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# Nutritional quality, cost and availability of gluten free food in England

## Abstract

Purpose: Coeliac disease is a life-long condition requiring strict adherence to a gluten free diet. Due to wide claims of availability and lower costs of gluten free food (GFF) and Clinical Commissioning Groups (CCGs) in England needing to save costs, access to prescriptions for patients with coeliac disease (CD) is being limited in England. The purpose of this study is to investigate the availability and cost of GFF in an area where patients with coeliac disease have restricted access to prescriptions and to assess the nutritional composition of GFFs available in comparison with foods containing gluten.

Methodology: Eight food categories that were representative of a range of commonly purchased GFFs were selected. Availability and cost of cheapest and most expensive branded and non-branded GFFs and gluten containing equivalents were surveyed at physical stores (n=19) and online stores (n=8). The nutritional composition of some of the widely available GFFs identified (n=190) and comparable foods containing gluten (n=218) were calculated using MyFitnessPal.

Findings: None of the budget stores or corner shops surveyed stocked any of the surveyed cereal-based GFFs. Online stores had more availability than physical stores, however there was no significant difference in cost. Gluten free foods cost on average 2.18 times more than food containing gluten. When making nutritional comparisons with gluten-containing food, protein content was lower across 55% of GFF categories. There was significantly less sugar in gluten free (GF) brown bread, crackers, and wholegrain pasta compared with those containing gluten. Another main finding was GF ready-meals contained significantly less salt than ready-meals containing gluten.

Originality: Limited resources and perceived wide availability of gluten-free products resulted in reduced GF prescriptions to patients in England. The findings in this study revealed that there is no availability of cereal-based GFFs in budget stores, high cost and limited access to prescriptions can influence adherence to a gluten free diet and is most likely to affect patients from deprived groups. This study recommends that the prescription of gluten free food to patients with CD should be continued.

**Keywords:** availability; coeliac disease; cost; gluten-free; nutrition

36

## 37 **Introduction**

38 Coeliac disease (CD) is a systemic immune-mediated disorder activated by gluten and  
39 related prolamines ingestion in genetically susceptible individuals. It is characterised by the  
40 presence of CD specific antibodies and human leukocyte antigen (HLA)-DQ2 and HLA-DQ8  
41 (Husby et al., 2012; Nelsen, 2002). The prevalence of CD in the Western World is estimated  
42 at approximately 1-2% of the population and is considered an autoimmune disease affecting  
43 both adults and children (Simón et al., 2017). In the UK, 0.24% of the population  
44 (approximately 150,000 people) are clinically diagnosed with CD, however seroprevalence is  
45 1 – 1.6%, and prevalence is increasing (Crooks, 2016). Gluten is an insoluble storage  
46 protein found in wheat, rye, barley and triticale, and is made up of peptides gliadin and  
47 glutenin (Wieser, 2007). These peptides are used in many foods to give them structure and  
48 improve palatability (Gobbeti and Gänzle, 2013), however, when a patient with coeliac  
49 disease ingests gluten, an immune reaction promotes secretion of high volumes of  
50 proinflammatory cytokines and inflammatory mediators which attack the intestinal villi,  
51 causing it to become inflamed (Mazzarella, 2015). Inflammation reduces the surface area of  
52 the villi making it difficult to effectively absorb nutrients (Buttriss, 2002). Left untreated, CD  
53 can result in villous atrophy, where the intestinal villi have completely eroded causing  
54 malabsorption (Theethira et al., 2014). Study found that 43% of CD patients exhibited  
55 persistent villous atrophy on a follow up biopsy, which was caused by non-adherence to a  
56 gluten-free (GF) diet, thought to be a consequence of social differences due to access/or  
57 education (Lebwohl et al., 2014). The only treatment available for individuals suffering with  
58 CD or associated complications is to follow a strict life-long, GF diet. This consists of foods  
59 that are naturally GF, and manufactured foods such as bread and pasta where substitutes  
60 replace wheat (e.g. corn, rice or potato starch) (Ciacci et al., 2015). Products containing  
61 less than 20ppm are considered GF by the Codex Alimentarius (FAO/WHO, 2015). Initiation  
62 of the GF diet has been found to restore integrity of the intestinal wall, and improve  
63 symptoms and deficiencies of CD, however, certain nutritional limitations exist (Barone et  
64 al., 2016; Theethira et al., 2014).

