

Nutritional content and quality of processed gluten-free products

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Abstract

The present work aimed to compare the macro- and micronutrient contents of gluten-free (GF) and gluten-containing (GC) products from a wide range of stores in Jeddah, Saudi Arabia. A case-control study was conducted. Twelve major supermarkets in Jeddah, Saudi Arabia were visited, and the nutritional information labels of 92 GF and 46 GC products were compared. Results showed that GF products were significantly lower in protein ($p = 0.004$), total sugar ($p = 0.01$), calcium ($p = 0.02$), iron ($p = 0.002$), and vitamin D ($p = 0.01$) than GC products. Furthermore, GF breads, flours, and pastas had significantly lower amounts of protein than their GC counterparts ($p < 0.001$, $p = 0.03$, and $p < 0.001$, respectively). Fibre was significantly higher in GF than GC biscuits and breads ($p = 0.04$ and $p = 0.01$, respectively). However, GF pastas had significantly lower content of fibre per 100 g than GC pastas ($p = 0.02$). Overall, the nutritional quality of GF products was not significantly different from GC products. Although GF and GC biscuits and cookies were considered low nutritional value products, the nutritional quality scores of GF biscuits and cookies were significantly higher than their GC counterparts. GF products were lower in protein, total sugar, vitamin D, calcium, and iron than GC products. The nutritional quality of GF products did not differ from GC products. Food manufacturers should pay more attention to the nutritional content of GF products. Future studies are needed for the nutritional assessment of GF products, and how nutritional content may influence the diet quality of individuals with celiac disease who follow gluten-free diets.

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Introduction

Celiac disease (CD) is a chronic inflammatory intestinal disease in which the intestines become inflamed and flattened. The prevalence of CD is 1% worldwide, and approximately 4.1% in Saudi Arabia (Al-Hussaini *et al.*, 2017; Safi, 2018). Due to their autoimmune responses to gluten, patients with CD may experience various GI symptoms, such as diarrhoea and vomiting. In addition, untreated CD may cause health complications such as poor bone health, miscarriage, and anaemia.

The only treatment for patients with CD is strict adherence to a gluten-free diet (GFD) (Capacci *et al.*, 2018; Rybicka, 2018; King *et al.*, 2019). There is no doubt that GFD and gluten-free (GF) products

are necessary to treat CD-related digestive disorders. However, it is known that GF processed foods have lower nutritional quality due to the replacement of wheat, barley, and rye flour with coconut, corn, and rice flour, thus leading to decreased intakes of carbohydrates, vitamins, and minerals, and increased intakes of fats and proteins (Saturni *et al.*, 2010; Rybicka, 2018; King *et al.*, 2019).

Although the GF market has expanded substantially over the past few years, and is still growing, the consistency of GF goods presents some obstacles to the success of GFD. Many GF products are not enriched, and have lower levels of folate, magnesium, thiamine, niacin, fibre, and riboflavin than gluten-containing (GC) products. Previous studies that examined the nutritional composition of

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refined GF products found them to contain high levels of lipids, sugars, sodium, and calories, and low levels of nutrients, including carbohydrates, fibres, calcium, iron, magnesium, and zinc; CD patients could therefore have an unhealthy intake of total and saturated fats, as well as nutritional imbalances and deficiencies (Saturni *et al.*, 2010; Rybicka, 2018).

Despite the magnitude and popularity of studies on GF products worldwide, there present work was one of the few studies conducted in Saudi Arabia to examine the nutritional information labels of GF processed foods, and compare their content with GC products. The objective of the present work was therefore to compare the macro- and micronutrient contents, and assess the nutritional quality of GF and GC products in a wide range of stores in Saudi Arabia.

Materials and methods

A case-control study was conducted between February - March 2021. The study compared the nutritional information labels of GF and GC products. Twelve major supermarkets from different locations in Jeddah, Saudi Arabia were chosen because they were the most popular and accessible supermarkets in the city. The data only included products found in supermarkets. Products found in web-based supermarkets were not included. Also, special healthy food stores were excluded as they were not common to ensure the availability and accessibility of the products.

Procedure

Supermarkets were visited and searched for GF and GC products. For GF products, all products in the supermarkets containing a GF label were mostly selected. Gluten-free products from different categories were examined, including flours, breads, pastas, flakes, biscuits, cupcakes, bars, and cookies. For each available GF product, a GC product with similar characteristics was selected; for example, GF flours were matched with a GC wheat flour.

