The nutritional quality of wholegrain and multigrain breads is not necessarily better than white breads: the case of gluten-free and gluten-containing breads

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Abstract

Despite the importance of breads through the history, the wide range of options might lead to a choice dilemma from health-conscious consumers when purchasing bread. In this study, commercial white, wholegrain and multigrain regular breads, sold in Europe, were collected, and classified into gluten-free and gluten-containing categories. For gluten-free-breads, no significant differences were found in energy, saturated fatty acids, sugar, fiber and salt between white and wholegrain breads regardless of the mention "multigrain". For gluten-containing, carbohydrates and fibers differed between white and wholegrain breads, while when considering multigrain presence all the nutritional composition varied significantly. Nevertheless, the mentions wholegrain and multigrain on gluten-free and gluten-containing breads do not guarantee a better nutritional quality compared to white bread. Gluten-free breads showed increased fiber, and decreased carbohydrates, sugar and energy which are comparable to gluten-containing wholegrain breads. This underlines the improvement of gluten-free breads and suggests further investigations to increase protein content.

Keywords: bread, multigrain, wholegrain, fiber, gluten-free, gluten-containing

1. Introduction

Bread is a staple food consumed worldwide and it is traditionally made using basic ingredients (i.e., wheat flour, water and yeast) providing essential nutrients (e.g., energy, protein and carbohydrates) in human diet. Obesity and other metabolic and cardiovascular diseases have been related to bread consumption. Nevertheless, bread is still a main asset in worldwide diet despite the lifestyles' changes. Bread's recipes and processes have been subjected to constant transformation to respond people demands. This rapid adaptation of the breads to cultures, countries and lifestyles, make breads an interesting case of food study and considering their impact on the diet and health, it is important a deeper analysis of what is in the market and if those breads are filling the social demands regarding aspects like nutrients, healthiness, sustainability. The use of additional ingredients beside those basic and the advent of new technologies have allowed a wide diversification of bread products over the centuries (Paciulli et al. 2021). As nutrients vehicles, breads have been the election carrier to solve nutrients deficiencies in the population through enrichment or fortification. Sensory appealing is driven by the use of different ingredients to create new flavors (and sensory experiences) such as microalgae, pulses, sourdoughs, and wholegrain flours (Naqash et al. 2017; Graça et al. 2018; Stantiall and Serventi 2018).

Wholegrains are considered as significant components of a healthy diet since they are valuable sources of phytochemicals such as phenolic compounds, antioxidants, phytic acid and sterols, water-soluble fiber (such as β-glucan and arabinoxylan), minerals, and vitamins (Mridula et al. 2015). There is increasing evidence that the consumption of wholegrain can be related to reductions in markers of overweight, obesity and type 2 diabetes (Della Pepa et al. 2018; Wang et al. 2020). Nevertheless, European Food Safety Authority (EFSA) noted that a cause and effect relationship could not be established between wholegrain and specific health effects due to variability of results of the randomized controlled trials submitted to substantiate this association (Agostoni et al. 2010). Precise association is difficult to determine due to different epidemiological methodologies, different methods of determining wholegrain intake, and different definitions of a wholegrain food (Kissock et al. 2021). In Europe, there is no legally recognized definition for wholegrain foods. For instance, wholegrain foods must contain ≥50% of dry matter from wholegrain ingredients in Scandinavian countries, at least ≥51% in UK, ≥90% in Germany, and 100% in some countries such as Netherlands and Spain (Ross et al. 2017). In 2010, The Healthgrain European Union Integrated Research Project recommended that a food may be labeled as "wholegrain" if it contains ≥30% wholegrain ingredients in the overall product and contains more wholegrain than refined grain ingredients on a dry-weight basis (Van Der

Kamp et al. 2014). This definition was intended to be useful in the context of nutritional guidelines and for labelling purposes.

In Europe, there is no legislation regarding labelling wholegrain food products (Mathews and Chu 2020). The more recent European commission notice (2017/C 393/05) provided guidelines on the application of the principle of quantitative ingredients declaration (European Commission Directorate-General for Health and Food Safety 2017). Thus, if "wholegrain" is mentioned on the label, the levels of whole-grain ingredients must be listed on the packaging as part of mandatory information. However, this information is mentioned within the list of ingredients list, and thus it might limit its visibility to consumers interested in products containing more wholegrain (Ross et al. 2017). In 2021, Whole Grain Initiative recommended that foods containing 25–50% whole-grain ingredients based on dry weight, may make a front-of-pack claim on the presence of wholegrain but cannot be designated 'wholegrain' in the product name (Van Der Kamp et al. 2021) (Van Der Kamp et al. 2021). They recommend to apply the rule of nutrient claim in a food (such as "source of" and "high" dietary fiber), where the amount required for the "high" qualification is twice the amount required for "source of" (Van Der Kamp et al. 2021)).

The market for wholegrain breads is growing (Market Data Forecast 2021) particularly amongst obese, diabetic and elderly populations (Călinoiu and Vodnar 2018; Capurso and Capurso 2019). Wholegrains breads are generally considered healthier choices compared to white breads made with refined flours (Avberšek Lužnik et al. 2019). This topic is still debatable, and results differ among studies conducted comparing the impact of these breads intake on human health. Considering glycemic index, whole wheat bread is recommended over the white bread (Nirmala Prasadi and Joye 2020; Romão et al. 2021). It is assumed that the mechanism of action of wholegrains is associated with their dietary fibers promoting satiety and contributing into lipogenesis and fat storage (McRae 2017). Several studies reported contradictory results, where some findings sustained that no significant difference between refined white bread and whole wheat bread (Jenkins et al. 1988; Zafar et al. 2020), while other reported a lower glycemic index in wholegrain breads (Avberšek Lužnik et al. 2019). Furthermore, it was reported that replacing refined flours with other grains or seeds such as pulses might result to reduced glycemic of gluten-free and gluten-containing breads (Zafar et al. 2020; Boukid et al. 2019; Udani et al. 2009). Commonly, breads made with blends of flours are commercially designed "multigrain" as they contain more than one type of grains such as wheat, maize, millet, sorghum, oat, barley, maize, and rice (Sagar and Pareek 2021). Some of the multigrain flours may include wholegrain ingredients but the term multi-grain does not necessarily ensure that the food certainly contained wholegrain ingredients (Mridula et al. 2015). Consumers might be confused between "multigrain" and "wholegrain", which are not interchangeable terms.