65

66 Adhering to a GF diet is difficult and takes a lot of self-control. Other factors influencing  
67 adherence include availability, cost, nutritional quality and access to gluten-free food (GFF)  
68 on prescription (MacCulloch and Rashid, 2014; Hall et al., 2013). It has previously been  
69 demonstrated that GFF cost on average 4.1 times more than food containing gluten (FCG)  
70 (Burden et al., 2015). Missbach et al. (2015) observed that GF foods were significantly

71 higher in cost than similar foods containing gluten (range= 205% - 267%) in Austria.  
72 Previous studies have also demonstrated limited availability of GF foods, with no availability  
73 of cereal-based GF staples in budget stores and corner shops. A persistent finding is the  
74 higher cost of GFFs when making comparisons with FCG (Singh and Whelan, 2011; do  
75 Nascimento et al., 2014; Fry et al., 2018). The cost of food is an important factor which  
76 influences food choice (Lennernäs et al., 1997). The socioeconomic status of patients may  
77 determine which stores they shop in (Ellaway and Macintyre, 2000), and so the lack of  
78 availability in budget stores and corner shops may affect adherence to a GF diet. This may  
79 particularly burden patients who have no or limited access to GF foods on prescription  
80 (Muhammad et al., 2017).

81

82 Studies focussing on analysing the nutritional composition of GFFs have found they contain  
83 low levels of essential micronutrients such as iron, folic acid, calcium, potassium, zinc and  
84 magnesium (Thompson, 2000; Estévez et al., 2016; Missbach et al., 2015). High fat content  
85 has been another observation. Studies have demonstrated that GF breads have significantly  
86 more fat than breads containing gluten (Kulai and Rashid, 2014; Fry et al., 2018). Studies  
87 have also reported lower levels of protein and fibre content when compared with similar  
88 gluten containing foods (do Nascimento et al., 2014; Miranda et al., 2014; Missbach et al.,  
89 2015. Meanwhile Fry et al. (2018) found fibre content to be significantly higher in GF items  
90 such as white and brown bread whilst protein was found to be lower in GF products  
91 compared to gluten containing foods.

92

93 Gluten-free foods have been available on prescription to patients with CD since the late  
94 1960's (Department of Health, 2017), however, due to wider availability and reduced cost,  
95 as of 5<sup>th</sup> December 2016, the National Health Service (NHS) made budget cuts, and the  
96 Clinical Commissioning Groups (CCGs) in England changed their policies on GF prescriptions  
97 (Coeliac UK, 2019a). CCGs are groups of general practices (GPs) that come together in an  
98 area to commission the best services for patients and the population. CCGs buy services for  
99 the local community from any local service provider that meets the NHS standards and cost  
100 and aims to provide better care for patients (NHS, 2019). This resulted in 40% of 207 local  
101 CCG's restricting or completely stopping GF prescriptions (Coeliac UK, 2019a). The rationale  
102 of wider availability and lower costs of GF foods conflicts with evidence found in previous  
103 research (Singh and Whelan, 2011; do Nascimento et al., 2014; Burden et al., 2015; Fry et  
104 al., 2018; Hanci and Jeanes, 2018).