The criteria used to select a GC counterpart product were: (1) a product with labels and description mostly similar to the GF product; (2) when various GC alternative products were available, a familiar brand was chosen, and a comparable GC product was selected to match various GF products. The data collected from nutritional information labels for each product included energy values and macro-

and micronutrient contents. Nutrient values for all products were recorded in dry weight. The product name, GF labelling, ingredients, health claims on packaging, product weight, serving size, brand name, and the nutritional information were also recorded. In the supermarket, a photo was taken for the nutrition facts and the front package of each product. This method was adopted from a previous study (Myhrstad *et al.*, 2021).

Nutritional content

The nutritional information per 100 g was recorded for each product, including energy (Kcal), total fat (g), saturated fat (g), trans fat (g), carbohydrate (g), sugar (g), fibre (g), protein (g), and salt (g). Other nutrients were recorded based on the information provided, including calcium (mg), folic acid (μg), iron (mg), vitamin D (μg), vitamin C (mg), potassium (mg), cholesterol (mg), vitamin B₂ (mg), vitamin B₃ (mg), vitamin B₅ (mg), and vitamin B₆ (mg).

Nutritional quality of processed gluten-free and gluten-containing products (nutrient profiling score)

The nutritional quality of processed GF and GC products was assessed using the nutrient profiling score of the National Nutrition Committee, The Saudi Food and Drug Authority (SFDA, 2022). The nutrient profiling score is a calculator that scores the nutrient profiles of solid and liquid products, adapted from the United Kingdom's nutrient profiling model (Department of Health, 2011).

The nutrient profiling score classifies nutrients as group A—energy (Kcal), saturated fat (g), total sugar (g), and sodium (mg)—or group C, which are amount of fruit, vegetables, or nuts (%/100 g), fibre (g), and protein (g). It then provides points-based content for each of the aforementioned nutrients based on 100 g of a product. Finally, the points of group C are subtracted from the points of group A to obtain the final score. Lower scores are considered better nutritional values. Scores ≤ 4 are considered high nutritional value products, while scores > 4 are considered low nutritional value products.

Statistical analysis

Statistical analyses were performed using SPSS version 28. The level of significance was set at $p < 0.05$ for all analyses. The variables were not normally distributed, thus, median and 25th - 75th quartile content of nutrient content per 100 g for both

GF and GC products were calculated. A Wilcoxon rank sum test was used to determine nutritional differences between GF and GC products. For nutritional values, data were analysed as categorical and continuous values.

Results

A total of 138 products were assessed in the present work, including 92 GF and 46 GC products. Twelve major supermarkets were visited. Out of twelve supermarkets, five had no GF products.

Health claims

Among GF products, “high in fibre” came first with 18.8%, followed by “high in protein” (12.2%) and “high in minerals” (1%).

For GC products, “high in fibre” was also the most common health claim presented on 23.9% of products, followed by “high in vitamins and minerals” (21.7%) and “high in protein” (4.3%).

Energy and nutrient content

The average values of total energy, total fat, saturated fat, carbohydrate, and fibre were similar in GF and GC products. Protein and sugar values were significantly lower in GF products as compared to GC products ($p = 0.004$ and $p = 0.01$, respectively). Table 1 shows energy and nutrient content per 100 g of GC and GF products.

Energy content

Across eight product types, the highest energy median for a GF product was for biscuits (451 Kcal/100 g), and for a GC product was cookies (490 Kcal/100 g). The lowest energy median for both GF and GC products was for bread (GF: 250 Kcal/100 g, and GC: 272 Kcal/100 g). However, there was no significant difference in energy content per 100 g across all eight product types. The median energy of the eight product types is illustrated in Table 2.

Total fat, saturated fat, and cholesterol contents

There was no significant difference in total fat content between GF and GC products (Table 2). Lower saturated fat content was present in six out of eight GF products (biscuits, breads, cookies, cupcakes, flakes, and flours) as compared to their GC counterparts. However, only GF biscuits ($p = 0.02$) had statistically significantly lower saturated fat content than GC biscuits (Table 2). There were no significant differences in cholesterol content between GF and GC products.

