e-ISSN:2687-2145

BANDIRMA ONYEDİ EYLÜL ÜNİVERSİTESİ SAĞLIK BİLİMLERİ VE ARAŞTIRMALARI DERGİSİ
BANU Journal of Health Science and Research

DOI: 10.46413/boneyusbad.1670137 ***Özgün Araştırma / Original Research***

Antioxidant Consumption in Adults With Celiac Disease: A Cross-Sectional Evaluation

Yetişkin Çölyak Hastalarında Antioksidan Alımı: Kesitsel Bir Değerlendirme

Esma OGUZ [1] **Fatma Esra GÜNEŞ**[2]

[1] *Res. Asst., Faculty of Health Sciences Department of Nutrition and Dietetics, Kırklareli University, Kırklareli, Türkiye*

[2] *Prof. Dr., Faculty of Health Sciences Department of Nutrition and Dietetics, İstanbul Medeniyet University, İstanbul, Türkiye*

Sorumlu yazar / Corresponding author

Esma OGUZ
esmaoguz34@gmail.com

Geliş tarihi / Date of receipt: *04.04.2025*

Kabul tarihi / Date of acceptance: *25.09.2025*

Atıf / Citation: Oguz, E., Güneş, F. E. (2025). Antioxidant consumption in adults with celiac disease: a cross-sectional evaluation. *BANÜ Sağlık Bilimleri ve Araştırmaları Dergisi, 7*(3), 884-893. doi: 10.46413/ boneyusbad.1670137

ABSTRACT

Aim: *This study aimed to evaluate the antioxidant intake of adult celiac patients and healthy individuals based on their dietary records and responses to an antioxidant consumption frequency questionnaire.*

Material and Method: *This cross-sectional descriptive study was conducted between February and June 2021 at the Association of Living with Celiac in Türkiye. A total of 32 adult celiac patients and 33 healthy individuals were included. Dietary intake data were collected using three-day food records and a Food Frequency Questionnaire (FFQ). Total Antioxidant Status (TAS) was calculated from dietary records (dietary TAS) and FFQ responses (FFQ TAS) based on the antioxidant content of reported foods.*

Results: *The proportion of energy derived from fat was significantly higher in celiac patients (p=0.001), whereas carbohydrate and fiber intakes were higher in healthy controls. Intakes of thiamine, pyridoxine, folate, potassium, magnesium, phosphorus, and vitamin C were significantly lower in celiac patients, while no significant differences were observed for vitamins A and E, selenium, or zinc. Both dietary TAS and FFQ-derived TAS values were significantly higher in healthy individuals compared to celiac patients (dietary TAS: p=0.031; FFQ TAS: p=0.027). A positive correlation was observed between dietary TAS and zinc intake in celiac patients, and between dietary TAS and vitamin A intake in healthy controls.*

Conclusion: *Celiac patients had significantly lower antioxidant intake compared to healthy individuals. These findings underscore the need for further research to assess antioxidant status and its long-term health implications in this population.*

Keywords*: Celiac disease, Antioxidants, Gluten-free diet, Food frequency questionnaire*

ÖZET

Amaç: *Bu çalışma, yetişkin çölyak hastalarının ve sağlıklı bireylerin antioksidan alımını, diyet kayıtları ve antioksidan tüketim sıklığı anketine yanıtları temel alarak değerlendirmeyi amaçlamıştır.*

Gereç ve Yöntem*: Kesitsel tanımlayıcı nitelikteki bu çalışma, Şubat–Haziran 2021 tarihleri arasında Türkiye'de Çölyakla Yaşam Derneği'nde yürütülmüştür. Çalışmaya 32 yetişkin çölyak hastası ve 33 sağlıklı birey dahil edilmiştir. Besin tüketim verileri, üç günlük besin kayıtları ve FFQ aracılığıyla elde edilmiştir. Toplam Antioksidan Durumu (TAS), bildirilen besinlerin antioksidan içerikleri esas alınarak diyet kayıtları (diyet TAS) ve FFQ yanıtları (FFQ TAS) üzerinden hesaplanmıştır.*

Bulgular: *Çölyak hastalarının enerji alımlarında yağdan gelen oran anlamlı düzeyde yüksek bulunurken (p=0.001), sağlıklı bireylerde karbonhidrat ve posa alımları daha yüksek saptanmıştır. Çölyak hastalarının tiyamin, pridoksin, folat, potasyum, magnezyum, fosfor ve C vitamini alımları anlamlı olarak düşük bulunmuş, A vitamini, E vitamini, selenyum ve çinko açısından ise gruplar arasında farklılık gözlenmemiştir. Hem diyet TAS hem de FFQ-TAS değerleri sağlıklı bireylerde çölyak hastalarına kıyasla anlamlı düzeyde yüksek bulunmuştur (diyet TAS: p=0.031; FFQ TAS: p=0.027). Çölyak grubunda diyet TAS ile çinko alımı, kontrol grubunda ise diyet TAS ile A vitamini alımı arasında pozitif ilişki saptanmıştır.*

