products compared with GC counterparts [32]. Similarly, earlier studies have reported that processed GF products often contain higher levels of total fat, saturated fat, and sodium to compensate for the texture and palatability lost when gluten is removed [20]. Importantly, over-reliance on such products may contribute to adverse metabolic effects, weight gain, and increased cardiovascular risk, particularly when nutrient-dense whole grains are replaced by refined starch-based alternatives [23]. However, recent evidence suggests a broadly comparable nutritional profile for these nutrients, potentially reflecting ongoing reformulation efforts by manufacturers [27,33].

Interestingly, although sodium content was generally comparable between GF and GC products across the food categories examined, the only statistically significant difference was observed within the pizza sub-category (Table 5). GF pizza products exhibited significantly lower sodium levels, higher dietary fibre content, and lower protein levels than their GC counterparts. The higher dietary fibre content observed in GF pizza products is consistent with findings reported by Bathrellou and Kontogianni, who identified higher dietary fibre content in GF dough-based products, including pizzas, compared with GC counterparts in the Greek market [27]. These findings suggest a more favourable nutritional profile with respect to dietary fibre and sodium content and may reflect changes in GF product formulation aimed at enhancing the nutritional quality of certain GF convenience foods [34–37].

However, the study also revealed notable nutritional differences between GF and GC products across several food categories (Table 4). The most pronounced differences were observed in protein and dietary fibre content. In particular, significant differences in protein content were identified within the starchy foods and bakery product categories. The lower protein content of GF products is consistent with findings from a previous study of cereal-based GF products in the Greek market, which reported that although GF products exhibited an overall nutritional profile comparable to that of GC products, protein content was consistently lower in several staple products, including breads, pasta, and flours [27]. Additionally, significantly lower protein content was also observed in GF products within the “Confectionery” category (Table 4), particularly in the “Chocolate/Wafer” sub-category (Table 6), in line with previous findings [32].

Several studies have demonstrated that GF products often exhibit reduced nutritional quality, particularly with respect to protein content, due to the absence of wheat and other gluten-containing cereals [26,38,39]. In some cases, protein levels in GF products have

been reported to be up to 63% lower than those of GC counterparts [40,41], and significantly lower protein content has been documented across a variety of food categories and countries [33,34,42,43]. This is largely attributable to the composition of GF formulations, which commonly rely on refined starches and flours, such as rice, corn, and potato starch, to replace gluten-containing cereals [44]. As a result, GF products are often characterized by lower protein content, particularly when these substitute ingredients are not fortified or enriched with protein. Moreover, lower protein quality may also occur, as commonly used ingredients such as rice starch contain lower levels of essential amino acids, including lysine and tryptophan [45,46].

Concerning dietary fibre, the overall content was higher in many GF food groups examined in the present study (Table 4). However, GF bread exhibited significantly lower dietary fibre than conventional bread (Table 5). Despite the increasing demand for GF products and ongoing improvements in their formulation, inconsistent findings regarding dietary fibre content continue to be reported across food groups in the literature. Al-Zaben et al. reported slightly higher fibre content in GF foods compared with conventional foods across all categories included in their study [33]. In contrast, Myhrstad et al. reported higher fibre content in conventional starchy foods and cereals, and comparable fibre content in snacks and confectionery [32]. Guennouni et al. also reported higher dietary fibre content in GF foods compared with conventional products [47].

A review of commercially available gluten-free breads worldwide reported that GF bread generally contained lower protein and higher fat levels than GC bread, while dietary fibre content exhibited substantial variability across countries [48]. The lower fibre content observed in GF bread in the present study may be partly explained by the widespread use of refined starches and rice flour, which are commonly used in commercial GF formulations and are naturally low in dietary fibre. Although numerous studies have demonstrated that fibre-enrichment strategies, including the incorporation of psyllium, bran, β -glucans, and other functional ingredients, can improve both the nutritional quality and technological properties of GF bread, these approaches have not been uniformly adopted in commercially available products [49,50]. Consequently, dietary fibre content remains highly variable among GF breads and may be influenced by differences in product formulation, ingredient selection, and country-specific manufacturing practices. Given that bread is a staple food and one of the most commonly consumed GF products among individuals following a GFD, the lower dietary fibre content observed in GF bread may be nutritionally relevant [49]. Previous studies have shown that low fibre intake among adults with CD following a GFD may contribute to constipation and other gastrointestinal symptoms [51]. In addition, the high glycaemic index of many commercial GF bread products, due to the extensive use of refined starches and rice flour, may adversely affect glycaemic control and increase cardiometabolic risk when consumed long term [48,49].

Although the nutritional composition of many GF products has improved over time, GF products cannot always be considered nutritionally equivalent to their GC counterparts, and continued development of GF products with enhanced nutritional value, particularly with respect to protein and dietary fibre content, remains necessary [52,53]. Despite long-standing concerns in the scientific literature regarding the nutritional quality of industrial GF products and the potential risk of nutritional deficiencies and metabolic disturbances associated with diets relying heavily on processed GF products, the perception that GF products are inherently healthier than their conventional counterparts remains widespread among consumers, the so-called “health halo” effect [20,54,55]. However, current evidence does not support this assumption [56,57]. The findings of the present study indicate that, although some GF products exhibit favourable nutritional characteristics, substantial vari-

ability in nutritional quality still exists across food categories, highlighting the importance of evaluating food labels not only for gluten content but also for nutritional composition.