105

106 Before CCGs made policy changes, 90% of patients with CD relied on prescriptions for GFF  
107 (Robins et al., 2008), this offered fundamental support to those on a low income, benefits,  
108 and the elderly. Furthermore, Kinsey et al. (2008), found that prescription GFFs were higher  
109 in non-starch polysaccharides (NSP), calcium and iron compared with commercially available  
110 GF foods. However, since the studies conducted by Robins et al. and Kinsey et al. in 2008,  
111 more recent studies have found a lack of availability of GF foods and higher costs associated  
112 with such items. Therefore, the removal of GFF prescriptions is likely to affect the nutritional  
113 adequacy of a patient with coeliac disease GF diet, which could lead to health complications.  
114 A combination of restricting prescriptions, high cost of GFF and limited availability could  
115 potentially influence adherence to a gluten free diet (Coeliac UK, 2019.b; Estévez et al.,  
116 2016). Health risks associated with non-adherence include osteoporosis, osteopenia,  
117 infertility, anaemia, vitamin D deficiency, increased risk of fractures and cancer (BDA, 2015;  
118 Kinsey et al., 2008).

119

120 Stopping access to GFFs for primary care patients has recently been rejected by the  
121 government, and the Department of Health and Social Care (2018) has decided to restrict  
122 gluten-free prescribing to breads and flour mixes only (NHSCC, 2018). However, CCGs have  
123 the ability to control their own policies and can ultimately decide how much food can be  
124 prescribed, and who is entitled to it. Currently, patients with coeliac disease living in  
125 Greater Preston still have no access to GF prescriptions and until regulations have been  
126 developed and formally agreed by Parliament, the CCG for Greater Preston do not have to  
127 make changes to current policy. With increasing prevalence of CD and restrictions to  
128 prescriptions for patients with coeliac disease, the purpose of this study was to assess the  
129 availability of GFF and compare cost and nutritional quality with FCG in an area where GF  
130 prescribing is currently on hold and may be limited once new prescription regulations have  
131 been implemented.

132

## 133 **Methodology**

### 134 *Store selection*

135 The area chosen for assessment was Greater Preston situated in North West England, as  
136 this was one of the areas where prescriptions for GFF were withdrawn on 5<sup>th</sup> December  
137 2016 (Coeliac UK, 2019a). Stores such as regular stores, quality stores, budget stores,  
138 health food shops, convenience stores and corner shops, as previously categorised by Singh  
139 and Whelan (2011) were visited. The availability and cost of branded and non-branded GFFs

140 were surveyed as were similar FCG at different stores after receiving consent from the store  
141 managers.

142

### 143 *Food categories*

144 An itinerary of eight food items were chosen and were representative of a range of  
145 commonly purchased GFFs (do Nascimento et al., 2014; Fry et al., 2018). Food items were  
146 categorised as biscuits, breads, cakes, cereals (breakfast), crackers, flour, pasta and ready-  
147 meals were analysed for availability and cost. Additionally, similar categories of FCG were  
148 also analysed for cost, so a direct comparison could be made.

149

### 150 *Survey*

151 Stores were surveyed between November 2017 and January 2018. Availability was  
152 measured by counting how many different GF brands were stocked in each of the eight  
153 food categories in all stores visited, and a photograph of the same stock was captured on  
154 camera by smart phone. The cost of the cheapest and most expensive item was recorded,  
155 and for items with wide availability, the cost of the cheapest and most expensive branded  
156 and none branded foods was recorded. The same method was adopted for similar FCG and  
157 all costs were captured by camera using a smart phone. Package weight was not used as  
158 covariate as food comparisons may be weighted differently hence costs were calculated as  
159 pence (£) per 100g.

160

### 161 *Online stores*

162 Appropriate keywords were entered onto a google search engine to find stores with  
163 availability of GFF that delivered to homes in Greater Preston. Nine stores were selected  
164 and represented online regular stores, quality stores, health food stores and stores  
165 specialising in GF foods. This was to achieve a comparable analysis of online store  
166 availability and cost. The stores selected were those that landed on the first google result  
167 page, as this is where 95% of websites receive most visits (Brafton, 2013). The eight GFFs  
168 categories were separately entered onto the search bar of each online store and listed foods  
169 available were noted. The cost in pence per 100g of the cheapest and most expensive  
170 foods was recorded, and for items with wide availability, the cost of the cheapest and most  
171 expensive branded and none branded foods were recorded (Hanci and Jeanes, 2018).