Sonuç: *Çölyak hastalarının, sağlıklı bireylere kıyasla antioksidan alımının anlamlı düzeyde daha düşük olduğu saptanmıştır. Bu popülasyonda antioksidan durumunun ve uzun dönem sağlık sonuçlarının araştırılması için ileri çalışmalara ihtiyaç vardır.*

Anahtar kelimeler: *Çölyak hastalığı, Antioksidanlar, Glutensiz diyet, Gıda Sıklığı Anketi*

This work is licensed under a Creative Commons Attribution-Non Commercial 4.0 International License.

INTRODUCTION

Celiac disease (CD) is an autoimmune disorder characterized by specific serological and histological findings triggered by gluten consumption. Gluten-containing foods such as wheat, barley, rye, and occasionally oats provoke an immune-mediated response in genetically predisposed individuals. CD is a growing public health concern, with an increasing prevalence of approximately 7.5% per year across diverse populations (Fasano & Catassi, 2012; King et al., 2020). The disease's pathogenesis is influenced by genetic and environmental factors (Serena, Lima, & Fasano, 2019).

The clinical presentation of CD varies significantly, encompassing both gastrointestinal and extraintestinal symptoms. Classical gastrointestinal manifestations include abdominal pain, diarrhea, vomiting, and bloating (Rivera, Assiri & Guandalini, 2013). However, adults with CD often experience systemic symptoms such as unintentional weight loss, osteoporosis, anemia, dental enamel defects, and skin conditions—primarily due to deficiencies in essential vitamins and minerals (Rivera, Assiri & Guandalini, 2013; Koehler, Wieser & Konitzer, 2014). Consistent with these clinical manifestations, recent studies have reported lower intakes of fiber, B-vitamins, iron, calcium, vitamin D, and magnesium in patients with CD (Suárez-González, Bousoño-García, Jiménez-Treviño, & Díaz-Martín, 2021, Bianchi et al., 2024).

Oxidative stress is a key contributor to various diseases, including diabetes, cardiovascular disorders, atherosclerosis, and cancer. It arises when reactive oxygen species (ROS) exceed the body's antioxidant defenses, leading to cellular damage (Pizzino et al., 2017). Inflammation, exacerbated by increased ROS levels and diminished antioxidant capacity, plays a significant role in CD pathogenesis. Antioxidants, both enzymatic and non-enzymatic, mitigate oxidative damage (Moretti et al., 2018).

Primary dietary antioxidants include phenolic compounds, tocopherols, ascorbic acid, and carotenoids. Endogenous antioxidants such as uric acid, hemoglobin, transferrin, and glutathione also contribute to oxidative balance (Janciauskiene, 2020). Rich dietary sources of antioxidants include oilseeds, cereals, legumes, fresh and dried fruits, vegetables, and nuts (Amarowicz, & Pegg, 2019; Hegazy, El-Sayed, Ibrahim, & Abdel-Azeem, 2019).

A gluten-free diet (GFD) requires the complete exclusion of gluten, a protein complex present in food products from wheat, rye, barley, oats, spelt, kamut or their hybridized strains (Melini, & Melini, 2019). Currently, the only effective treatment for CD is lifelong adherence to a strict GFD (Mazzola et al., 2024; Noori et al., 2024). However, eliminating gluten-containing grains—key sources of dietary antioxidants—raises concerns about potential deficiencies (Ghunaim et al., 2024). Given the crucial role of dietary quality in CD management and the limited research on antioxidant intake among adult celiac patients, this study aimed to evaluate their antioxidant consumption patterns and compare them with healthy individuals.

MATERIALS AND METHODS

Study Aim and Type

This is a cross-sectional descriptive study.

Study Population and Sample

This study was conducted at the Association of Living with Celiac between February and June 2021. Participants were recruited through the Association's announcements and completed an online questionnaire via Google Forms. Written informed consent was obtained from all participants prior to data collection. The study population included adults aged 18–64 years. Sample size calculations were performed using G*Power 3.1 software. Based on a significance level of $\alpha = 0.05$, a power of $\beta = 0.80$, and an effect size of 0.50 (Cohen's d), a minimum of 30 participants per group was required. The effect size was determined based on previous studies investigating antioxidant intake in celiac patients (Mahmud et al., 2015).