Therefore, the present study has a dual objective. The first aim is to evaluate the nutritional composition of commercial regular breads sold in the European market by retrieving information from their packaging and to investigate differences in terms of energy, macronutrients (carbohydrates, sugars, fat, saturates "SFA", proteins and fibers) and salt contents among gluten-free and gluten containing bread products. This study considered both gluten-free and gluten-containing products separately to identify similarities/ dissimilarities among white, multigrain and wholegrain breads. Then, a section was allocated to compare gluten-free to gluten-containing products to evaluate if the efforts in formulations and processing of gluten-products enabled parity in nutritional value with gluten-containing products. This analysis will further provide a better understanding of the nutrient's intake of the European population through the consumption of a staple food, in this case bread.

2. Material and methods

2.1. Data collection & extraction

The search was carried out in January 2022, by consulting the Mintel Global New Product Database (Mintel GNPD-Mintel Group Ltd., London, UK, https://portal.mintel.com/portal/). The Mintel GNPD search was conducted using the parameters specified in Table 1 available during 2021 in Europe (44 countries including UK). Out of the super-category of "foods", the search was concerted on the category "Bread & Bread Products". The term "slices" was added as a filter to narrow the research to regular French ("pain de mie") leavened white breads. Similar setting was used for multigrain breads (made with more than two types of grains) with the use of "multigrain bread" as product name. Non multigrain products refer to product made using one type of grain. Wholegrain breads were retrieved using the same setting with specifying that product designation include the mention "wholegrain". Non wholegrain products refer to products made only with refined flours and no wholegrain flour was used. Nutritional facts, i.e., energy (kcal/100 g), total fat (g/100 g), saturated fatty acids-SFA (g/100 g), carbohydrates (g/100 g), sugars (g/100 g), fiber (g/100 g); protein (g/100 g), and salt (g/100 g), were set as a filter for all the products. The results of all searches were exported to Microsoft Excel (Microsoft Office, Washington, WA, USA). Furthermore, brands and countries of products are reported in Table S1. The search was conducted for gluten-containing and gluten-free products. For gluten-containing (GC) and gluten-free (GF) products, breads were grouped as white bread (WB), wholegrain (WGB) and containing multigrain (MG) or non-containing multigrain (NMG).

2.2. Data extraction

For all the selected products, the nutritional labelling of all products, energy (kcal/100 g), total fat (g/100 g), saturated fatty acids-SFA (g/100 g), carbohydrates (g/100 g), sugars (g/100 g), fiber (g/100 g); protein (g/100 g), and salt (g/100 g) were collected. All products country, brand and list of ingredients were also collected.

2.3. Statistical data analysis

The statistical analysis was carried out using the Statistical Package for Social Sciences software (IBM SPSS Statistics, Version 25.0, IBM corp., Chicago, IL, USA). All data were checked for normality using the Shapiro–Wilk test. Energy and nutrient contents per 100 g of products were analyzed using Kruskal–Wallis non-parametric one-way ANOVA for independent samples with multiple pairwise comparisons when considering 4 bread categories (NMG-WB, NMG-WGB, MG-WP and MG-WGB) for gluten-free and gluten-containing products. Mann–Whitney non-parametric test were used for two independent samples, white “WB” (NMG-WB+MG-WB) vs wholegrain “WGB” (NMG-WGB+MG-WGB). A principal component analysis (PCA) was performed based on the correlation matrix to compare gluten-free breads to those gluten-containing.

Table 1. Search strategy used on Mintel Global New Product Database.

Criteria	Gluten-free white bread	Gluten-free wholegrain bread	Gluten-free multigrain white bread	Gluten-free multigrain wholegrain bread	Gluten-containing white bread	Gluten-containing wholegrain bread	Gluten-containing multigrain white bread	Gluten-containing multigrain wholegrain bread
Code	GF-NMG-WB	GF-NMG-WGB	GF-MG-WB	GF-MG-WGB	GC-NMG-WB	GC-NMG-WGB	GC-MG-WB	GC-MG-WGB
Sub-Category	Bread & Bread Products							
Product name	White bread	Wholegrain bread	White bread	Wholegrain bread	White bread	Wholegrain bread	White bread	Wholegrain bread
Filter	Text: Slices	Text: Slices	Text: Multigrain Slices	Text: Multigrain Slices	• Ingredient: wheat flour • Text: slices	• Ingredient: wheat • Text: slices	• Ingredient: wheat flour • Text: slices, multigrain	• Ingredient: wheat flour • Text: slices, multigrain
Claim	Gluten-free	Gluten-free	Gluten-free	Gluten-free	-	-	-	-
Region	Europe							
Nutrition (from the label)	Energy (kcal/100 g); Fat (g/100 g); Saturated Fatty acids-SFA (g/100 g); Carbohydrates(g/100) g; Sugars (g/100 g); Fiber (g/100 g); Protein (g/100 g); Salt (g/100 g).							

GC-NMG-WB: gluten-containing non multigrain white bread; GC-NMG-WG: gluten-containing non multigrain wholegrain bread; GC-MG-WB; gluten- containing multigrain white bread; GC-MG-WGB: gluten-containing multigrain wholegrain bread; GF-NMG-WB: gluten-free non multigrain white bread; GF-NMG-WG: gluten-free non multigrain wholegrain bread; GF-MG-WB; gluten-free multigrain white bread; GF-MG-WGB: gluten-free multigrain wholegrain bread.

3. Results and discussion

3.1 Nutritional profile of gluten-free breads

Nutritional profile of gluten-free GF-WB (n = 71) and GF-WGB (n= 53) sold in the EU market is outlined in Figure 1. To understand if products designed "multigrain" differ from breads without this designation, GF-WB (n=71) were divided into GF-NMG-WB (n=44) and GF-MG-WB (n=27). Similarly, GF-WGB (n=53) were divided into GF-NMG-WGB (n=49) and GF-MG-WGB (n=4). Figure 2 illustrates the results of the four categories examined.