172

173 *Nutritional content*

174 Nutritional quality of GFFs and FCG were calculated using MyFitnessPal (MyFitnessPal.com,  
175 2015). This involved foods from the eight food categories, however bread was separated  
176 into white and brown, flour into white and wholemeal, and pasta into white and wholegrain  
177 so that comparisons could be made with previous research (Miranda et al., 2014; Fry et al.,  
178 2018). Food items were entered into MyFitnessPal search bar and products were selected if  
179 listed. This app was selected as the nutritional data available from MyFitnessPal contained  
180 information obtained from product labels which should be declared according to European  
181 Union legislation 1169/2011 (EUFIC, 2011). These mandatory nutrients (per 100 grams)  
182 included energy, protein, carbohydrates, sugars, total fat, saturated fat and salt, which were  
183 systematically collected for GFFs and similar FCG. Additionally, fibre content was obtained  
184 where data was available and any food items, which could not be found, were excluded  
185 from analysis.

186

187 *Statistical Analysis*

188 Statistical analyses were performed using SPSS version 24 (IBM Corp, 2016). Normal Q-Q  
189 plots and Shapiro-Wilk test of normality ( $p > 0.05$ ) were used to assess if data deviate from  
190 a normal distribution. Independent samples t-tests were used to compare the availability  
191 and cost of GFFs at online stores and stores located around Greater Preston, and to  
192 compare the average nutritional content of GFF and similar FCG across all product  
193 categories. Equal variances were assumed if the Levene's test for homogeneity of variance  
194 was non-significant ( $p > .05$ ). A one-way analysis of variance (ANOVA) was performed to  
195 observe differences in the cost and availability of GFF compared with FCG across all store  
196 categories and independent samples *t*-tests were applied to make cost comparisons  
197 between two store categories.  $p \leq 0.05$  was considered statistically significant.

198

199 **Results**

200 A total of 27 stores were investigated, of which 19 were located around Greater Preston and  
201 eight online stores that delivered within the Greater Preston area. Out of the 27 stores  
202 visited, seven (25.9%) stocked no GFF, with the remaining 20 (74.1%) stocking at least four  
203 categories of GFF. Across the seven different store types, 2,780 GF foods were identified  
204 (crossovers occurred), 1,800 of which were available online, and 980 stocked in physical  
205 stores around Greater Preston). The number of GFFs available from each food category per  
206 store type is shown in Table 1. A one-way ANOVA revealed food category had a significant  
207 effect on availability except for flour ( $p = 0.156$ ). Store types stocking one or more GFFs

208 from every food category included online, regular, quality and health food shops (100%),  
209 with convenience stores stocking on average 87.5%. In general, budget stores and corner  
210 shops stocked no cereal-based GFFs, whilst online stores were found to stock the widest  
211 range. Of the physical stores, regular and quality stores had the highest availability and all  
212 stores stocked at least one GFF item from each food category with the exception of  
213 convenience stores, that carried no stock of GF ready meals.

214

215 Insert Table 1 here

216

217 A one-way ANOVA revealed that store type had a significant effect on cost ( $f(4,1008) =$   
218  $12.40, p < .001, \eta^2 = .047$ ). To explore the location of significance, a Tukey's HSD *post hoc*  
219 was conducted, which revealed some GFFs significantly differed in cost depending on type  
220 of store (Table 2). For example, the average cost of cereals was significantly more  
221 expensive in health food shops than regular stores (1.10 and 0.67 pence per 100g  
222 respectively,  $p < .001$ ). The cost of 1,047 GFFs within the eight food categories (cheapest  
223 and most expensive items) were compared with 750 similar foods containing gluten. Only  
224 items with A one-way ANOVA revealed cost had a significant effect on whether or not food  
225 contained gluten ( $f(1,1781) = 870.299, p < .001, \eta^2 = .328$ ). Independent *t*-tests showed  
226 that all GFFs were significantly more expensive than FCG (Table 2), costing on average 2.18  
227 times more, with bread representing the highest price difference (62.2%) and ready meals  
228 the lowest price difference (38.89%). GF bread costs an average 2.65 times more than GC  
229 bread products.