Inclusion criteria were being aged between 18 and 64 years, having a physician-confirmed diagnosis of celiac disease with adherence to a gluten-free diet for at least one year for the celiac group, and absence of celiac disease with adherence to a regular diet for the control group. Exclusion criteria included the presence of diabetes mellitus, cardiovascular disease, cancer, or any other metabolic or chronic condition affecting food intake; adherence to a gluten-free diet in the healthy control group; pregnancy or lactation; and incomplete or unreliable food records. During recruitment, 42 celiac patients and 40 healthy individuals initially responded. After applying the exclusion criteria, 10 celiac patients (due to incomplete records or comorbidities) and 7

healthy individuals (incomplete records) were excluded. Thus, the final analysis included 32 celiac patients and 33 healthy individuals. The control group was selected from healthy volunteers from the community (friends, relatives, and acquaintances of patients).

Data Collection Tools

Demographic Information Form: Participants' age, gender, education level, and other sociodemographic characteristics were collected using a structured demographic information form developed by the research (Satia, Watters & Galanko, 2009).

Food Frequency Questionnaire (FFQ): Dietary intake data were assessed using a semi-quantitative Food Frequency Questionnaire (FFQ) developed by Satia, Watters & Galanko (2009), which includes 82 food items rich in antioxidants. The Turkish validity and reliability of this tool were established by Öztag & Güneş (2022). The FFQ records the frequency of consumption (e.g., never, once per month, 1–2 times per week, once per day) and portion size (small, medium, or large) for each item. Antioxidant-rich foods such as fruits and vegetables, commonly grown and consumed in Türkiye, are particularly emphasized. To ensure accurate portion estimation, the Food Atlas for Türkiye (Güneş & Imeryüz, 2008) was used. Participants were informed in detail about how to complete both the FFQ and the food records. A short instructional text was included at the beginning of the questionnaire, and portion-size examples were provided with pictures from the Food Atlas. Participants were also contacted by researchers when clarification was required.

Food Records: Participants were also asked to complete three-day food records, including two weekdays and one weekend day, to provide a more detailed picture of actual intake. Prior to data collection, participants were given clear written instructions, including examples of portion sizes and household measures, and informed that the aim was to capture typical intake patterns. These records were analyzed to complement the FFQ and assess daily variations in antioxidant consumption.

BeBiS Software and TAS Database: The antioxidant content of consumed foods was evaluated using the BeBiS software (Ebispro for Windows, Stuttgart, Germany; Turkish Version, BeBiS 8.2) and the TAS database developed by Carlsen et al. (2010). This database includes total antioxidant status (TAS) values for over 3100 foods from various countries, including Türkiye, and expresses the values per 100 grams of each food. Data obtained from both the FFQ and the three-day food records were entered into the software. The dietary antioxidant intake was then calculated by multiplying the consumed amount of each food item by its corresponding TAS value from the Carlsen database.

Ethical Consideration

Ethics committee approval for this study was obtained from a university's clinical research ethics committee (Date: 28.01.2021 and, Approvel Number:8), and the study was conducted in accordance with the principles of the Declaration of Helsinki.

Data Analysis

All analyses were conducted using SPSS 20.0 (SPSS Inc., Chicago, IL, USA). The Kolmogorov–Smirnov test was used to assess normality. Descriptive statistics (mean, standard deviation, median, 25th and 75th percentiles) were calculated. Between-group comparisons were performed using the independent samples t-test or Mann–Whitney U test, as appropriate. Relationships between FFQ TAS and dietary TAS were analyzed using Spearman's correlation coefficient. Statistical significance was accepted at $p < 0.05$.

RESULTS

Table 1 presents the demographic characteristics of participants. The gender distribution was comparable between groups, with a predominance of female participants (84.4% among celiac patients, 90.9% among healthy individuals). Mean age was 31.7 ± 8.0 years for celiac patients and 29.7 ± 7.0 years for healthy individuals. No significant differences were observed in gender, age, marital status, or occupation.

Table 2 summarizes the use of multivitamins, vitamins, and minerals among participants. While no significant difference was observed in multivitamin use between celiac patients and healthy controls, the use of vitamins and minerals was significantly higher among celiac patients ($p = 0.030$).