Results of energy showed no significant difference between GF-WB and GF-WGB (Figure 1), and neither when going deeper within the four groups (GF-NMG-WB, GF-MG-WB, GF-NMG-WGB and GF-MG-WGB) (Figure 2). Fat content was found higher in WGB compared to WB (Figure 1). This variability can be attributed in part to higher amount of fat in wholegrains due to the preservation of germ rich in fat and in second part to differences in the amounts of fat deriving from flours/ starches/ seeds in bread formulations. More specifically, GF-NMG-WGB had the highest amount, and no significant differences were found among GF-NMG-WB, GF-MG-WB, and GF-MG-WGB (Figure 2). Nevertheless, no significant differences were found in SFA between WGB and WB (Figure 1). Likewise, Figure 2 showed that even dividing these two categories in those designed multigrain and those without, similar results were observed. This underline that similar amounts of SFA were added to gluten-free formulations. Indeed, vegetable oils mostly sunflower oil and rapeseed oil were commonly used in these formulations. As illustrated in Figure 1, carbohydrates were found higher in GF-WB compared to GF-WGB. This difference is due to higher amounts of starchy ingredients used in GF-WB. GF-NMG-WGB showed the lowest amount, while the remaining categories showed similar amounts, due to the inclusion of higher amounts of wholegrain flours. Indeed, NWG-WGB are made from wholegrain rice flour (n=26), whole buckwheat flour (n=10), wholegrain amaranth flour (n=7), wholegrain millet flour (n=4), and whole quinoa flour (n=2) (Table 2). Compared to GF-NMG-WB, similar ingredients were used in GF-MG-WB and the use of wholegrain flours was at low levels. Probably, this can contribute to the absence of difference between both categories besides limited number of samples designed "multigrain" white breads. On the other hand, GF-NMG-WB were made chiefly from refined flours [rice flour (n=40), millet flour (n=11), quinoa flour (n=13), sorghum flour (n=1), buckwheat flour (n=11), oat flours (n=1), and teff flour (n=1)] and starches [corn starch (n=40), rice starch (n=17), potato starch (n=22), and tapioca starch (n=12)]. Furthermore, few products contained wheat starch (1 product) and oat ingredients (4 products), presumably due to their unsafe reputation for celiac patients. Noteworthy, wheat starch and oat ingredients can be considered suitable for a gluten-free diet (if the maximum gluten contamination level do not exceed 20 ppm) in Europe based on European Commission Regulation (EC) 41/2009 (European Commission Regulation (EC) 41/2009 2009).

Regarding sugar content, no significant difference was found among the bread groups in Figure 1 and Figure 2. Probably, this can be attributed to similar amounts of added sugars to gluten-free regular breads as substrate for yeasts during fermentation (Roman et al. 2019).

Noteworthy, GF-WGB and GF-WB showed high values of fiber content (up to 16 g/ 100g), which is due to the different types of purified fibers that are added in the recipes, namely sugar beet fiber, psyllium, plantain fiber, citrus fruits fiber, apple fiber, chickpea fiber, corn fiber, and bamboo fiber, and inulin (Table 2). No significant differences in fiber content were found between GF-WB and GF-WGB probably due the frequent use of plant fibers in both categories as previously reported (Allen and Orfila 2018a). These fibers are incorporated to improve the nutritional value of gluten-free breads made chiefly from starchy ingredients and thus to reduce rapidly digestive starch and potentially glycemic index (Djordjević et al. 2021). Particularly, psyllium was frequently incorporated due to its effectiveness in reducing risks of health issues such as hypercholesterolemia, type 2 diabetes, obesity, constipation, diarrhea, hemorrhoids, and irritable bowel syndrome (McRorie et al. 2021). Additionally, this ingredient is used in breads as a natural and clean label alternative to gums and hydrocolloids that must be labelled as additives (Belorio and Gómez 2020). Furthermore, they play a functional role in increasing water holding capacity of the dough and increasing breadcrumb moistness (Sciarini et al. 2017). Furthermore, seeds rich in fibers were added in their intact forms (for topping) and as flours (as functional ingredient). Among oilseeds, sunflower seed, linseed, sesame seed, flaxseed, poppy seed, chia, nigella seeds, and pumpkin seeds are the most used. These seeds were reported to improve the nutritional characteristics of gluten-free breads by contributing into fiber contents (Huerta et al. 2019) and functional properties as fat substitutes, due to their water absorption capacity and rheological properties (Korus et al. 2015; Huerta et al. 2019). Depending on their level of addition, they contribute into the modulation of the rheology of the doughs and the end-quality of breads including volume, texture, and organoleptic characteristics (De Lamo and Gómez 2018). Figure 2 showed that GF-NMG-WGB and GF-MG-WGB had slightly higher amounts of fiber compared to NMG-WB and MG-WB. The differences can be potentially attributed to the use of wholegrain flours as a main ingredient.

Protein was found higher in GF-WGB compared to GF-WB. Specially, GF-NMG-WB had the lowest value, while the remaining categories were statistically similar. These differences might be attributed to the different content of proteins of the flours used. Furthermore, protein fortification is a common practice in gluten-free bread formulations. Proteins are added in different forms isolates, such as soy proteins, whey protein and egg white. Furthermore, legumes and seeds can contribute into the increase of protein (Huerta et al. 2019). No significant difference in salt contents were observed. In general, in gluten free breads, salt content is added as a flavor enhancer and do play a minor functional role, in opposition to what occurs in gluten-containing breads.