Protein content

GC bread ($p < 0.001$), flour ($p = 0.03$), and pasta ($p < 0.001$) products contained significantly higher levels of protein (Table 2) than their GF counterparts (protein content/100 g) (GC products: 10, 11.8, and 12 g, and GF products: 3.9, 7.4, and 7.5 g, respectively).

Table 1. Differences in energy, macronutrient, and salt contents of gluten-free (GF) and gluten-containing (GC) products per portion (100 g).

Nutrition attribute	GF product (n = 92)*	GF (mean ± SD)	GC product (n = 46)*	GC (mean ± SD)	p-value
Energy (Kcal)	373 (343 - 433)	368.7 ± 99.4	374 (356 - 425)	386.4 ± 72.7	0.51
Fat (g)	5.3 (1.8 - 15)	9.5 ± 10.1	4.3 (1.9 - 14.3)	8.9 ± 8.5	0.78
Saturated fat (g)	0.8 (0.3 - 3.7)	2.8 ± 4.1	1.3 (0.4 - 8)	4.7 ± 7.1	0.08
Cholesterol (mg)	0 (0 - 3.1)	5.1 ± 10	0 (0 - 0.3)	3.3 ± 9.1	0.59
Carbohydrate (g)	70.2 (46.7 - 78.2)	61.9 ± 20.8	67 (59 - 73)	65.6 ± 12.3	0.92
Protein (g)	6.6 (4.6 - 9.1)	8.1 ± 5.8	8.8 (6.2 - 11.9)	9.4 ± 4.9	0.004
Fibre (g)	3.7 (2.6 - 7.3)	5.6 ± 5.4	4.1 (2.5 - 6.9)	4.7 ± 3.0	0.76
Sugar (g)	6.3 (0.7 - 20)	10.5 ± 10.3	15.1 (3.1 - 26.7)	15.5 ± 12.6	0.01
Salt	0.3 (0.05 - 0.7)	0.4 ± 0.4	0.3 (0.03 - 0.5)	1.7 ± 9.4	0.33

*Data are presented as median (25th - 75th). The difference in nutrients mean was assessed by Wilcoxon rank sum test. Bold values indicate statistically significant differences between products.

Table 2. Differences in energy, fat, saturated fat, cholesterol, and protein content of gluten-free (GF) and gluten-containing (GC) products per portion (100 g) based on product type.