Table 1. Demographic Characteristics of Celiac Patients and Healthy Individuals

	Celiac patients (*n*=32)		Healthy individuals (*n*=33)		*p*-value
	Mean ± SD		Mean ± SD		
Age (year)	31.7 ± 8.0		29.7 ± 7.0		0. 536
Gender	**n**	**%**	**n**	**%**	
Male	5	15.6	3	9.0	0.475
Woman	27	84.4	30	91.0	
Marital Status					
Married	15	45.2	9	27.3	0.168
Single	17	54.8	24	72.7	
Occupation					
Unemployed	8	25	4	12.0	0.284
Private sector	8	25	7	21.0	
Public sector	7	21.9	8	24.0	
Employee	3	9.4	1	3.0	
Student	6	18.8	13	40.0	

Calculated using Chi-square test. Calculated using Mann Whitney U (25.0–75.0 percentiles) test

Table 2. Use of Multivitamins, Vitamins, and Minerals among Celiac Patients and Healthy Individuals

	Celiac patients (*n*=32)		Healthy individuals (*n*=33)		*p*-value
Multivitamin Use	**n**	**%**	**n**	**%**	
Not using	25	78.1	30	90.9	0.295
Once per week	3	9.4	2	6.1	
At least once a week	4	12.5	1	3.0	
Use of Vitamins and Minerals					
Not using	19	59.4	29	87.9	0.030*
Once per week	5	15.6	1	3.0	
At least once a week	8	25.0	3	9.1	

Chi-square test, *$p < 0.05$

The average daily energy and nutrient intakes of the participants are presented in Table 3. No significant differences were observed between celiac patients and healthy controls in energy, protein, or fat intake. However, the percentage of energy from fat was significantly higher in celiac

patients (p=0.001), while both carbohydrate intake and the percentage of energy from carbohydrates were significantly higher in healthy individuals (p=0.004). Fiber intake was also greater in healthy participants compared to celiac patients (p= 0.000).

Regarding micronutrients, intakes of thiamine, pyridoxine, folate, potassium, magnesium, and phosphorus were significantly higher in healthy individuals. Vitamin C intake was also greater in healthy controls (p=0.005). In contrast, no significant differences were found in vitamin A, vitamin E, selenium, or zinc intakes between the groups.

Table 3. Comparison of Daily Energy and Nutrient Intakes Between Celiac Patients and Healthy Individuals

Energy and Nutrient Intakes	Celiac patients (*n*=32)	Healthy individuals (*n*=33)	*p*-value
Energy (kcal/day)	868.26 (126.24-2375.60)	976.78 (620.25-2446.75)	0.72[b]
Protein (g/day)	39.63 ± 15.82	46.93 ± 16.93	0.77[a]
Protein (%of energy)	17.50 (10.00-26.00)	19.00 (10.00-24.00)	3.84[b]
Fat (g/day)	45.94 (7.86-107.93)	36.44 (20.06-122.57)	0.145[b]
Fat (%of energy)	44.34 ± 12.70	35.39 ± 5.59	**0.001**[a]
Carbohydrate (g/day)	82.54 (1.16-304.21)	116.10 (63.30-272.74)	**0.004**[b]
Carbohydrate (%of energy)	38.21 ± 13.62	46.36 ± 6.28	**0.004**[a]
Fiber (g/day)	10.58 ± 5.28	15.71 ± 5.90	**0.000**[a]
Thiamine (mg)	0.45 (0.05-1.19)	0.61 (0.38-1.74)	**0.005**[b]
Pyridoxine (mg)	0.76 (0.04-1.68)	0.82 (0.55-2.38)	**0.018**[b]
Vitamin A (µg)	724.03 (2.93-6980.61)	817.55(340.61-5280.94)	0.865[b]
Vitamin C (mg)	64.65 ± 42.54	93.58 ± 37.2	**0.005**[a]
Vitamin E (mg)	8.71 (1.42-28.12)	7.90 (2.43-80.03)	0.420[b]
Vitamin D (µg)	1.70 (.00-67.40)	2.72 (0.65-18.69)	**0.027**[b]
Folate (µg)	191.17 ± 81.38	234.05 ± 62.75	**0.030**[a]
Potassium (mg)	1409.76 (119.73-3249.97)	1711.05 (1035.23-3539.06)	**0.016**[b]
Magnesium (mg)	145.14 ± 60.21	190.53 ± 69.76	**0.007**[a]
Phosphorus (mg)	639.95 (67.60-1487.59)	797.85 (466.29-1895.85)	**0.011**[b]
Selenium (µg)	11.88 ± 9.28	13.21 ± 7.89	0.537[a]
Zinc (mg)	6.45 ± 2.82	6.63 ± 2.68	0.796[a]

Data are presented as mean ± standard deviation for normally distributed variables and median (minimum–maximum) for non-normally distributed variables. a: Independent samples t-test and b: Mann–Whitney U test were used for group comparisons. $p < 0.05$ was considered statistically significant.

Table 4 compares total antioxidant consumption between the two groups. Healthy individuals had significantly higher dietary TAS and FFQ TAS levels compared to celiac patients (p=0.045).