230

231 Insert Tale 2 here

232

233 A comparison of energy and macronutrients of widely available forms of GFFs (n=190) and  
234 a gluten containing equivalent (n=218) from each food category was analysed using  
235 independent t-tests and results are displayed in Table 3. Across all food categories, the  
236 nutritional content of GFF compared with a gluten free equivalent did not significantly differ  
237 between biscuits, cakes and cereals ( $p > 0.05$ ). The only significant difference in energy was  
238 observed in flour, where GF white flour contained significantly more than white flour  
239 containing gluten ( $p = 0.05$ ). In the breads, crackers, flour and white pasta categories, the  
240 average protein content in GF foods was significantly lower than their gluten containing  
241 equivalents ( $p < 0.05$ ). When compared with FCG, gluten free flours and white pasta



242 contained significantly more carbohydrates ( $p < 0.05$ ), although less carbohydrates were  
243 observed in GF white bread ( $p = 0.001$ ).

244

245 There was significantly less sugar in GF brown bread, crackers, and wholegrain pasta  
246 compared with those containing gluten ( $p < 0.05$ ). Another finding was GF ready-meals  
247 contained significantly less salt than ready-meals containing gluten ( $p = 0.002$ ). When  
248 comparing the gluten containing bread categories, more total fat was found in both GF  
249 brown and white bread ( $p = .02$  and  $p = .007$  respectively). Interestingly, GF white bread was  
250 found to contain significantly more fibre than white bread containing gluten ( $7.15 \pm 2.13$  and  
251  $2.72 \pm 1.46$  g/100g respectively,  $p < .001$ ), however, white GF pasta contained less fibre  
252 ( $p < .001$ ). In general, protein content was found to be significantly lower in 55% of GFF  
253 compared with FCG.

254

255 Insert Table 3 here

256

## 257 **Discussion**

258

### 259 *Availability of gluten-free food*

260 The present study identified 2,780 GFFs within eight food categories, across seven store  
261 types, demonstrating availability of a wide range of products, however availability varied  
262 significantly between store type ( $p < .001$ ). This could be attributable to the difference in  
263 store sizes which was not factored into the analysis. Overall, online stores offered the  
264 widest range of GFF compared to physical stores, which was also an observation made by  
265 Burden et al. (2015) and could be due to several reasons. Online stores run their operations  
266 from warehouses which have the capacity to carry large volumes of stock, their profitability  
267 margins are likely to be high due to lower running costs, their logistics are very efficient, for  
268 example fast turnaround between order time and delivery time; and marketing campaigns  
269 reach out to new customers (Fernie et al., 2010). These may all contribute to increased  
270 availability to meet consumer demand. The wider range of GFF available online offers  
271 consumers more choice and is a service which may help CD patients who have limited  
272 mobility. However, access is only available to those who are computer literate, have access  
273 to the internet and can afford delivery costs (Webb, 2013).

274

275 Of all physical stores surveyed, regular stores carried the most stock of cereal-based GFF  
276 followed by quality stores, health food shops and convenience stores, with budget stores

277 and corner shops stocking none. This is similar with previous findings, however the present  
278 study observed a wider choice, for example, Singh and Whelan. (2011), reported less  
279 availability of GF breads in regular supermarkets than the present study. Furthermore,  
280 Burden et al. (2015), observed the highest availability of GFF in quality supermarkets, and  
281 although there was more availability in quality stores in the present study, the highest  
282 availability was found in regular stores. Similarly, Hanci and Jeanes (2018) reported that GF  
283 food availability has increased in premium and online stores. This could be due to  
284 manufacturers responding to increasing demand of GFF due to the increasing prevalence of  
285 CD and associated complications. There has also been a growth in supermarkets own-label  
286 GFFs (Smith, 2010), which may offer further explanation as to why there is a wider range of  
287 GFF available than previously reported. With CD on the increase, future studies may see an  
288 increase in availability, particularly in stores with own-brand labels.