Nutrition attribute	Product type	GF product (n = 92)*	GF (mean ± SD)	GC product (n = 46)*	GC (mean ± SD)	p-value
Energy (Kcal)	Bar	447.5 (329 - 527)	393.5 ± 151.6	382 (367 - 388)	378.6 ± 10.9	0.44
	Biscuit	451 (440 - 483)	463.2 ± 31.7	483 (469.2 - 512.6)	491.7 ± 38.0	0.06
	Bread	250 (229 - 281)	254.1 ± 28.6	272 (262.3 - 276.7)	302.7 ± 94.2	0.23
	Cookie	380.9 (380.9 - 495)	426.5 ± 65.5	490.3 (480.1 - 505.6)	492.1 ± 13.8	0.19
	Cupcake	410 (408 - .5 - 410.7)	409.7 ± 1.25	367.5 (356.6 - 367.5)	367.5 ± 15.3	0.13
	Flake	383.5 (365.7 - 397.2)	373 ± 82.6	380 (372 - 384.6)	382.5 ± 18.5	0.71
	Flour	351.5 (343.2 - 358.8)	351.6 ± 9.7	354 (350 - 354)	355.6 ± 6.6	0.59
	Pasta	356 (349 - 373)	312.9 ± 107.4	357 (350 - 357.1)	354.5 ± 6.2	0.82
Fat (g)	Bar	23 (7.8 - 38)	22.9 ± 14.0	8.3 (6.2 - 12.6)	9.2 ± 4.1	0.09
	Biscuit	15 (13.3 - 22)	17.2 ± 5.7	20.6 (18.4 - 25.5)	21.6 ± 5.9	0.17
	Bread	3.6 (3.2 - 6.3)	4.6 ± 2.1	4 (3 - 6.7)	5.2 ± 3.5	0.88
	Cookie	19.1 (16.6 - 24)	20.1 ± 4.9	24.6 (21.8 - 25.7)	24.1 ± 2.1	0.19
	Cupcake	20 (20 - 20)	20 ± 0	15.8 (13.3 - 15.8)	15.8 ± 3.5	0.13
	Flake	2.6 (1.5 - 5.3)	3.4 ± 2.3	3.2 (1.9 - 7.1)	4.4 ± 3.2	0.45
	Flour	0.9 (0.2 - 2.9)	1.7 ± 1.8	1.5 (1.2 - 1.5)	1.9 ± 1.0	0.43
	Pasta	1.7 (0.9 - 2.8)	2.1 ± 1.5	1.6 (1.6 - 1.9)	1.7 ± 0.3	0.92
Saturated fat (g)	Bar	5.1 (2.8 - 8)	6.6 ± 4.7	3.3 (1.9 - 5.1)	3.4 ± 2	0.22
	Biscuit	5.9 (1.5 - 9.9)	6.3 ± 5.9	11.5 (9.6 - 17.1)	14.1 ± 8.5	0.02
	Bread	0.5 (0.4 - 1.5)	1.1 ± 1.2	2 (1 - 6.1)	6.5 ± 11.5	0.11
	Cookie	4.6 (2.3 - 9.8)	5.8 ± 5.2	10.3 (8.1 - 12.8)	10.4 ± 2.5	0.19
	Cupcake	3.1 (2.6 - 3.8)	3.1 ± 0.67	7.5 (6.6 - 7.5)	7.5 ± 1.1	0.13
	Flake	0.4 (0 - 1.1)	0.7 ± 1.1	0.9 (0.4 - 1.3)	1.1 ± 0.8	0.11
	Flour	0.2 (0.2 - 0.4)	0.3 ± 0.2	0.3 (0.3 - 0.3)	0.4 ± 0.17	0.36
	Pasta	0.4 (0.2 - 0.8)	0.6 ± 0.7	0.4 (0.1 - 0.4)	0.3 ± 0.2	0.29
Cholesterol (mg)	Bar	3.1 (0 - 3.1)	2.1 ± 1.8	0.1 (0 - 0.1)	1 ± 1.6	0.40
	Biscuit	8.3 (0 - 30)	12.7 ± 14.8	2.4 (0.2 - 12.6)	5.1 ± 7.1	0.76
	Bread	-	-	-	-	-
	Cookie	0	0	3.3 (0 - 16.1)	6.4 ± 9.1	0.40
	Cupcake	-	-	32.5 (20 - 32.5)	32.5 ± 17.6	-
	Flake	-	-	-	-	-
	Flour	-	-	-	-	-
	Pasta	7.4 (0 - 7.4)	7 ± 9.9	-	-	-
Protein (g)	Bar	14 (7.8 - 27.2)	16.1 ± 9.5	6.2 (6.1 - 21.5)	12.1 ± 13.3	0.11
	Biscuit	5 (3.3 - 6.7)	5.6 ± 2.7	7.4 (5 - 8.1)	6.3 ± 3.1	0.26
	Bread	3.9 (3.1 - 5.1)	4.2 ± 1.5	10 (10 - 11.9)	10.5 ± 1.5	< 0.001
	Cookie	19.1 (4.2 - 19.1)	13.1 ± 8.1	7.5 (6 - 10.9)	8.1 ± 2.6	0.73
	Cupcake	4.8 (4.6 - 5.2)	4.9 ± 0.3	4.1 (3.3 - 4.1)	4.1 ± 1.1	0.53
	Flake	7.6 (6.5 - 9.7)	8.7 ± 4.5	8.2 (6.2 - 9.4)	8.0 ± 2.1	1.0
	Flour	7.4 (4.5 - 9.2)	6.9 ± 3.4	11.8 (10.3 - 11.8)	11.7 ± 1.4	0.03
	Pasta	7.5 (6.2 - 8.5)	6.6 ± 2.6	12 (12 - 12.3)	12.1 ± 0.3	< 0.001

*Data are presented as median (25th - 75th). The difference in nutrients mean was assessed by Wilcoxon rank sum test. Bold values indicate statistically significant differences between products.

