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ORIGINAL PAPER

Nutritional Differences Between a Gluten-free Diet and a Diet Containing Equivalent Products with Gluten

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Abstract The gluten-free (GF) products market represents one of the most prosperous markets in the field of food and beverages in the immediate future. Historically, counselling for celiac disease has focused on the absence of gluten in foods, however the nutritional quality of GF foodstuffs is an important aspect to consider. The aim of the present work was to compare the nutritional composition of the 206 GF rendered products most consumed in Spain, against the composition of 289 equivalent foods with gluten, and to make a comparison between the diet including GF products and the same diet with equivalent products with gluten in a 58 adult celiac population. The results of the present collaborative study pointed out differences in calorie, macronutrient, fiber, sodium, salt and cholesterol content between GF rendered and gluten-containing foodstuffs. Thus, calorie and nutrient intake in a GF diet is different when compared to its equivalent diet with gluten. Following a diet based on GF products could suppose a nutritional imbalance for celiac patients as well as for non-celiacs who follow a diet that includes many GF rendered foodstuffs.

Keywords Celiac disease · Gluten-free diet · Market · Gluten · Products

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Abbreviations
CD Celiac disease
GF Gluten-free

Introduction

Celiac disease is an immune-mediated systemic disorder triggered by ingestion of gluten or related prolamines in genetically susceptible individuals. The presentation and clinical manifestations of CD have changed over the time. In recent years, gastrointestinal symptoms, such as diarrhea or malabsorption, have progressively decreased as the mode of CD onset among both adults and children, whereas nonspecific signs and atypical manifestations have increased [1]. Some authors indicated that the global prevalence ranges from 1 to 2 % [2]. Nevertheless, population-based screening studies in children have exposed a CD prevalence ranging from 0.3 to 3 % [3].

The only treatment for CD is a lifetime total elimination of gluten from the diet, thus achieving complete remission of symptoms. Ingestion of small amounts of gluten can cause major disruptions in gluten intolerants. For this reason, in the absence of effective alternatives, it is essential to follow a gluten-free (GF) diet.

In recent years there has been an increasing interest on GF foodstuffs. As it was recently pointed out by the report of Markets and Markets research service, the GF products market is experiencing a double-digit growth [4]. The global GF product market is projected to reach a value of $6,206.2 million, growing at a compounded annual growth rate of 10.2 % by 2018 [4]. This means that GF product market represents one of the most prosperous markets in the field of food and beverages in the near future.

Historically, counselling for celiac disease has focused on the absence of gluten in GF foods, however the nutritional quality of GF foodstuffs is an important aspect to consider [5].

Firstly, publications have shown that 20–38 % of celiac patients [6, 7] have some nutritional deficiencies such as calorie/protein [8], dietary fiber [9–12] mineral [11, 13] or vitamin [11, 14] deficiency. This situation is partly justified by the fact that the specific products for this population are rarely fortified, unlike general use products. In addition, some studies underline an excessive amount of saturated fats in GF products content [9, 15].

Furthermore, it is important to note that not only people with gluten intolerance consume these products. The rest of the population also has access to them. In fact, basing on incorrect information, people not suffering from CD may either think that these products are healthier than conventional products, or feel they are helpful for weight loss programmes. For these reasons the consumption of GF foodstuffs has risen exponentially in recent years [16].

In this scenario, the aim of the present work was to compare the nutritional composition of those GF products most commonly consumed in Spain with their gluten-containing equivalents, in order to evaluate if there are differences in food composition. Moreover, we wanted to make a comparison between the diet including GF products and the same diet including equivalent foodstuffs with gluten.