289

290 Although the present study supports a wider range of GF items available than in recent  
291 years, it also demonstrates availability is poor in budget stores and corner shops, a  
292 consistent finding in previous studies (do Nascimento et al., 2014; Hanci and Jeanes, 2018;  
293 Singh and Whelan, 2011; Burden et al., 2015). Budget stores may choose not to stock  
294 cereal-based GFF because offering them for sale at prices their shoppers are accustomed to  
295 may not be profitable. Gluten-free ingredients are expensive, and there are additional costs  
296 incurred during manufacturing such as dedicated GF factories, dedicated areas within  
297 factories, and investment in new technologies (Coeliac UK, 2016). Therefore, suppliers of  
298 GF foods may not have the flexibility to negotiate low prices and until ingredient and  
299 production costs of GFFs reduce, it is unlikely that budget stores will stock them.

300

301 A wider range of GFFs offer patients with coeliac disease more options, allowing them to  
302 choose food based on personal preferences which can contribute to adhering to a GF diet  
303 (Wright, 2017). However, this only applies to patients with higher disposable expenditures.  
304 Gluten-free food options remain limited for patients shopping on a budget, or are unable to  
305 access larger stores, or have no internet access. This study has demonstrated there are  
306 more cereal-based GFF items available than previously reported, which supports the NHS's  
307 principle of wider availability of GFF, however, availability remains poor in budget stores and  
308 corner shops, and until all stores stock 100% of common foods that are GF then availability  
309 should be considered limited.

310

311 *Cost of gluten-free food*

312 The present study found GFF within eight food categories presented significantly higher  
313 prices than FCG, costing on average 2.18 times more (118% price difference). This could  
314 be attributable to the use of more expensive grains in replacement of wheat (Jnawali et al.,  
315 2016), or the usage of innovative processing techniques to improve the nutritional quality  
316 and organoleptic properties of GFF (Padalino et al., 2016). Therefore, it is understandable  
317 that they are costlier than FCG.

318

319 A difference in cost of GFF and FCG has been a consistent finding, however the price  
320 difference in the present study is lower than previously reported (Singh and Whelan, 2011;  
321 Lee et al., 2007; Stevens and Rashid, 2008). In the UK, Burden et al. (2015) found GFF cost  
322 on average 4.1 times more than FCG. More recently, Fry et al. (2018) surveyed websites of  
323 four leading UK supermarkets as well as a leading online food retailer and found that 10  
324 common GFFs were on average 159% more expensive than FCG. The high cost of GFF is a  
325 key influential factor for adherence to a GF diet (Muhammad et al., 2017). This can be  
326 supported by responses from a patient survey which revealed that 82% of 1,000 primary  
327 care patients revealed it was harder to manage their diet due to GF foods costing more than  
328 regular foods (BSNA, 2013). Therefore, due to the CCG ceasing prescriptions for GFF in  
329 Greater Preston, local patients with coeliac disease who have heavily relied on GF  
330 prescriptions may find it difficult to adhere to a gluten free diet due to affordability.  
331 Furthermore, patients have been found to be more likely to adhere to a GF diet when  
332 obtaining their food on prescription (Hall et al., 2013).