Carbohydrate, total sugar, and fibre contents

Across eight product types, carbohydrate content was statistically different between GF and GC bars ($p = 0.01$), where GF bars (31 g/100 g) had lower levels of carbohydrates than GC bars (69.2 g/100 g) (Table 3). Gluten-containing pasta products ($p = 0.003$) contained significantly higher levels of total sugar than their GF counterparts. Significantly higher

amounts of fibre were found in GF biscuits (3.3 g/100 g, $p = 0.04$) and breads (7.3 g/100 g, $p = 0.01$) as compared to their GC counterparts. In contrast, GF pasta had significantly lower fibre content per 100 g than GC pasta ($p = 0.02$). Table 4 shows carbohydrate, total sugar, and fibre contents per 100 g for eight GC and GF product types.

Table 3. Differences in carbohydrate, total sugar, fibre, and salt contents of gluten-free (GF) and gluten-containing (GC) products per portion (100 g) based on product type.

Nutrition attribute	Product type	GF product ($n = 92$)*	GF (mean \pm SD)	GC product ($n = 46$)*	GC (mean \pm SD)	p -value
Carbohydrate (g)	Bar	31 (19 - 40)	30.1 \pm 15.1	69.2 (47.5 - 71.5)	61.4 \pm 18.8	0.01
	Biscuit	73.3 (64 - 77)	70.8 \pm 7.2	63.8 (62.5 - 68.2)	65.2 \pm 3.6	0.09
	Bread	45 (41.7 - 48.2)	45.1 \pm 3.7	49.2 (43.3 - 50)	52.4 \pm 13.9	0.11
	Cookie	42.6 (41.6 - 63)	50.4 \pm 11.5	62 (55.3 - 65.7)	61.1 \pm 5.4	0.19
	Cupcake	52 (50.2 - 53)	51.7 \pm 1.5	50.8 (48.3 - 50.8)	50.8 \pm 3.5	1.0
	Flake	81.5 (78.5 - 84.2)	77.7 \pm 17.1	76 (71.2 - 83.1)	75.6 \pm 8.5	0.16
	Flour	76.6 (73 - 80)	74.3 \pm 8.5	74.2 (63 - 74.2)	70.6 \pm 6.6	0.15
	Pasta	75 (70.4 - 76)	65.8 \pm 22.7	72 (67 - 72)	70.3 \pm 2.9	0.11
Sugar (g)	Bar	13.5 (3.1 - 23)	13.9 \pm 10.2	20 (11.2 - 24.8)	18.4 \pm 9.1	0.66
	Biscuit	16 (3.2 - 21.5)	14.3 \pm 11.4	24.1 (13.3 - 33.4)	24.5 \pm 13.5	0.17
	Bread	4.9 (4.1 - 7.3)	6.3 \pm 4.0	4 (3.3 - 5)	4.4 \pm 2.1	0.21
	Cookie	19.1 (19 - 20)	19.4 \pm 0.8	31.3 (21.1 - 32.5)	28.3 \pm 6.9	0.28
	Cupcake	25.5 (25 - 26.7)	25.7 \pm 0.9	30.8 (30 - 30.8)	30.8 \pm 1.1	0.13
	Flake	15.6 (8.5 - 24)	16.1 \pm 9.2	21.1 (14 - 29.9)	20.8 \pm 10.3	0.21
	Flour	0.5 (0.1 - 2.3)	3.0 \pm 7.1	1.4 (1 - 1.4)	1.4 \pm 0.5	0.68
	Pasta	0.2 (0 - 0.6)	0.8 \pm 1.7	3 (2.2 - 3.3)	2.8 \pm 0.6	0.003
Fibre (g)	Bar	7.5 (4.7 - 11)	8.4 \pm 5.1	7 (6 - 8.5)	7.2 \pm 1.7	0.91
	Biscuit	3.3 (2.8 - 5.4)	4.2 \pm 2.1	1.4 (0.6 - 3.3)	1.8 \pm 1.4	0.04
	Bread	7.3 (6.4 - 8.8)	7.4 \pm 1.6	3.3 (2 - 6)	4.2 \pm 2.3	0.01
	Cookie	7.1 (4.9 - 7.2)	6.3 \pm 1.9	3.4 (1.6 - 5)	3.3 \pm 1.9	0.06
	Cupcake	2.1 (1.3 - 3.3)	2.2 \pm 1.1	0.8 (0 - 0.8)	0.8 \pm 1.1	0.53
	Flake	3.4 (2.3 - 10)	7.6 \pm 10.5	6.2 (4.6 - 8.9)	7.1 \pm 3.2	0.16
	Flour	3.1 (1.1 - 9.2)	4.5 \pm 3.8	1.9 (1.4 - 1.9)	1.9 \pm 0.7	0.44
	Pasta	2.4 (1.8 - 4.1)	2.8 \pm 1.7	3.4 (3.4 - 6.4)	4.6 \pm 2.1	0.02
Salt	Bar	0.1 (0.1 - 0.8)	0.4 \pm 0.3	0.6 (0.1 - 0.6)	0.4 \pm 0.3	0.82
	Biscuit	0.7 (0.3 - 0.9)	0.7 \pm 0.5	0.3 (0.2 - 0.5)	0.3 \pm 0.1	0.13
	Bread	0.9 (0.4 - 1.1)	0.8 \pm 0.3	0.4 (0.3 - 0.4)	0.6 \pm 0.8	0.05
	Cookie	0.5 (0.3 - 0.5)	0.4 \pm 0.1	0.2 (0.2 - 0.3)	0.3 \pm 0.1	0.39
	Cupcake	0.8 (0.7 - 0.9)	0.8 \pm 0.1	0.1 (0.1 - 0.1)	0.1 \pm 0.04	0.13
	Flake	0.3 (0.2 - 0.5)	0.4 \pm 0.3	0.4 (0.2 - 0.8)	0.5 \pm 0.3	0.79
	Flour	0.01 (0.004 - 0.1)	0.2 \pm 0.6	31.5 (0 - 31.5)	31.5 \pm 44.5	0.93
	Pasta	0.01 (0 - 0.1)	0.1 \pm 0.1	0 (0 - 0.004)	0.004 \pm 0.01	0.14