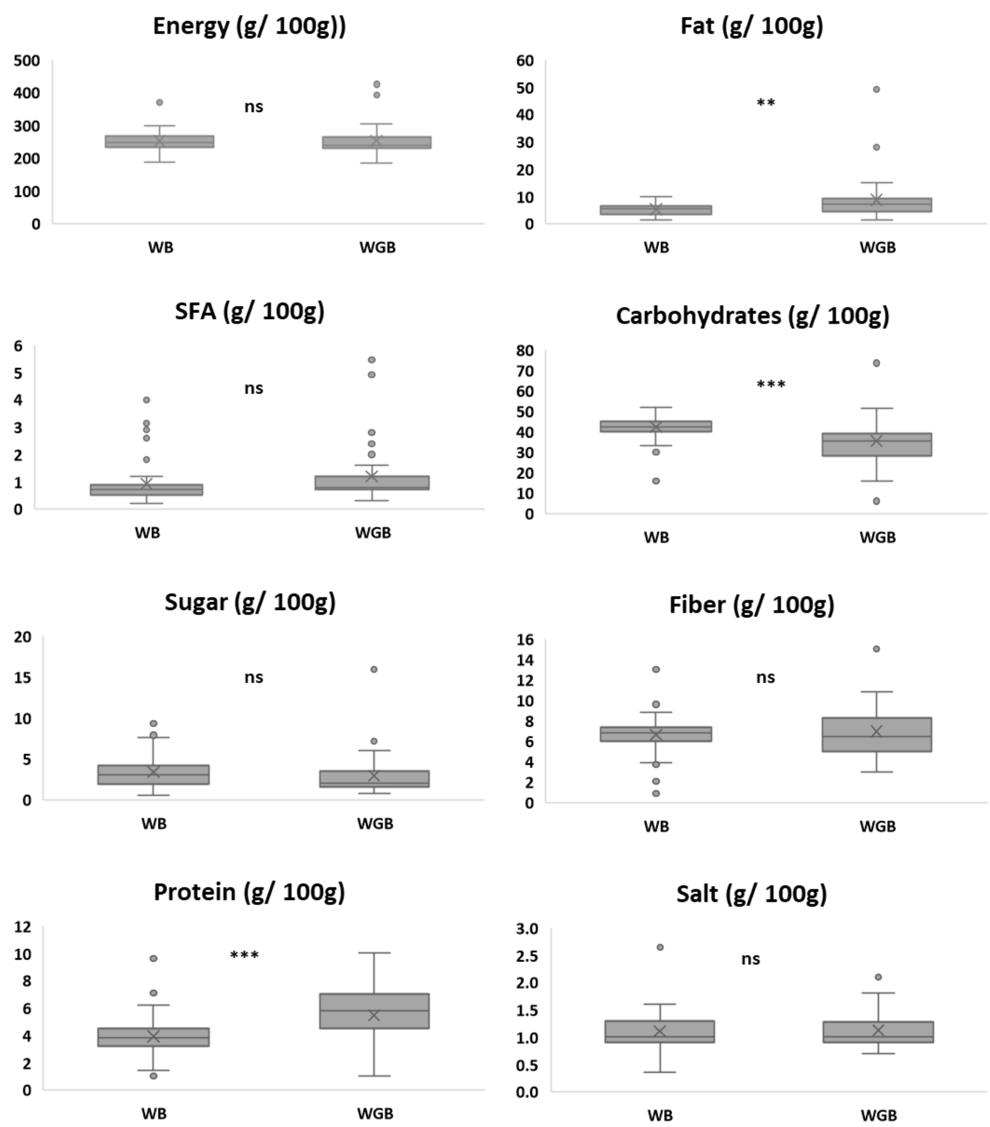

Figure 1: Nutritional profile of white (WB) (N = 71) and wholegrain (WGB) (N = 53) gluten-free breads sold in the EU market. The box-plot legend: the box is limited by the lower (Q1 = 25th) and upper (Q3 = 75th) quartile; the median is the horizontal line dividing the box; Whiskers above and below the box indicate the 10th and 90th percentiles; outliers: the points outside the quartile 10–90th percentiles. *p < 0.05, **p < 0.01, ***p < 0.001, ns non-significant (p > 0.05). WB: white brad; WGB: wholegrain bread.