333

334 *Nutritional content of gluten-free food*

335 The present data shows that 75% of GFF across all categories displayed differences in  
336 nutritional composition compared with FCG. A key finding was a significantly lower protein  
337 content in GF bread, crackers, flour and pasta compared with gluten-containing equivalents,  
338 with bread and flours having more than two times less protein. Gluten is an important  
339 constituent for food manufacturers, as its major storage proteins gliadin and glutenin gives  
340 food elasticity and structure, producing an end-product which is visually appealing and  
341 highly palatable (Gobbetti and Gänzle, 2013). Manufacturers use a wheat substitute, such  
342 as corn and rice flour and add proteins, gums and emulsifiers to substitute gluten to  
343 formulate GFF to represent FCG (Padalino et al., 2016). Rice flour is an inexpensive widely  
344 available ingredient which is commonly used to formulate GF breads (Sandri et al., 2017),

345 however the protein content in rice flour is almost 50% less than wheat flour (Lásztity,  
346 1983).

347

348 Lower protein content in GFF compared with FCG has been a consistent finding in previous  
349 research (Miranda et al., 2014; Fry et al., 2018; Wu et al., 2015; do Nascimento et al.,  
350 2014; Missbach et al., 2015). This has resulted in food technologists investigating the re-  
351 formulation of GFF with pseudo-cereals, which naturally contain high amounts of essential  
352 amino acids (Drzewieki et al., 2003). Gambus et al. (2002) found that replacing corn starch  
353 with amaranth flour in the re-formulation of GF bread increased its protein content by 32%  
354 with no effect on its sensory quality. A more recent study by Alvarez-Jubete et al. (2009),  
355 found that formulating GF bread with 50% rice flour or 50% potato starch with amaranth,  
356 buckwheat or quinoa flour increased protein, fibre, calcium, iron, vitamin E and polyphenol  
357 contents. Therefore, the use of pseudo-cereals in the formulation of GF foods will enhance  
358 its protein content and overall quality, providing an improved product for the consumer.  
359 Although some manufacturers have made advances in improving quality of GFFs (Wang et  
360 al., 2017), their availability on the market may be limited. This could be due to the extra  
361 cost of ingredients and the advanced technology needed in their re-formulation. Also,  
362 certain food manufacturers may choose least expensive ingredients to keep production costs  
363 at a minimum to keep costs down for consumers.

364

365 Carbohydrates are an important source of energy, and over a third of the diet should consist  
366 of starchy foods (NHS Choices, 2017). The present study found that flours and white pasta  
367 had significantly more carbohydrates than their gluten-containing equivalents. This could be  
368 due to the poor protein content in GF flours that are also used to produce pasta. When  
369 making comparisons with breads however, a significantly lower carbohydrate content was  
370 found in GF white bread compared with gluten-containing equivalents. This is an interesting  
371 finding, considering starch ingredients such as corn, cassava, potato and rice are commonly  
372 used as main ingredients or partial substitutes in GF breads. Additionally, gel forming  
373 starches such as pregelatinized starches and gums act as stabilising agents to achieve  
374 structure, texture and crumb in the absence of gliadin and glutenin (Horstmann et al.,  
375 2017). Previous studies have observed no significant differences in GF breads when  
376 comparing them with breads containing gluten (CG) (Kulai and Rashid, 2014; do Nascimento  
377 et al., 2013). This further supports the notion of application of better-quality ingredients  
378 during reformulation of GF white bread.

379

380 The present study found that ready-meals containing gluten had over 50% more salt than  
381 GF ready-meals. This could be due to GFF manufacturers attempting to meet salt targets  
382 set by the Department of Health (DH, 2014). In 2004, the World Health Organisation  
383 (WHO) reported that people were consuming too much salt (9-12g/day) and set a global  
384 goal to reduce salt intake to <5g/day by 2025 (WHO, 2016). This prompted governments to  
385 design salt-reduction initiatives, and the food industry was asked to voluntarily reformulate  
386 salt content in foods as an attempt to improve public health (DH, 2014; FSA, 2008; WHO,  
387 2004). As the production of GF ready meals is relatively recent, manufacturers can  
388 formulate foods with less salt without the consumer being affected. This may offer further  
389 explanation as to why GF ready-meals contained less salt compared to GC ready-meals.