Materials and Methods

Comparison Between Nutritional Composition of GF Rendered Foodstuffs and Equivalent Products with Gluten

Information from the nutritional panels of 206 specific GF rendered foodstuffs of representative Spanish GF brands, as well as that of 289 equivalent products containing gluten, were sampled from different groceries in the Basque Country's provinces (Araba, Gipuzkoa and Bizkaia) during the years 2012 and 2013. A total number of 17 GF rendered brands and 16 brands of equivalent products containing gluten were used in the study. This information was included in a spreadsheet, and we analyzed the variability in nutrient composition of GF rendered foods in relation with gluten-containing ones. Only nutrients available on labels were analyzed: total carbohydrates, simple carbohydrates, proteins, total lipids, saturated lipids, fiber, sodium, salt and cholesterol. Differences in micronutrients contents, such as vitamins and minerals were not studied. Using the reference of Gibert et al. [17] products were classified into different groups (cookies, bakery-patisserie, pasta, breakfast cereals, cereal bars, baby formulas, flour, dough/pastry/pizza, cakes and breads). It is important to point out that based on their different organoleptic and conservation properties, four new groups were included in the present study compared with Gibert et al. [17]. A more detailed description of the foodstuffs analyzed is described in Electronic Supplementary Material.

Subjects

Fifty eight celiac adults (46 females and 12 males, age between 18 and 75 years old) from the Basque Country took part in the study. Exclusion criteria included history of cardiovascular disease or diabetes, pregnancy, thyroid disorders, total cholesterol levels >300 mg/dL, levels of triglyceride >300 mg/dL and blood pressure level >140/90 mm Hg. All participants received oral and written information about the nature and purpose of the survey, and all of them gave written consent for involvement in the study. This study was approved by the Ethical Committee in University of Basque Country (CEISH/76/2011).

Dietary Assessment

Three days of food records (two weekdays and one weekend day) were selected for each patient. A 24-h food recall and a food frequency questionnaire (FFQ) were filled in by each celiac patient. Food portions and amounts were determined using photographs and nutrient intake was calculated by a computerized nutrition program system (AyS, Software, Tandem Innova, Inc.).

Comparison Between a Diet with GF Rendered Foods and a Simulated Diet with Equivalent Products with Gluten

A simulation of a gluten containing diet was performed by duplicating recorded GF diets and replacing GF foodstuffs by their equivalent foods containing gluten. Then a nutritional comparison between both diets (GF and gluten containing diets) was carried out.

Statistical Analysis

Statistical analyses were performed by using the IBM SPSS statistical program 19 (IBM Inc., Armonk, NY, USA). The results for continuous variables are given as the arithmetic mean ± SD and the range. Statistical analyses were performed with Student's t test. P values <0.05 were accepted as significant. The *post-hoc* compute achieve power was calculated by the difference between two independent means with G Power 3.1.7 program [18].

Results and Discussion

Nutritional Composition of GF Products Versus Equivalent Foods with Gluten

The results of the present collaborative study indicate the existence of significant differences between the composition of GF rendered foodstuffs and gluten-containing products (Tables 1 and 2).

Data obtained in the present investigation confirm the theory that there is a great nutritional content variability between GF rendered foods and their gluten-containing counterparts in the bread category. These differences are in accordance with Segura and Rosell [5], who observed that GF breads had great divergences in fat and protein composition, and consequently their contribution to the recommended daily protein intake was very low. In our research GF breads had almost a third less protein than their equivalent with gluten ($P<0.001$). Besides, GF breads provided twice as much fat ($P=0.001$), which was mainly saturated fat. This fact could be explained by the formulations of GF breads [19], whose ingredients provide less protein but more fat (Table 1). Moreover, in the case of lipid fraction, this includes saturated fatty acid and cholesterol, which may indicate the frequent use of raw animal substances.

Our research is the first study, to date, that extends nutritional differences to other foodstuffs groups such as pasta, flour dough/pastry/pizza or bakery group (Tables 1 and 2). An explanation for the differences observed between the nutritional composition of GF and gluten containing foodstuffs could be based on the list of ingredients used, as was postulated in the introduction section of Segura and Rosell [5]. Commonly starches, hydrocolloids, gums, enzymes or other protein sources (soybean, amaranth, quinoa, etc.) are used to produce GF products, in order to improve the viscoelasticity and some other nutritional aspects of GF rendered foodstuffs [20, 21].