Table 4. FFQ TAS and Dietary TAS Levels in Celiac Patients and Healthy Individuals

	Celiac patients (*n*=32)	**Healthy individuals (*n*=33)**	***p*-value**
	Median (Min-max)	**Median (Min-max)**	
Dietary TAS (mmol/day) 0.045*	1.80 (0.03-16.27)	1.83 (0.21-6.55)	
FFQ TAS (mmol/day) 0.001*	7.88 (1.27-25.53)	8.72 (0.99-32.76)	

Mann Whitney U (25.0–75.0 percentiles) test, *$p < 0.05$ Abbreviation:TAS, Total Antioxidant Status; FFQ, Food Frequency Questionnaire

Table 5 presents correlations between TAS values and antioxidant intake. A positive correlation was found between zinc intake and FFQ TAS in celiac patients (p=0.021) and between vitamin A intake and dietary TAS in healthy individuals (p=0.032).

Table 5. Correlation Between Dietary TAS and FFQ TAS in Celiac Patients and Healthy Individuals

		Celiac patients (*n*=32)		**Healthy individuals (*n*=33)**	
		Dietary TAS	**FFQ TAS**	**Dietary TAS**	**FFQ TAS**
A Vitamin (mcg/day)	**r**	0.260	0.144	0.374	-0.202
	p	0.151	0.430	0.032*	0.260
C Vitamin (mg/day)	**r**	0.245	0.078	0.234	-0.027
	p	0.177	0.672	0.190	0.883
E Vitamin (mg/day)	**r**	0.059	0.192	0.307	-0.073
	p	0.747	0.291	0.082	0.686
Lycopene (mcg/day)	**r**	0.107	-0.146	0.204	0.278
	p	0.560	0.426	0.254	0.117
Lutein+zexanthin (mcg/day)	**r**	-0.111	-0.137	0.164	0.052
	p	0.546	0.455	0.360	0.773
Carotone (mg/day)	**r**	0.236	0.229	-0.307	-0.177
	p	0.193	0.208	0.082	0.326
Selenium (mcg/day)	**r**	-0.215	-0.032	0.151	-0.025
	p	0.237	0.861	0.400	0.891
	r	0.405	0.085	0.256	0.069

Zinc (mg/day)	***p***	0.021*	0.645	0.151	0.704

Spearman correlation, *$p < 0.05$

DISCUSSION

To date, little attention has been given to the antioxidant intake of adult celiac patients in comparison with healthy individuals. Although the nutritional inadequacies of gluten-free diets have been widely reported, the specific contribution of antioxidants has remained largely unexplored (Cardo, García-Moral & Cebolla, 2021; Bianchi et al., 2024). In this study, dietary TAS and FFQ-derived TAS values were assessed using food consumption records and an antioxidant consumption frequency questionnaire completed by celiac patients and healthy individuals. Previous studies have consistently demonstrated that dietary antioxidant intake can reduce the risk of various diseases (Colarusso et al., 2017; Wang, Teng, Zhang, & Wu, 2024). Notably, the consumption of antioxidant-rich foods has been suggested to mitigate oxidative stress and inflammation in celiac patients, potentially improving their overall health and quality of life (Piazza et al., 2023).

Most studies investigating antioxidant capacity in celiac patients have focused on serum total antioxidant capacity levels, particularly before and after the adoption of a GFD (Piątek-Guziewicz et al. 2017; Moretti et al., 2018). For instance, a previous study reported significantly lower serum TAC levels in individuals with celiac disease compared to healthy controls (Ferretti et al., 2012). Unlike these studies, the current research did not measure plasma TAS levels. Instead, it explored the relationship between questionnaire-derived TAS values and dietary TAS values, providing a novel perspective on antioxidant intake patterns in celiac patients.

Adherence to a lifelong GFD remains the only effective treatment for celiac disease. While a GFD is associated with improved health outcomes, extensive research over the past two decades has highlighted its potential to cause nutritional deficiencies and imbalances (Penagini et al., 2013; Vici, Belli, Biondi & Polzonetti, 2016). Restrictive diets, including GFDs, often lead to inadequate intake of both macronutrients and micronutrients (Rybicka, 2108). Gluten-free products, in particular, have been shown to contain lower levels of key nutrients such as vitamins D, E, and B12, iron, folate, magnesium, potassium, and sodium compared to gluten-containing foods (Vici et al., 2016). However, these deficiencies can generally be mitigated through appropriate supplementation strategies (Deora, Aylward, Sokoro & El-Matary, 2017).

In this study, the percentage of energy from fat was significantly higher in celiac patients, whereas both carbohydrate and fiber intakes were lower compared to healthy individuals. These findings are consistent with previous studies reporting increased fat consumption and reduced intake of complex carbohydrates and dietary fiber among individuals with celiac disease (Ting et al., 2020; Cardo et al., 2021; van Megen et al., 2023). The insufficient fiber intake is of particular concern, as it may contribute to gastrointestinal symptoms, impaired satiety regulation, and altered gut microbiota composition (Cardo et al., 2021).