*Data are presented as median (25th - 75th). The difference in nutrients mean was assessed by Wilcoxon rank sum test. Bold values indicate statistically significant differences between products.

Table 4. Differences in some vitamin and mineral contents of gluten-free (GF) and gluten-containing (GC) products per portion (100 g).

Nutrition attribute	GF product (n = 92)*	GC product (n = 46)*	p-value
Calcium (mg)	75.4 (1.7 - 116.1)	474 (13.7 - 621)	0.02
Folic acid (µg)	125 (1 - 125)	166 (148 - 185.5)	0.61
Potassium (mg)	284.5 (126.8 - 349.8)	230 (153 - 258.7)	0.39
Iron (mg)	2.4 (0.5 - 4.6)	11.5 (8 - 12.5)	0.002
Vitamin D (µg)	0 (0 - 0)	3.1 (1.2 - 6.7)	0.01
Vitamin B ₂ (mg)	1.4 (1.4 - 1.4)	1.3 (1.1 - 1.5)	0.53
Vitamin B ₆ (mg)	1.4 (1.4 - 1.4)	1.22 (1 - 1.4)	0.26
Vitamin C (mg)	16.4 (16.2 - 16.4)	40 (0 - 40)	0.56

*Data are presented as median (25th - 75th). Bold values indicate statistically significant differences between products.

Salt content

GC bread products ($p = 0.05$) contained slightly lower levels of salt than GF products (salt content/100 g) (GC products: 0.4, and GF products: 0.9) (Table 3).

Vitamin and mineral contents

In general, statistically significant differences were found between GF and GC products for calcium ($p = 0.02$), iron ($p = 0.002$), and vitamin D ($p = 0.01$). Table 4 shows some vitamin and mineral contents per 100 g of GC and GF products.

Nutritional quality of processed gluten-free and gluten-containing products (nutrient profiling scores)

The nutritional quality of GF biscuits ($p = 0.04$) and cookies ($p = 0.02$) was significantly better than their GC counterparts (Table 5). Stratifying the value to low and high showed that almost half of all GC and

GF products were considered to have low nutritional value (Table 5). The majority of flour and pasta products (both GC and GF) were considered to have high nutritional value, along with GC bread products. However, not all differences reached statistical significance. As expected, all the GF and GC cookies and cupcakes were considered to have lower nutritional values.

Figure 1 shows the percentages of food products scored as “low nutrition value” in GF and GC products using “Nutrient Profiling Score”. No significant differences were found in the percentage of “low nutrition value” between GF and GC products ($p > 0.08$). In general, around 58% were scores as “low nutrition value” of both GF and GC products. The percentage of “low nutrition value” in GF cookies and flakes were lower than GC cookies and flakes.