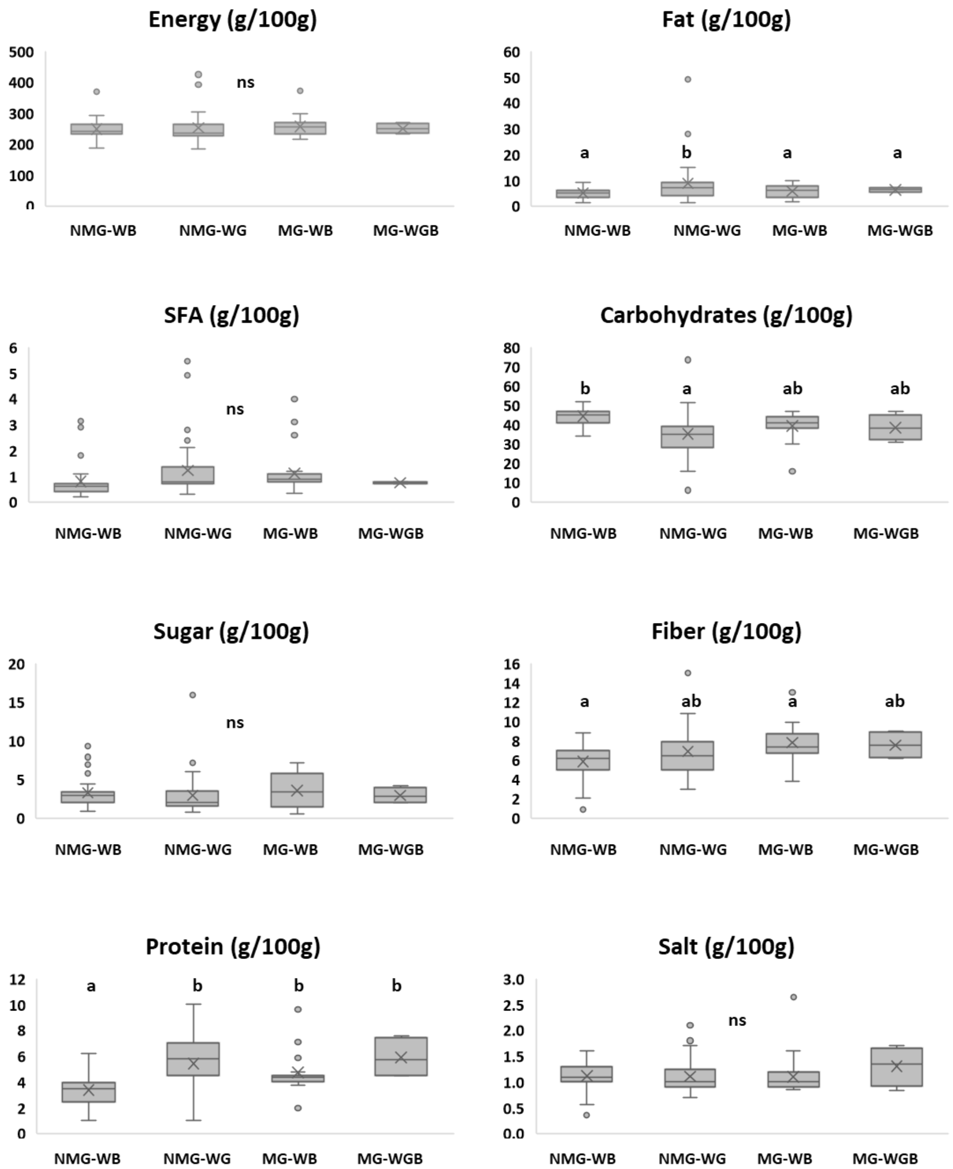

Figure 2: Nutritional profile of gluten-free white (N = 44) and wholegrain (N = 49) breads without the designation "multigrain" vs multigrain white (N = 27) and multigrain wholegrain (N = 4) breads sold in the EU market. The box-plot legend: the box is limited by the lower (Q1 = 25th) and upper (Q3 = 75th) quartile; the median is the horizontal line dividing the box; Whiskers above and below the box indicate the 10th and 90th percentiles; outliers: the points outside the quartile 10–90th percentiles. Different letters indicate significant differences among bread types, $p < 0.05$. ns non-significant ($p > 0.05$). NMG-WB: non multigrain white bread; NMG-WG: non multigrain wholegrain bread; MG-WB; multigrain white bread; MG-WGB: multigrain wholegrain bread.

Table 2: Grains and seeds used in making gluten-free breads.

	White bread	Wholegrain bread	Multigrain white bread	Multigrain wholegrain bread
Wholegrain flours	-	Wholegrain rice flour (n=26), whole buckwheat flour (n=10), wholegrain amaranth flour (n=7), wholegrain millet flour (n=4), whole quinoa flour (n=2),	Wholegrain rice flour (n=2) (0.9 and 1.4%),	Whole rice flour (n=2) (1.4-34%), wholegrain, buckwheat flour (7%) (n=2)
Refined grain flours	Rice flour (n=40), millet flour (n=11), quinoa flour (n=13), sorghum flour (n=1), buckwheat flour (n=11), oat flours (n=1), teff flour (n=1),	Rice flour (n=46), millet flour (n=11), amaranth flour (n=5), quinoa flour (n=15), buckwheat flour (n=12), carob flour (n=2), oat flour (n=1), chestnut flour (n=3),	Rice flour (n=22), millet flour (n=9), amaranth flour (n=1), quinoa flakes/flour (n=12), sorghum flour (n=6), buckwheat flour (n=7) carob flour (n=2), oat flakes/flours (n=2),	Millet flour (n=2), buckwheat flour (n=2), rice flour (n=3),
Pulses flours	Lentil flour (n=1)	Lentil flour (n=1), bean flour (n=2)	Bean flour (n=1), lentil flour (n=1)	Lupine flour (n=1)
Starches	Corn starch (n=40), rice starch (n=17), potato starch (n=22), tapioca starch (n=12), wheat starch (n=1)	Corn starch (n=22), rice starch (n=7), potato starch (n=8), tapioca starch (n=4), cassava starch (n=6)	Corn starch (n=24), rice starch (n=17), potato starch (n=5), tapioca starch (n=3)	Rice starch (n=2), corn starch (n=2),
Fiber	Psyllium (n=28), citrus fruits fiber (n=2), apple fiber (n=6), bamboo fiber (n=4)	Sugar beet fiber (n=3), psyllium (n=18), plantain fiber (n=2), citrus fruits fiber (n=2), apple fiber (n=6), chickpea fiber (n=1), corn fiber (n=1), bamboo fiber (n=3), inulin (n=4)	Sugar beet fiber (n=1), psyllium (n=1), plantain fiber (n=1), citrus fruits fiber (n=3), apple fiber (n=5)	Psyllium (n=2)
Seeds	Soybean flour (n=22), flaxseed flours (n=4), linseed (n=7), pumpkin seeds (n=1), carob seed flour (n=1), chestnut flour (n=1)	Sunflower seed flour (n=20), linseed flour (n=22), flaxseeds flour(n=5), chia seeds (n=20), sesame seeds (n=12), pumpkin seeds (n=11)	Soybean flour (n=15), sunflower seed (n=26), linseed (n=22), sesame seed (n=1), flaxseed (n=6), poppy seed (n=5), chia (n=2), nigella seeds (n=1), pumpkin seeds (n=3), chestnut flour (n=2)	Sunflower seeds (n=4), soy flour (n=1), linseed (n=3), chia seeds (n=2),

3.2 Nutritional profile of gluten-containing breads

Figure 3 illustrates the nutritional profile of gluten-containing GC-WB (n = 57) and GC-WGB (n = 59) sold in the EU market. GC-WB were further subdivided into GC-NMG-WB (n=29) and GC-MG-WB (n=28), to discriminate between those non-containing or containing multigrains. GC-WGB (n=59) were classified into GC-NMG-WGB (n=28) and GC-MG-WGB (n=31).