Celiac patients also showed significantly lower intakes of thiamine, pyridoxine, folate, potassium, magnesium, phosphorus, and vitamin C compared to healthy controls, while no differences were observed for vitamin A, vitamin E, selenium, and zinc. These results are in line with previous reports indicating that adherence to a gluten-free diet may reduce the intake of B vitamins and minerals due to limited consumption of fortified grains and fiber-rich foods (Thompson, Dennis, Higgins, Lee, & Sharrett, 2005; Cardo et al., 2021; van Megen et al., 2023). In particular, the lower vitamin C intake observed in our study aligns with earlier findings (Barone et al., 2016; Unalp-Arida, Liu, & Ruhl, 2022) and may have clinical implications. Inadequate vitamin C could potentially increase the risk of infections and osteoporosis in this population (Habel, Frankenfeld, Gallo, Moshfegh, & Slavin, 2017; Bianchi et al., 2024). Overall, these findings emphasize the importance of tailored dietary counseling to improve the nutritional quality of gluten-free diets and prevent potential micronutrient deficiencies.

The strength of this study lies in its rigorous nutritional assessment, which was conducted by a team of expert dietitians, ensuring the accuracy and reliability of dietary data. However, there are some limitations. First, a biochemical evaluation of total antioxidant levels, such as plasma total antioxidant status, was not performed, which could have provided a more comprehensive understanding of the antioxidant capacity in the

study population. Second, the web-based nature of the study may have affected the completeness and accuracy of dietary records, as online self-reported data are prone to recall bias and reporting errors.

CONCLUSION

This study highlights that celiac patients exhibit lower antioxidant intake than healthy individuals. To the best of our knowledge, this is one of the first studies to evaluate antioxidant intake in adult celiac patients using both dietary records and FFQ-derived TAS values. Given the role of antioxidants in mitigating inflammation and oxidative stress, interventions are needed to optimize gluten-free diets. Strategies should focus on fortifying gluten-free products and increasing the consumption of antioxidant-rich foods, such as quinoa, buckwheat, almond flour, and chickpeas. Addressing these inadequacies may also reduce the risk of comorbidities such as osteoporosis, cardiovascular disease, and impaired immune function in this population. Dietitians play a crucial role in ensuring that gluten-free diets are nutritionally adequate and balanced. Beyond individual counseling, collaboration with the food industry to develop antioxidant-enriched gluten-free products could provide broader public health benefits. Future research should incorporate biochemical evaluations and longitudinal designs to further explore the relationship between dietary antioxidant intake and long-term health outcomes in celiac patients.

Ethics Committe Approval

Ethics committee approval was received for this study from the Marmara University Non-Interventional Clinical Research Ethics Committee (Date: 28.01.2021 and, Approvel Number:8).

Author Contributions

Idea/Concept: E.O., F.E.G.; Design: E.O., F.E.G.; Supervision/Consulting: F.E.G.; Analysis and/or Interpretation: E.O., F.E.G.; Literature Search: E.O., F.E.G.; Writing the Article: E.O.; Critical Review: F.E.G.

Peer-review

Externally peer-reviewed.

Conflict of Interest

The authors have no conflict of interest to declare.

Financial Disclosure

The authors declared that this study has received no financial support.

REFERENCES

Amarowicz, R., & Pegg, R. B. (2019). Natural antioxidants of plant origin. In *Advances in Food and Nutrition Research* (Vol. 90, pp. 1–81). Academic Press. doi:10.1016/bs.afnr.2019.02.011

Barone, M., Della Valle, N., Rosania, R. E. A., Facciorusso, A., Trotta, A., Cantatore, F. P., ... & Francavilla, R. (2016). A comparison of the nutritional status between adult celiac patients on a long-term, strictly gluten-free diet and healthy subjects. *European Journal of Clinical Nutrition, 70*(1), 23–27. doi:10.1038/ejcn.2015.107

Bianchi, P. I., Aronico, N., Santacroce, G., Broglio, G., Lenti, M. V., & Di Sabatino, A. (2024). Nutritional consequences of celiac disease and gluten-free diet. *Gastroenterology Insights, 15*(4), 878–894. doi:10.3390/gastroent15040061

Cardo, A., García-Moral, A., & Cebolla, Á. (2021). Nutritional imbalances in gluten-free diet in celiac disease. *Nutrients, 13*(11), 4008. doi:10.3390/nu13082877

Carlsen, M. H., Halvorsen, B. L., Holte, K., Bøhn, S. K., Dragland, S., Sampson, L., ... Blomhoff, R. (2010). The total antioxidant content of more than 3100 foods, beverages, spices, herbs and supplements used worldwide. *Nutrition Journal, 9*, 1–11. doi:10.1186/1475-2891-9-3