390

391 The present study found that GF white pasta contained significantly less fibre than white  
392 pasta CG. This could be due to the removal of cereals, which can leave food with a high  
393 starch and low fibre content (Saturni et al., 2010). However, a key finding in the current  
394 study was significantly more fibre in GF white bread than white breads CG. This could be an  
395 outcome of the re-formulation of GF breads with pseudo-cereals to improve overall quality.  
396 For example, when Gambus et al. (2002), replaced corn starch with amaranth flour in GF  
397 bread, a 152% increase in fibre was observed. Furthermore, buckwheat flour has been  
398 found to improve nutritional quality of bread as well as improve its viscosity due to its high  
399 fibre content (Mariotti et al., 2013). Similar findings were reported by Fry et al. (2018),  
400 however, do Nascimento et al. (2014), found significantly lower fibre content in GF bread  
401 compared with bread CG. Therefore, based on results in the present study and by Fry et al.  
402 (2018), higher fibre content in UK GF white breads may be attributable to several factors;  
403 more manufacturers are re-formulating their GF breads to achieve a better-quality product;  
404 and GFF manufacturers may be responding to new government dietary recommendations  
405 published in 2016 regarding daily increase of fibre from 18g a day to 30g a day (PHE, 2016).  
406 Total fat content of GF breads in the present study was significantly higher than bread CG,  
407 which supports previous findings (Fry et al., 2018; Kulai and Rashid, 2014). This could be  
408 attributable to the addition of fats during formulation to create consistency, increase volume  
409 and reduce staling (Mancebo et al., 2017).

410

## 411 **Limitations**

412

413 There were several limitations for the present study. Firstly, nutritional composition of food  
414 was not obtained via direct chemical analysis. Instead, data was obtained from

415 'MyFitnessPal', which is an application that obtains nutritional information from  
416 manufacturers' labels. Only selected GFF (n=190) and FCG (n=218) products were  
417 analysed. Secondly, a comparison of micronutrients in GF foods and foods containing gluten  
418 could not be investigated using the method adopted due to micronutrient contents on labels  
419 not being a mandatory requirement under current (EU) legislation 1169/2011 (FSA, n.d.).  
420 Direct chemical analysis is the only viable way to acquire micronutrient composition of foods.  
421 Thirdly, the price and nutritional content of all food analysed was based on g/100g and  
422 serving sizes have not been factored in to the analysis. Fourth, surveillance of foods in  
423 physical stores was based on observations of items which were displayed on the shelves,  
424 and any foods which had not been replenished may have been missed. The authors also  
425 recommend that the full range of GF breads and the price difference between types of GF  
426 bread in comparison with regular equivalents should be further studied. Finally, the sample  
427 size of stores and surveyed GFFs were limited to 27 stores within the Greater Preston area.

428

## 429 **Conclusion**

430

431 The present study has shown wider availability of cereal-based GFF, however access  
432 remains poor in budget stores and corner shops which are reported to be frequented by  
433 people on lower incomes. The price of GFF remains significantly high compared with FCG,  
434 which has been shown to affect some patients' adherence to a GF diet. Nutritional quality  
435 has improved based on previous research, and advantages were observed in fibre content,  
436 however, protein quality was significantly lower in 55% of GFFs analysed, and a higher fat  
437 content was found in breads. With increasing prevalence of CD, a demand for more GFFs  
438 may see manufacturers reduce their prices further as the market becomes more  
439 competitive. This is quite promising, however, ingredients equal in quality to FCG may be  
440 compromised to keep production costs down which could result in larger disparities in  
441 nutritional quality. In view of restrictions to GFF prescriptions, further longitudinal studies  
442 are required to evaluate the true impact that limiting access to GFF will have on health and  
443 adherence across all population groups. Therefore, full prescriptions for GF food should still  
444 be available for primary care patients with CD and should remain until availability,  
445 accessibility, price and nutritional content of GF food is improved.

446

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