Table 5. Nutritional quality of processed gluten-free (GF) and gluten-containing (GC) products.

Product type	GF product (n = 92)*	GC product (n = 64)*	p-value
Bar	13 (8 - 17)	13 (3 - 13)	0.46
Biscuit	18 (11 - 21)	20.5 (18.7 - 27.5)	0.04
Bread	8 (1.5 - 9.2)	1 (-2 - 13)	0.32
Cookie	12 (9.5 - 16)	21.5 (16.2 - 23.7)	0.02
Cupcake	19.5 (17.2 - 21)	17 (17 - 17)	0.13
Flake	6 (1 - 11.5)	10 (2 - 13)	0.41
Flour	-1 (-5 - 1)	-3 (-4 - -3)	0.89
Pasta	-3 (-5 - 0)	-5.5 (-6 - -2)	0.08
All products	8 (-1 - 14)	11 (-1.2 - 17)	0.41

*Data are presented as median (25th - 75th). The difference in nutrients mean was assessed by Wilcoxon rank sum test. Bold values indicate statistically significant differences between products.

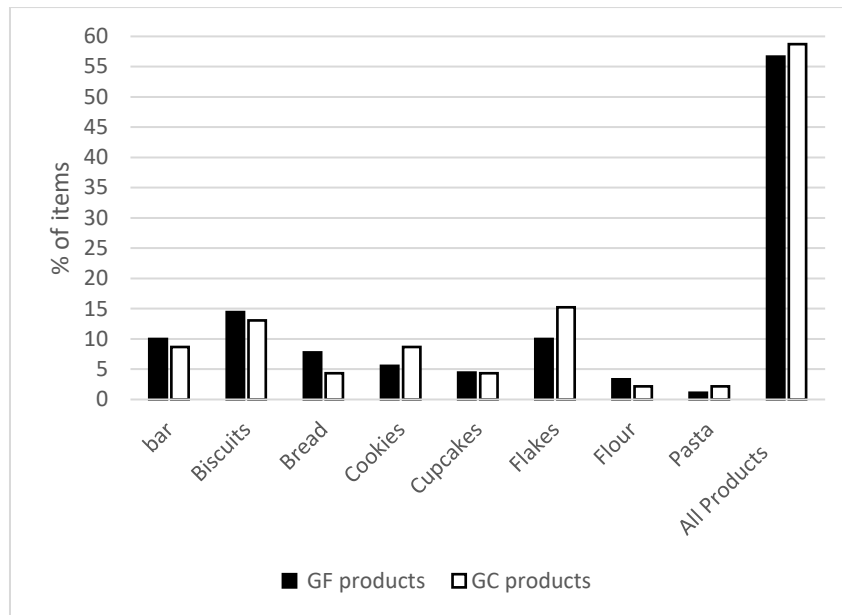


Figure 1. Percentages of food items scored as “low nutrition value” in GF and GC products using “Nutrient Profiling Score”.

Discussion

The objective of the present work was to compare macro- and micronutrient content, and thus nutritional quality, between gluten-free and gluten-containing products. The nutritional content and quality of 92 GF products and 46 GC products collected from different supermarkets in Jeddah, Saudi Arabia were compared. In general, it was found that GF products were lower in protein, total sugar, vitamin D, calcium, and iron than their equivalent GC products. Gluten-free breads, pastas, and flours had lower amounts of protein than their GC counterparts. Fibre was higher in GF biscuits and breads than their GC counterparts. Overall, the nutritional quality of GF products was not different from GC products. Although GF and GC biscuits and cookies were considered low nutritional value products, the nutritional quality scores of GF biscuits and cookies were higher than their GC counterparts.