Colarusso, L., Serafini, M., Lagerros, Y. T., Nyren, O., La Vecchia, C., Rossi, M., ... Wolk, A. (2017). Dietary antioxidant capacity and risk for stroke in a prospective cohort study of Swedish men and women. *Nutrition, 33*, 234–239. doi:10.1016/j.nut.2016.07.009

Deora, V., Aylward, N., Sokoro, A., & El-Matary, W. (2017). Serum vitamins and minerals at diagnosis and follow-up in children with celiac disease. *Journal of Pediatric Gastroenterology and Nutrition, 65*(2), 185–189. doi:10.1097/MPG.0000000000001475

Fasano, A., & Catassi, C. (2012). Celiac disease. *New England Journal of Medicine, 367*(25), 2419 2426. doi:10.1056/NEJMcp1113994

Ferretti, G., Bacchetti, T., Saturni, L., Manzella, N., Candelaresi, C., Benedetti, A., ... Dastoli, G. (2012). Lipid peroxidation and paraoxonase-1 activity in celiac disease. *Journal of Lipids, 2012*, 587479. doi:10.1155/2012/587479

Ghunaim, M., Seedi, A., Alnuman, D., Aljohani, S., Aljuhani, N., Almourai, M., ... & Seedi, A. Jr.

(2024). Impact of a gluten-free diet in adults with celiac disease: Nutritional deficiencies and challenges. *Cureus, 16*(12), e74983. doi:10.7759/cureus.74983

Güneş, E., & İmeryüz, N. (2008). *Besin Atlası.* Istanbul: Ada Ofset.

Habel, L., Frankenfeld, C. L., Gallo, S., Moshfegh, A. J., & Slavin, M. (2017). Differences in nutritional intake and bone health among adults with and without celiac disease: Data from the National Health and Nutrition Examination Survey, 2009–2012. *The FASEB Journal, 31*(1 Supplement), 315.6. doi:10.1096/fasebj.31.1_supplement.315.6

Hegazy, A. M., El-Sayed, E. M., Ibrahim, K. S., & Abdel-Azeem, A. S. (2019). Dietary antioxidant for disease prevention corroborated by the Nrf2 pathway. *Journal of Complementary and Integrative Medicine, 16*(3), 20180161. doi:10.1515/jcim-2018-0161

Janciauskiene, S. (2020). The beneficial effects of antioxidants in health and diseases. *Chronic Obstructive Pulmonary Disease, 7*(3), 182–202. doi:10.15326/jcopdf.7.3.2019.0152

King, J. A., Jeong, J., Underwood, F. E., Quan, J., Panaccione, N., Windsor, J. W., ... Kaplan, G. G. (2020). Incidence of celiac disease is increasing over time: A systematic review and meta analysis. *American Journal of Gastroenterology, 115*(4), 507–525. doi:10.14309/ajg.0000000000000523

Koehler, P., Wieser, H., & Konitzer, K. (2014). Celiac disease – a complex disorder. In P. Koehler, H. Wieser, & K. Konitzer (Eds.), *Celiac Disease and Gluten* (pp. 1–96). 1st ed. Boston: Academic Press.

Mahmud, F. H., De Melo, E. N., Noordin, K., Assor, E., Sahota, K., Davies-Shaw, J., ... Harrington, J. (2015). The Celiac Disease and Diabetes-Dietary Intervention and Evaluation Trial (CD DIET) protocol: A randomized controlled study to evaluate treatment of asymptomatic coeliac disease in type 1 diabetes. *BMJ Open, 5*(5), e008097. doi:10.1136/bmjopen-2015 008097

Mazzola, A. M., Zammarchi, I., Valerii, M. C., Spisni, E., Saracino, I. M., Lanzarotto, F., & Ricci, C. (2024). Gluten-free diet and other celiac disease therapies: Current understanding and emerging strategies. *Nutrients, 16*(7), 1006. doi:10.3390/nu16071006

Melini, V., & Melini, F. (2019). Gluten-free diet: Gaps and needs for a healthier diet. *Nutrients, 11*(1), 170. doi:10.3390/nu11010170

Moretti, S., Mrakic-Sposta, S., Roncoroni, L., Vezzoli, A., Dellanoce, C., Monguzzi, E., ... & Elli, L. (2018). Oxidative stress as a biomarker for monitoring treated celiac disease. *Clinical and Translational Gastroenterology, 9*(6), e157. doi:10.1038/s41424-018-0031-6