No significant differences were observed in energy, fat, SFA, sugars, protein and salt, except carbohydrates (Figure 3). Even though not all products have reported the amounts of wholegrains in their list of ingredients, it can be speculated that the added amounts were quite low and did not induce relevant changes into the nutritional profile. It can be also hypothesized that the high intra-variability within white breads vs wholegrains breads due to different formulations (Table 3) and different manufactures (Table S1) masked the inter-variability. This aligns with previous results focused on products sold in the Italian market showing WG inclusion cannot be always considered a marker of the overall nutritional quality of foods (Dall'asta et al. 2022). Figure 4 particularly shows that GC-MG-WB provided the highest energy which can be related to its highest fat and SFA contents compared to the rest types. Carbohydrates were found significantly higher in GC-WB compared to GC-WGB (Figure 3), and more particularly GC-MG-WGB showed significantly the lowest value, while other breads were found similar. This can be attributed to the high amounts of wholegrain included in the formulations (up to 62%, Table 2) resulting in lower carbohydrates and sugars. Fiber content was found significantly lower in GC-NMG-WB compared to the rest of breads. Protein content was found similar, independently on the presence/absence of the mention "multigrain". No differences were found in salt content, except GC-MG-WB that had the highest amount.

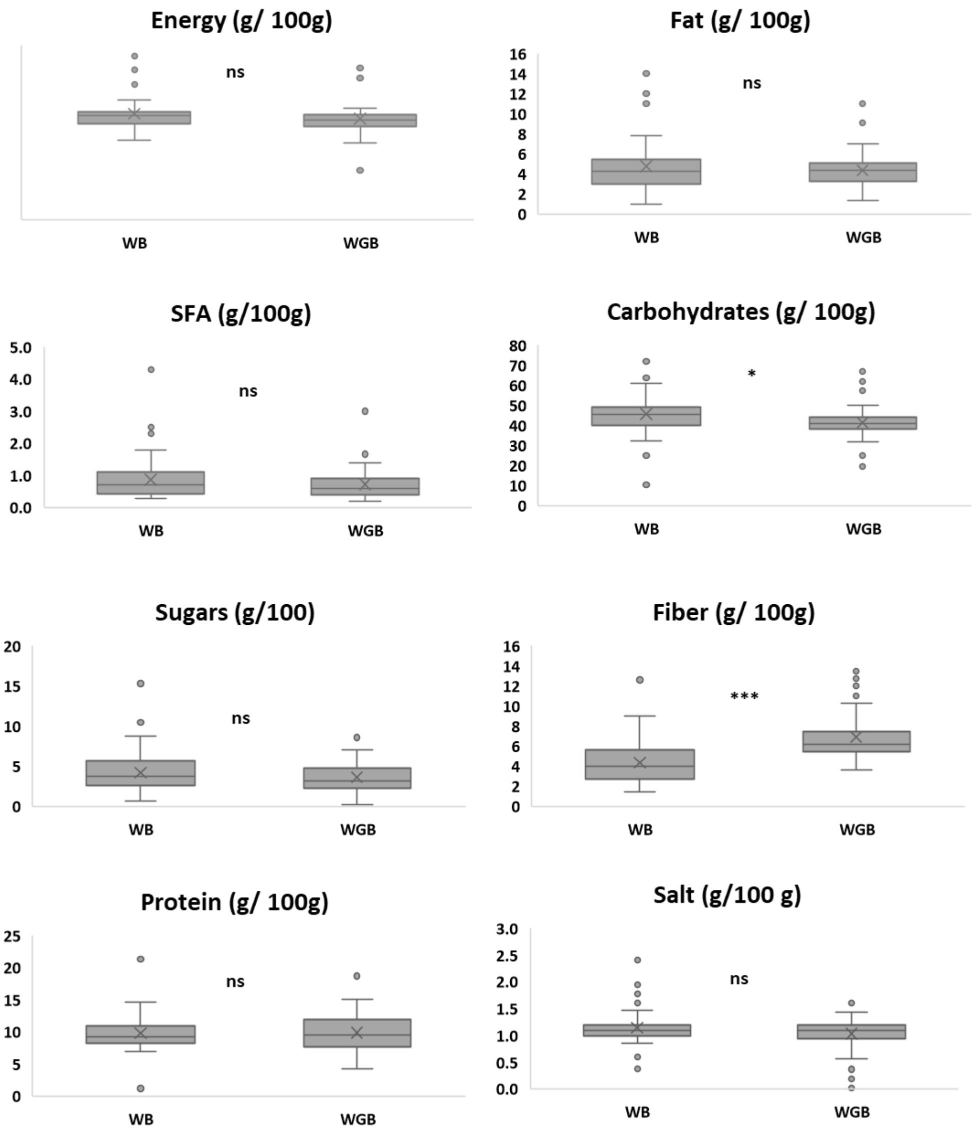

Figure 3: Nutritional profile of white (N = 57) and wholegrain (N = 59) gluten-containing breads sold in the EU market. The box-plot legend: the box is limited by the lower (Q1 = 25th) and upper (Q3 = 75th) quartile; the median is the horizontal line dividing the box; Whiskers above and below the box indicate the 10th and 90th percentiles; outliers: the points outside the quartile 10–90th percentiles. *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$, ns non-significant ($p > 0.05$). WB: white bread; WGB: wholegrain bread.