In the present research, the group of pasta had a similar nutrient profile than breads, presenting lower protein content and a greater amount of total and saturated fat than their equivalents with gluten (Table 1). Additionally, this group of GF products had more sodium and less fiber declared on their labels, as it was the case for cereal bars or flour (Table 2). As far as the GF rendered bakery group is concerned, the foodstuffs analyzed in this group had lower energy content than their counterparts with gluten, due to their low total carbohydrates and protein content (Table 1). Notwithstanding, they had higher sodium and cholesterol content than equivalents products with gluten (Table 2).

It must be pointed out that there were differences among brands, and thus, these findings, as well as those postulated by Jasthi et al. [22], should lead the database developers to include specific brands of GF products in their food and nutrient database.

Table 1 Energy, protein, total carbohydrates, simple carbohydrates, total lipids and saturated lipids label content per 100 g of products in gluten containing and gluten-free rendered foodstuffs classified by food groups

Content	Foodstuff	Flour			Cereal bars			Pasta			Breads			Dough/Pastry/Pizza			Bakery		
		Mean	SD	*P*	Mean	SD	*P*	Mean	SD	*P*	Mean	SD	*P*	Mean	SD	*P*	Mean	SD	*P*
Energy (kJ)	With gluten	1,428	57.09	*0.02*	1,739	118	0.05	1,357	269	0.53	1,222	296	*0.03*	1,243	272	*0.00*	1,787	246	*0.01*
	Gluten–free	1,493	38.4		1,550	114		1,298	374		1,385	320		1,591	415		1,658	305	
Protein (g)	With gluten	9.77	1.69	*<0.00*	6.86	1.68	0.30	11.4	1.86	*0.02*	10.0	2.16	*<0.00*	2.00	1.71	*<0.00*	6.38	1.47	*0.00*
	Gluten–free	1.43	0.79		5.67	1.15		9.00	3.42		3.47	2.83		6.30	1.15		3.79	2.16	
Total carbohydrates (g)	With gluten	71.3	3.94	*<0.00*	64.0	8.79	0.14	64.9	11.90	0.951	55.8	12.3	0.08	59.5	18.7	0.31	53.0	8,72	*0.04*
	Gluten–free	82.7	4.27		55.3	2.31		65.1	18.56		61.2	14.8		54.1	18.1		49.3	9.95	
Simple carbohydrates (g)	With gluten	4.87	8.15	0.60	30.0	5.26	0.15	2.89	1.56	*0.00*	4.77	3.48	0.92	12.9	14.1	0.12	22.8	11.2	0.11
	Gluten–free	3.00	4.65		25.0	0.00		0.93	2.16		4.86	3.32		21.6	22.2		18.9	10.1	
Total lipids (g)	With gluten	1.61	0.65	0.66	13.1	5.40	0.39	2.16	0.69	*0.03*	3.86	2.15	*0.00*	4.83	5.08	*<0.00*	21.6	7.31	0.24
	Gluten–free	1.43	1.27		9.67	5.77		4.47	3.56		7.42	7.71		15.3	12.7		19.9	7.97	
Saturated lipids (g)	With gluten	0.08	0.28	0.33	5.43	2.57	0.72	0.35	0.49	*0.02*	0.85	0.66	*<0.00*	1.50	2.13	*<0.00*	8.67	5.61	0.05
	Gluten–free	0.28	0.49		6.00	.00		1.71	1.86		3.03	3.55		5.80	5.08		6.57	4.65	

Values are expressed as means and standard deviations (SD)

Italic style was used for significant differences *P* values < 0.05

Table 2 Fiber, sodium, salt and cholesterol label content per 100 g of product in gluten containing and gluten-free rendered foodstuffs classified by food groups