Noori, E., Hashemi, N., Rezaee, D., Maleki, R., Shams, F., Kazemi, B., ... & Rahimi, F. (2024). Potential therapeutic options for celiac disease: An update on current evidence from gluten-free diet to cell therapy. *International Immunopharmacology, 133*, 112020. doi:10.1016/j.intimp.2024.112020

Öztag, M., & Güneş, F. E. (2022). Validation of a food frequency questionnaire for assessing total antioxidant status. *Clinical Nutrition ESPEN, 48*, 351–355. doi:10.1016/j.clnesp.2022.01.019

Penagini, F., Dilillo, D., Meneghin, F., Mameli, C., Fabiano, V., & Zuccotti, G. V. (2013). Gluten-free diet in children: An approach to a nutritionally adequate and balanced diet. *Nutrients, 5*(11), 4553–4565. doi:10.3390/nu5114553

Piątek-Guziewicz, A., Mach, T., Zagrodzki, P., Paśko, P., Krośniak, M., & Zwolińska-Wcisło, M. (2017). Ferric reducing ability of plasma and assessment of selected plasma antioxidants in adults with celiac disease. *Folia Medica Cracoviensia, 57*(4), 43–57.

Piazza, S., Colombo, F., Bani, C., Fumagalli, M., Vincentini, O., Sangiovanni, E., ... Dell'Agli, M. (2023). Evaluation of the potential anti-inflammatory activity of black rice in the framework of celiac disease. *Foods, 12*(1), 63. doi:10.3390/foods12010063

Pizzino, G., Irrera, N., Cucinotta, M., Pallio, G., Mannino, F., Arcoraci, V., ... Bitto, A. (2017).Oxidative stress: Harms and benefits for human health. *Oxidative Medicine and Cellular Longevity, 2017*, 8416763. doi:10.1155/2017/8416763

Rivera, E., Assiri, A., & Guandalini, S. (2013). Celiac disease. *Oral Diseases, 19*(7), 635-641. doi:10.1111/odi.12091

Rybicka, I. (2018). The handbook of minerals on gluten-free diet. *Nutrients, 10*(11), 1683. doi:10.3390/nu10111683

Satia, J. A., Watters, J. L., & Galanko, J. A. (2009). Validation of an antioxidant nutrient questionnaire in Whites and African Americans. *Journal of the American Dietetic Association, 109*(3), 502–508. doi10.1016/j.jada.2008.11.033

Serena, G., Lima, R., & Fasano, A. (2019). Genetic and environmental contributors for celiac disease. *Current Allergy and Asthma Reports*, *19*(9), 40. doi: 10.1007/s11882-019-0871-5

Suárez-González, M., Bousoño-García, C., Jiménez-Treviño, S., & Díaz-Martín, J. J. (2021).

Gluten-free diet: Nutritional strategies to improve eating habits in children with celiac disease: A prospective, single-arm intervention study. *Nutrients, 13*(4), 1108. doi:10.3390/nu13041108

Thompson, T., Dennis, M., Higgins, L. A., Lee, A. R., & Sharrett, M. K. (2005). Gluten-free diet survey: Are Americans with coeliac disease consuming recommended amounts of fibre, iron, calcium and grain foods? *Journal of Human Nutrition and Dietetics, 18*(3), 163–169. doi:10.1111/j.1365-277X.2005.00607.x

Ting, A., Katz, T., Sutherland, R., Liu, V., Tong, C. W., Gao, Y., ... & Ooi, C. Y. (2020). Evaluating the dietary intakes of energy, macronutrients, sugar, fiber, and micronutrients in children with celiac disease. *Journal of Pediatric Gastroenterology and Nutrition, 71*(2), 246–251. doi:10.1097/MPG.0000000000002743

Unalp-Arida, A., Liu, R., & Ruhl, C. E. (2022). Nutrient intake differs among persons with celiac disease and gluten-related disorders in the United States. *Scientific Reports, 12*(1), 5566. doi:10.1038/s41598-022-09346-y

van Megen, F., Fossli, M., Skodje, G. I., Carlsen, M. H., Andersen, L. F., Veierød, M. B., ... & Henriksen, C. (2023). Nutritional assessment of women with celiac disease compared to the general population. *Clinical Nutrition ESPEN, 54*, 251–257. doi10.1016/j.clnesp.2023.01.031

Vici, G., Belli, L., Biondi, M., & Polzonetti, V. (2016). Gluten-free diet and nutrient deficiencies: A review. *Clinical Nutrition, 35*(6), 1236–1241. doi:10.1016/j.clnu.2016.05.002

Wang, S., Teng, H., Zhang, L., & Wu, L. (2024). Association between dietary antioxidant intakes and chronic respiratory diseases in adults. *World Allergy Organization Journal*, *17*(1), 100851. doi: 10.1016/j.waojou.2023.100851