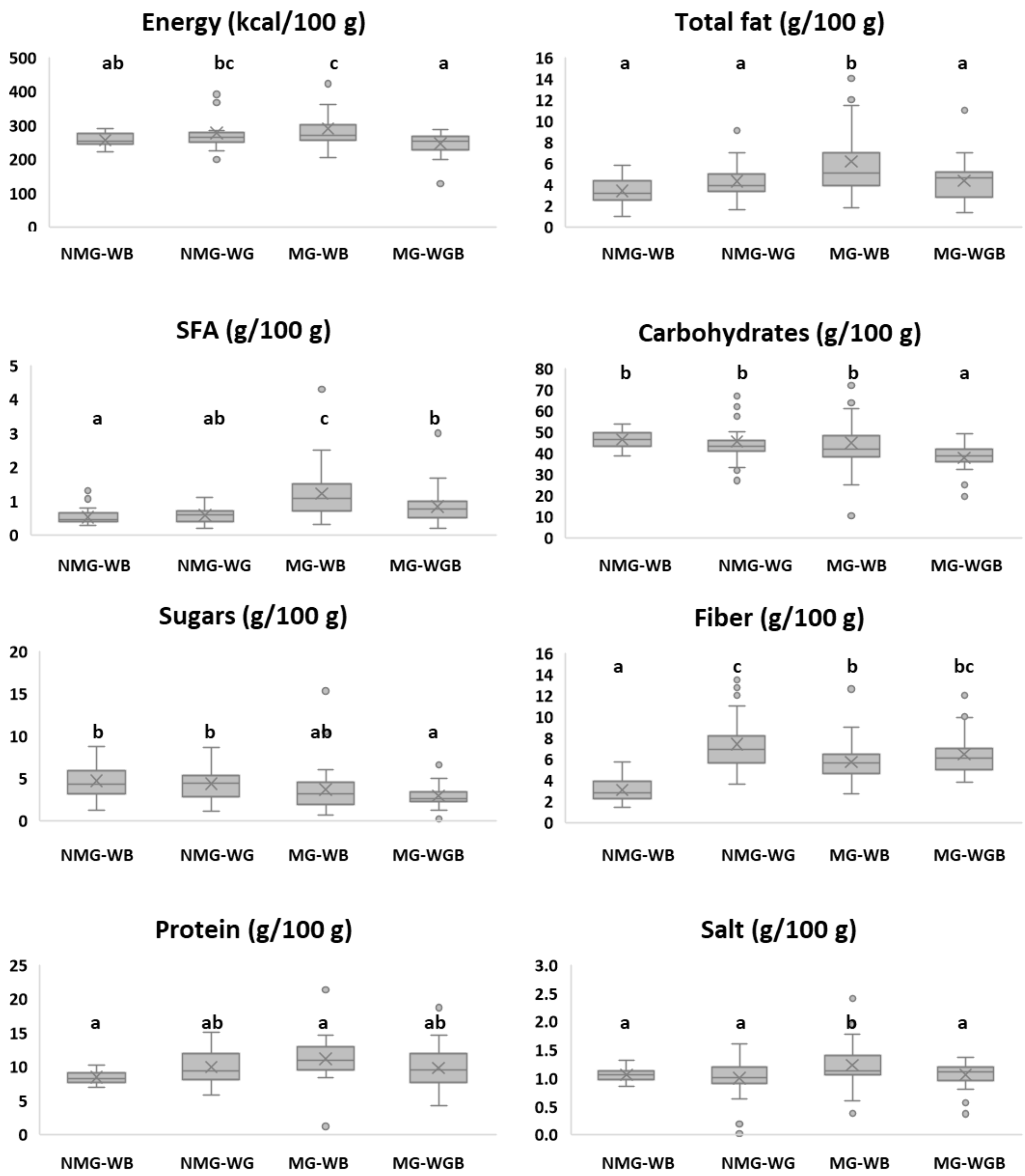

Figure 4: Nutritional profile of white (N = 29), wholegrain (N = 28), white multigrain (N = 28), and multigrain wholegrain (N = 31) gluten-containing breads sold in the EU market. The box-plot legend: the box is limited by the lower (Q1 = 25th) and upper (Q3 = 75th) quartile; the median is the horizontal line dividing the box; Whiskers above and below the box indicate the 10th and 90th percentiles; outliers: the points outside the quartile 10–90th percentiles. Different letters indicate significant differences among bread types, $p < 0.05$. NMG-WB: non multigrain white bread; NMG-WG: non multigrain wholegrain bread; MG-WB; multigrain white bread; MG-WGB: multigrain wholegrain bread.

Table 3: Grains and seeds used in making gluten-containing breads.

	White bread	Wholegrain bread	Multigrain white bread	Multigrain wholegrain bread
Whole cereal grain flours	Whole wheat flour (n=2)	Whole wheat flour (n=28) (26-100%), wholegrain wheat flour sourdough (n=2) (20%), sprouted wholegrain wheat flours (n=1) (12%), semi-whole flour (n=1), wheat bran (n=2) Wholegrain rye flour (15-57%) (n=2), wholegrain sprouted rye grains (19%) (n=1), wholegrain rye malt (n=2),	Wholegrain wheat flour (n=4) (2.4-20%), wholegrain rye flour (n=2) (1.2%),	Wholewheat flour (n=15) (9-62%), wholegrain rye flour (n=8), wheat bran (n=3), wheat germ (n=7), wheat fiber (n=2), oat fiber (n=2),
Refined cereal grains flours	Wheat flour (60-73%) (n=29), fermented wheat flour (n=1), rye flour (n=1), barley flour (n=1)	Wheat Flour (n=28), malted rye flour (n=2), rye flour (n=7), black rice flour (n=1), oat flour (n=1), malted and roasted barley flour (n=2), corn flour (n=1), barley flour (n=4), spelt wheat flour (n=1), buckwheat flour (n=1), kamut flour (n=2), quinoa flour (n=2), millet flour (n=2)	Wheat flour (n=28) (25-58%), barley flour (n=24), oat flour (n=19), rye flour (n=21), spelt flour (n=1), buckwheat flour (n=3), quinoa flour (n=1), millet (n=5), corn (n=7)	Wheat flour (n=31), rye flour (n=14), barley flour (n=27), oat flour (n=31), spelt (n=3), buckwheat (n=7), corn (n=10), rice (n=), quinoa (n=2), millet (n=12), amaranth (n=1), corn (n=1)
Oil seeds	Soybean flour (n=12), seed mix (n=1) (sunflower seed, sesame seed, linseed)	Sunflower seed flour (n=2), linseed flour (n=2), flaxseeds flour (n=2), chia seed (n=1)	Soybean flour (n=2), sunflower seed (n=24), linseed (n=24), sesame seed (n=24), flaxseed (n=6), poppy seed (n=5), chia (n=2)	sunflower seeds (n=27), soy flour (n=5), linseed (n=24), pumpkin seed (n=4), sesame seeds (n=9), poppy seeds (n=2), chia seeds (n=2),
Pulses	Mix of pulses flour (n=1) (black bean red bean, navy bean, chickpea, yellow lentil), fava flour (n=1), bean flour (n=1)	-	Lupin flour (n=1)	-