Content	Foodstuff	Baby formulas			Flour			Cereal bars			Pasta			Cookies			Dough/Pastry/Pizza			Bakery		
		Mean	SD	*P*	Mean	SD	*P*	Mean	SD	*P*	Mean	SD	*P*	Mean	SD	*P*	Mean	SD	*P*	Mean	SD	*P*
Fiber (g)	With gluten	3.82	1.19	*0.02*	5.23	3.39	0.11	6.57	5.29	0.03	4.38	1.98	0.00	3.11	2.06	0.56	2.18	1.88	0.35	3.06	2.41	0.83
	Gluten-free	2.32	2.14		2.86	1.86		15.3	2.89		1.93	1.33		2.84	1.62		3.03	3.51		3.18	3.13	
Sodium (mg)	With gluten	17.5	15.6		0.00	0.00	*0.04*	0.00	0.00	*0.03*	56.4	103	*0.01*	327	168	*0.00*	342	307	*0.01*	248	112	*0.01*
	Gluten-free	–	–		525	530		177	63.5		283	298		186	157		145	229		414	362	
Salt (mg)	With gluten	43.9	38.8		0.00	0.00	*0.04*	0.50	0.71	*0.00*	141	257	*0.01*	817	421	*0.00*	856	767	*0.01*	608	292	*0.00*
	Gluten-free	–	–		1,312	1,324		350	0.00		707	745		466	392		362	573		1,035	904	
Cholesterol (mg)	With gluten	–	–		–	–		1.33	1.53		31.7	37.8	*0.01*	37.0	27.3	0.64	121	122	0.47	120	61.8	*0.00*
	Gluten-free	–	–		–	–		–	–		2.00	0.00		27.5	35.4		26.0	27.4		43.6	41.0	

Values are expressed as means and standard deviations (SD)

Italic style was used for significant differences *P* values < 0.05

One limitation of the present study was the sample size. Although 206 specific GF were used for the study, when the products were divided in 10 groups the subsample size for some groups (cereal bars and cakes) was really small. Nevertheless, in the case of fiber content for cereal bar and cake groups, statistical powers (1-β) of 74 and 48 % were obtained, respectively.

Comparison Between a Diet with GF Rendered Foods and a Diet with Equivalent Products with Gluten

A GF diet is commonly recognized as the only treatment for celiac disease. But it also has been investigated, although little evidence exists as a potential treatment for other medical conditions, including dermatitis herpetiformis, irritable bowel syndrome, neurologic disorders, rheumatoid arthritis, and diabetes mellitus [23]. Furthermore, in recent years following a GF diet has been popularised among people who want to lose weight. One clear example of the boom in this kind of diet is that the global GF product market is projected to become hugely valuable in the near future [16].

The GF diet, compulsory for celiacs and gluten-sensitive individuals in order to avoid the appearance of symptoms related to the diseases, conditions the type of food groups that people have to consume. It has been identified as a cause of failure to reach a balanced diet [24–26]. Along these lines, it has been observed by Rea et al. [27] that following a GF diet resulted in an excess in energy, animal protein, and lipid intake, thus being partially responsible for the high percentage of overweight celiac children.

Taking this idea into consideration and in order to highlight the deficits or excesses that could lead the following of GF diet, a comparison between the diet that includes GF products and the same diet with gluten foodstuffs (a simulated diet) was carried out.

In the present study, following a GF diet in women resulted in a lower dietary protein intake (Table 3). This is in accordance with Kinsey et al. [6] who observed that protein intake in men following a GF diet was higher, but lower in women, when compared to the protein intake of the general population. Considering that gluten is the primary protein of wheat flour, its removal from the foodstuff leads to a reduced protein content. Therefore, GF foodstuffs from groups such as breads and pasta have less protein content, which results in a lower protein intake. Furthermore, it could be hypothesized that the differences observed between men and women were because men compensated for the lack of protein content of GF foodstuffs with other protein sources (fish, meat, eggs, etc.) and women did not.