To address nutritional challenges, a balanced GFD incorporating whole plant foods, including fruits, vegetables, legumes, nuts, and naturally GF wholegrain cereals and pseudocereals (e.g., millet, buckwheat, quinoa, and certified GF oats), is recommended [58]. Given that lifelong elimination of dietary gluten remains the only effective treatment for individuals with CD, the present study also evaluated the nutritional adequacy of an indicative 7-day GFD. Conventional GC foods were replaced by GF counterparts identified in the Greek market, and nutrient intakes were evaluated against established dietary reference values. The analysis demonstrated that recommended intakes were achieved for all evaluated macronutrients and most micronutrients, including dietary fibre, calcium, magnesium, zinc, folate, vitamin A, vitamin C, and vitamin B12, despite the limited availability of nutrient composition data for several GF products included in the study.

Among the micronutrients evaluated, recommended intakes were not fully achieved only for iron and vitamin D. These findings may partly reflect underestimation of intakes due to incomplete micronutrient information available on the labels of some GF products included in the dietary plan. However, the limited fortification of many GF products with iron and vitamin D may also contribute to inadequate intakes, given that fortification of GF foods is typically voluntary [5]. Concerning iron, intake was adequate for men but fell slightly below the recommended intake for premenopausal women. Attention to iron intake remains important, as iron deficiency is commonly reported among individuals with CD, and iron supplementation may be recommended for certain patients [5,59]. Meeting vitamin D requirements remained challenging based on the available data. These findings are consistent with previous studies indicating that a GFD, even when well balanced, often fails to meet vitamin D requirements [53,56,59]. Vitamin D deficiency is common among adults with CD despite adherence to a strict GFD, suggesting that supplementation may be required in some cases [49,60,61].

It is worth mentioning that nutrient and energy requirements vary according to age, sex, body size, and physical activity level [30]. Therefore, although the present meal plan provides an illustrative example of a balanced GFD, individualized dietary planning remains necessary in clinical practice. Consequently, dietary counselling by a registered dietitian is recommended for individuals with CD to tailor a GFD to their individual nutritional needs [13]. Moreover, the nutritional adequacy of a GFD has implications beyond the management of CD, as GFDs are also adopted by individuals with non-coeliac gluten sensitivity and even by people without diagnosed gluten-related disorders [55].

The present study has several limitations. The list of GF products available in the Greek market was selective rather than exhaustive and may not fully represent all GF products currently available in Greece. In addition, the number of products included in certain food categories was limited, which may have affected the generalizability of category-specific findings. The analysis relied on manufacturer-reported nutritional information, while no information regarding the methods used to determine nutrient composition was available on product labels. Consequently, inaccuracies in the reported nutritional values cannot be excluded. Furthermore, nutritional information extracted from labels was incomplete for some products. In particular, dietary fibre information was not available for all products included in the analysis, as fibre declaration is not mandatory on food labels in all cases. Consequently, comparisons involving dietary fibre were based on a subset of products and should be interpreted with caution. Comparisons between GF and GC products were limited to nutrients consistently reported on product labels, and therefore, several micronutrients could not be reliably compared between the two groups. The nutritional adequacy assessment of the indicative GF meal plan was based on nutrient databases

and manufacturer-provided information and was therefore limited by the lack of detailed micronutrient composition data for several GF products. In addition, the proposed meal plan was intended as an illustrative example for adults aged 19–59 years, whereas the development and evaluation of dietary plans tailored to specific age groups and energy requirements was beyond the scope of the present study.

Future studies should include long-term evaluation of the proposed dietary plans in practice, including assessment of their impact on nutritional status indicators. In addition, laboratory analysis of commercially available GF products would be valuable to verify the accuracy of manufacturer-reported nutritional information and confirm the nutrient composition declared on food labels. Such analyses would strengthen the evidence regarding the nutritional quality of GF products and support the identification of nutritionally favourable options for individuals with CD. Furthermore, comparisons of GF products available in the Greek market with those from other countries may help identify differences in nutritional quality and formulation characteristics.

5. Conclusions

The present study demonstrated significant differences in the nutritional composition of commercially available GF products compared with their GC counterparts, with respect to protein and dietary fibre content, whereas energy, fat, saturated fat, carbohydrate, sugar, and sodium content were broadly comparable. Lower protein content was consistently observed across several GF food categories, especially in bakery and starchy products, while dietary fibre content varied between food groups. Although some GF products exhibited favourable nutritional characteristics, substantial variability in nutritional quality was identified across categories.

The analysis of the indicative 7-day meal plan showed that recommended intakes were met for all evaluated macronutrients and most micronutrients, suggesting that nutritional adequacy can be achieved with appropriate planning of a GFD. However, meeting iron and vitamin D requirements remains challenging, highlighting the importance of careful dietary planning, including adequate consumption of fortified products and the use of supplementation when necessary.

Overall, the findings emphasize the importance of evaluating not only the gluten-free status of foods, but also their overall nutritional composition. Increased availability of nutritionally balanced GF products, together with appropriate dietary guidance, may contribute to improved long-term dietary management and nutritional health among individuals following a GFD.

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Abbreviations

The following abbreviations are used in this manuscript:

CD	Coeliac Disease
WGO	World Gastroenterology Organisation
GFD	Gluten-Free Diet
GF	Gluten-Free
GC	Gluten Containing
EU	European Union
DGA	Dietary Guidelines for Americans
DRI	Dietary Reference Intakes

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