Previous studies showed that GF products were higher in total fat and lower in protein, carbohydrate, total sugar, and calcium than the equivalent GC products (Saturni *et al.*, 2010; Missbach *et al.*, 2015; Bascuñán *et al.*, 2017; Allen and Orfila, 2018; Fry *et al.*, 2018; Aguiar *et al.*, 2021). In the present work, GF bread, pasta, and flour had lower amounts of protein than their GC counterparts, consistent with other studies (Myhrstad *et al.*, 2021; Aguiar *et al.*, 2021). Gluten-free products are generally lower in protein, vitamin D, calcium, and iron than GC products for two reasons: first, patients with CD are

at risk of lactose intolerance and multiple food allergies, so many manufacturers have developed GF products that do not contain milk or eggs; second, iron enrichment is mandatory in GC flour but not in GF flour, which indicates that non-CD individuals can meet their iron requirements through GC foods that cannot be eaten by CD patients. Therefore, when individuals turn to a GFD, the intake of iron from processed foods is reduced.

Although fibre did not differ between GF and GC products, GF biscuits and breads had higher amounts of fibre than their GC counterparts, consistent with previous studies (Mazzeo *et al.*, 2015; Jamieson and Neufeld, 2020; Aguiar *et al.*, 2021). Many GF processed product labels in the present work claimed that the products were fortified with fibre and used multiple seeds and grains (Jamieson and Neufeld, 2020). In addition, several studies have reported high amounts of total and saturated fat in GF products (Allen and Orfila 2018; Myhrstad *et al.*, 2021; Aguiar *et al.*, 2021). Manufacturers use fat to improve texture; this causes high intakes of fat and saturated fat, and may trigger several health conditions, such as cardiovascular diseases and non-alcoholic fatty liver diseases (Siriwardhane *et al.*, 2019; Valvano *et al.*, 2020). However, the present work did not find any differences in fat and saturated fat content between GF and GC products, perhaps because manufacturers have controlled the amount of fat and saturated fat used in processed GF products.

To our knowledge, this is the first study that has assessed the nutritional quality of GF processed

products in Saudi Arabia. Assessment of the nutritional value of GF processed products as a whole—and not for a single nutrient—is very limited (Lavriša *et al.*, 2020; De Las Heras-Delgado *et al.*, 2021). Limited studies have concluded that GF products were of low nutritional value as compared to GC products (Nikniaz *et al.*, 2020; Myhrstad *et al.*, 2021). With the exception of biscuits and cookies, no differences were found in the nutrient profiling scores of GF and GC products. Almost 60% of GF and GC products were considered to have low nutritional value. Gluten-free biscuits are considered a healthier option than GC biscuits due to their lower saturated fat and higher fibre content. In comparison to another recent study in Slovenia, only 50% of GF cake, muffins, and pastry, as compared to 90% of their GC counterparts, were scored as having low nutritional value (Lavriša *et al.*, 2020). The nutrient imbalance of GF products may have a direct influence on food intake in individuals with CD. Many studies in adults and children with CD have reported an insufficiency of several nutrients among these segments of population (Di Nardo *et al.*, 2019; Cardo *et al.*, 2021).

Strengths and limitations

The present work was among the first studies conducted in Saudi Arabia to compare the macro- and micronutrient content of GF and GC products. The present work collected GF and GC products from a wide range of supermarkets in Jeddah. Although the study collected the products from only one city in Saudi Arabia, we do not expect that the products would be different from other cities in Saudi Arabia because the distributors of the GF products distribute more or less the same products across the country. A limitation of the present work was that nutrient contents were obtained from the nutritional information labels. The nutritional information labels contain basic nutrition information, and no information regarding enrichment or fortification. Previous research has shown that using indirect analysis to estimate the nutrient composition of GF foods is also considered a valid and reliable method (Mazzeo *et al.*, 2015; Wu *et al.*, 2015).

Conclusion

The present work was the first to compare macro- and micronutrients, and the nutritional quality between GF and GC products. GF products were lower in protein, total sugar, vitamin D, calcium, and

iron than GC products. However, the nutritional quality of GF products was not different from GC products. Although GF and GC biscuits and cookies were considered low nutritional value products, the nutritional quality scores of GF biscuits and cookies were higher than their GC counterparts. This result has vast implications for the diet quality of adults and paediatric patients with CD who follow a GFD. For patients following a GFD, it is important to ensure variety in the diet to prevent nutritional deficiencies and related chronic diseases. Food manufacturers should pay more attention to the nutritional content of GF products, as fortification of GF products is needed to enhance the health of individuals with CD. Future studies are needed for a full nutritional assessment of GF products, including glycaemic index and load, and how this may influence the diet quality of individuals with CD who follow a GFD.

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