3.3. Gluten-containing vs gluten free

Considering gluten-free and gluten-containing categories, PCA was performed to visualize the variability/ similarity in nutritional profiles of the different bread types (Figure 5). The total accumulative variance from the first two principal components accounted for 70% of the total variance; the first component accounted for 41%, and the second component accounted for 29%. The first component was expressed as function of fats, SFA, sugars, carbohydrates, salt and fibers, while the second component was expressed as a function of energy, proteins, carbohydrates, sugars, fat and fibers (Figure 5A). The projection of the bread types on the factorial space enabled the separation of gluten-free and gluten-containing breads based on PC2 (Figure 5B). Indeed, it was readily evident the aggregation of gluten-free products in the negative side of PC2, while gluten-containing products were located in the upper side except GC-MG-WGB. This shows the significant variability in the nutritional composition between both categories. Indeed, protein content was found lower in the gluten-free breads in alignment with previous studies focused on products sold in Australian supermarkets (Wu et al. 2015; Hughes et al. 2020). Further studies are still required to increase protein content through the use of pulses or their protein isolates to avoid beany flavors at high level of addition that might hamper their organoleptic properties (Boukid et al. 2021). Notably, GC-MG-WGB were located near the gluten-free breads due to similarities in nutritional profiles, i.e., low carbohydrates and high fibers compared to those gluten-containing breads. Unexpectedly, gluten-free breads were less dense energy in consistence with previous findings focused on breads sold in the Italian market (Angelino et al. 2020). This can be due to the efforts made for improving the nutritional quality of gluten-free bakery products such as reducing starchy ingredients (Morreale et al. 2018). Previously reported studies indicated that gluten free breads were higher in fat and sugar contents (Matos and Rosell 2015; Allen and Orfila 2018~~b~~), Present analysis indicates that recipes of commercial products have been improved making and resulted more balanced and closer to the gluten-containing breads. Similar conclusions were drawn for Norwegian products showing that fat and sugars contents were not different between the groups (Myhrstad et al. 2021).

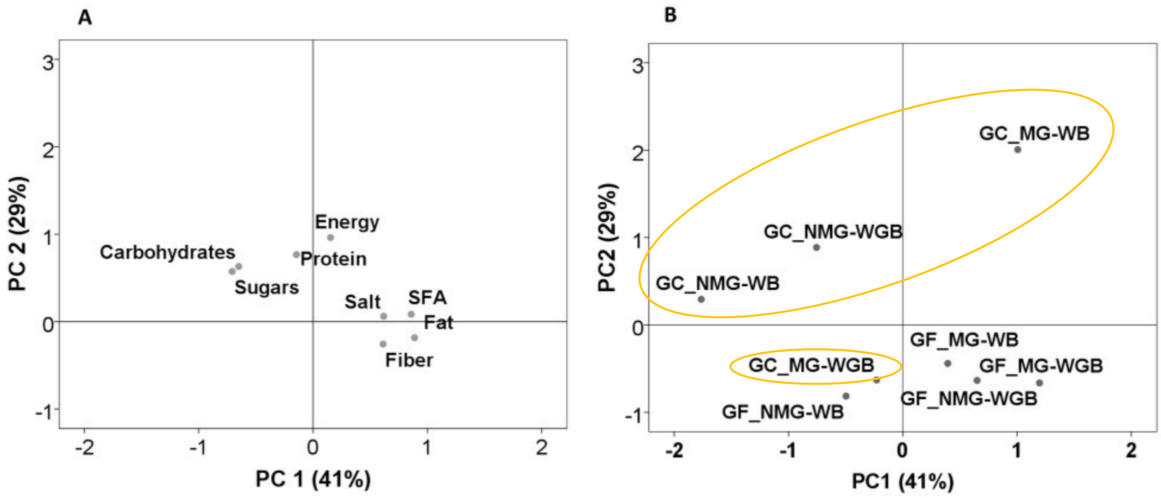

Figure 5: Principal component analysis (PCA) describing the intra-category variability of bread products based on their nutritional profile (energy (kcal/100 g), total fat (g/100 g), saturates (g/100 g), total carbohydrates (g/100 g), sugars (g/100 g), protein (g/100 g), fiber (g/100 g) and salt (g/100 g)). Loading plots of Principal Component (PC) 1 and 2 (**A**) and rotated principal scores of bread types projected into the first two principal components PC1 and PC2 (**B**). GC_NMG-WB: gluten-containing non multigrain white bread; GC_NMG-WG: gluten-containing non multigrain wholegrain bread; GC_MG-WB; gluten- containing multigrain white bread; GC_MG-WGB: gluten-containing multigrain wholegrain bread; GF_NMG-WB: gluten-free non multigrain white bread; GF_NMG-WG: gluten-free non multigrain wholegrain bread; GF_MG-WB; gluten-free multigrain white bread; GF_MG-WGB: gluten-free multigrain wholegrain bread.

4. Conclusion

Gluten-free and gluten-containing breads labeled “wholegrain” did not show significant differences in nutritional profiles (except for fat, carbohydrates and proteins in the case of gluten-free breads and carbohydrates and fibers in case of gluten-containing breads) compared to white breads. This aligns with the results of the survey of ingredients, showing high similarity and small differences in terms of ingredients. In most cases, when comparing “multigrain” vs “non multigrain”, no relevant changes were observed in terms of nutritional value and ingredients. This indicates that this designation “wholegrain” and “multigrain” did not imply an added nutritional value and thus it can be deduced that the terminology is mostly used for marketing motives. Despite the nutritional improvement in gluten-free breads showing low carbohydrates, low energy and high fiber contents, similar to gluten-containing wholegrain breads, protein content is still a limitation that needs to be further addressed to enable consumers a nutritionally equivalent products, especially for patients genetically predisposed to adverse reaction to gluten. The use of fruits, vegetables, algae, insects and to upgrade the quality of gluten-free products is a public health priority. There is also opportunity for the use of wholegrain for an improved nutritional quality, but it needs to be ensured the added value of wholegrains and not only on-pack promotion. Thus, clear regulation of health or nutrition claims of wholegrain mention in association with fiber content might improve on-pack information and thereby attract more consumers. ~~This in turn will boost food manufacturers to use wholegrain and thus increase fiber intake.~~

Conflicts of Interest

The authors declare no conflict of interest.

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