Information obtained in the present study also suggested that a GF diet was related to a higher intake of fat in women (apparently saturated fat) and a lower dietary fiber in all patients (Table 3). This is in accordance with the data

Table 3 Macronutrient (carbohydrates, proteins and lipids) percentage from the energy intake and fiber intake (g/d) for males and females following a diet with gluten-free rendered foods and a diet with equivalent products with gluten

		Females			Males		
Content		Mean	SD	*P*	Mean	SD	*P*
Carbohydrates % from the total energy intake	With gluten	42.3	6.6	0.26	39.7	8.7	0.32
	Gluten–free	42.0	6.6		39.0	8.7	
Lipids% from the total energy intake	With gluten	39.9	5.8	*<0.00*	41.7	6,5	0.30
	Gluten–free	40.9	5.6		42.3	6.6	
Proteins% from the total energy intake	With gluten	17.8	2.8	*<0.00*	18.7	3.6	0.80
	Gluten–free	17.2	3.0		18.7	3.6	
Fiber intake (g/d)	With gluten	17.6	5.4	*0.01*	23.7	9.0	*0.03*
	Gluten–free	16.1	6.7		20.9	8.9	

Values are expressed as means and standard deviations (SD)

Italic style was used for significant differences *P* values < 0.05

published by other authors [6, 9, 25, 26]. Whereas a higher fat intake could be due to the ingredients used for an optimization of the texture and/or palatability of GF foods, the lower fiber intake could be due to qualitative or quantitative differences in bread and cereals of a GF diet [26].

Several studies present in the literature have described excessive fat and protein intake, and reduced intake of carbohydrates and fiber [22, 25] in GF diets, which together are determining factors in cardiovascular disease risk. Taking these data as well as those from the present study into account, we suggest that following a GF diet could lead to a risk of cardiovascular disease for celiac patients. This fact is attributable to the nutritional composition of specific foods without gluten [20]. Thus, it may be suggested that the imbalance in nutrient intake of celiac patients is conditioned by the GF foodstuffs and not by the other foods present in the diet. Otherwise there would be no differences between the GF diet and the virtual simulated diet with equivalent gluten-containing products. However, it must be remembered that this study is a direct comparison between the nutrient intake of celiac patients and what would be their virtual nutrient intake if gluten-free products were replaced by gluten products. For a better comparison, the food intake of celiac and non-celiac patients might be contrasted in future studies.

This study has some limitations. The difference obtained in regard to the comparison between diet with GF foods and gluten counterparts were in all cases more pronounced in women than in men. This difference is given by the sample size used. There are several reasons that can explain this fact. On the one hand, it was a study in celiac volunteers, with a known prevalence disease ratio of 2:1 (female:male) [28]. In fact, other GF diet researches had a similar participant number and distribution [9]. Besides, we must not forget that it is a nutritional study. In this type of studies, women traditionally tend to show a greater interest and participate more [29].

However, an important aspect to consider is the statistical power of the results. So, for example, in the case of fiber in both men and women, there were significant differences between the diet containing GF foods and its gluten-containing counterpart, but the statistical power of the results was very different. A statistical power (1-β) of 97 % for females and 44 % for males was obtained. Taking this into consideration we can assume that females' results are more robust than males' are.

In summary, considering this information as a whole, more studies are needed in order to improve both the organoleptic quality and the nutritional properties of GF products. Moreover, it can be concluded that there are marked differences between following a diet with GF products and a diet with gluten-containing products. This may represent a nutritional concern for celiac patients, but it may also be a problem for non-celiacs who consume many GF rendered foods, such as people trying to lose weight and/or who consider that this kind of diet is even healthier.

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Conflict of Interest The authors declare that they have no conflict of interest.

Studies with human subjects This study was approved by the Ethical Committee in University of Basque Country (CEISH/76/2011). All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008. Informed consent was obtained from all patients for being included in the study.

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