

1 **Guiding trust: the role of labeling information in the market for gluten-free pasta (2019-2023)**

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9 **Abstract**

10 Labeling transparency is crucial in today's consumer landscape, ensuring informed choices and trust. Food
11 labels are the first piece of consumers' information and become critical when foods must meet dietary
12 restrictions. Gluten-free pasta, with its widespread consumption, is a fitting model to evaluate labels'
13 contribution to food literacy. The scope of this study is to examine the clean status and transparency of
14 gluten-free pasta labels in the global marketplace analyzing by ingredient composition, nutritional facts,
15 nutritional claims, and the implementation of quantitative ingredient declarations (QUID). To achieve this,
16 Mintel Global New Product Database (GNPD) was used to retrieve a total of 1188 products sold from 2019
17 to 2023. Findings revealed variations in gluten-free pasta ingredients, with fresh and dry types varying in
18 nutrients. Branded and private-label pasta differed in salt content, while pulses-based pasta was fiber and
19 protein-rich but pricier. Organic pasta did not consistently show superior qualities, and whole grains did not
20 change nutrition or price. Vegan options were similar in nutrition and price to vegetarian choices. While
21 nutritional claims generally complied with regulations, inconsistent use of QUID usage highlighted the
22 need for stricter labeling standards to ensure product transparency and support consumer decision-making.
23 Our findings underline the critical role of clear and accurate labeling in empowering consumers and
24 advocate for enhanced regulatory oversight.

25

26 **Keywords:** whole grains, pulses, organic, branded, vegan, food labeling.

27

28 **1. Introduction**

29 Food market trends are guided by sustainability and health principles, but other more realistic factors
30 include transparent communication, consumer trust, and food literacy that will help in reaching responsible
31 production and consumption (Achini et al., 2021; Shangguan et al., 2019). Those have fueled the debate
32 about more for less or less for more, which relates to more profound knowledge that allows informed
33 decisions. Food transparency emerges as a key factor in supporting consumer trust in food safety (Rupprecht
34 et al., 2020). Food literacy involves a comprehensive understanding of where food originates, its production
35 methods, and its health implications. Educated consumers tend to make more informed and sustainable
36 choices, recognizing the impact of their food decisions (van Bussel et al., 2022). Today's consumers are
37 notably well-informed and conscientious about the foods they choose to consume. They seek to understand
38 the origins of their food, the methods used in its production, and its effects on both personal health and the
39 environment. Companies that prioritize transparency share openly this information through clear and
40 informative labeling (Priya and Alur, 2023). Consumers rely heavily on product labels to make informed
41 choices about the foods they purchase and consume (Shangguan et al., 2019).

42 Gluten-free pasta presents an interesting model for evaluating the contributions of food labeling to food
43 literacy, given its extensive consumption. This pasta type manifests in diverse forms, with fresh and dry
44 varieties representing distinct categories characterized by unique ingredients, preparation modalities,
45 textures, and cooking techniques (Conte et al., 2021). Traditionally, gluten-free pasta has been mainly made
46 with gluten-free grains (Suo et al., 2024). However, in recent times, there has been a notable shift towards
47 the incorporation of pulses, which offer health benefits due to their richer composition in macro- and micro-
48 nutrients (Moreno-Araiza et al., 2023). Tubers such as potatoes are also used in making the classical Italian
49 fresh pasta known as "gnocchi" (Burgos et al., 2019). The distinction between refined and wholegrain
50 variants holds significant importance for consumers due to its direct impact on nutritional content and
51 overall health benefits (Boukid et al., 2022). The classifications further extend to vegan and vegetarian
52 options and the market offers choices for vegan and vegetarian diets with filled and non-filled variations.
53 Moreover, consumers can select branded or private-label gluten-free pasta products, allowing for
54 personalized preferences and brand loyalty (Sgroi and Salamone, 2022). Organic certification has also
55 emerged as a significant factor for consumers seeking gluten-free pasta with a focus on sustainable and
56 environmentally friendly agricultural practices (Schmid et al., 2023; Wilson and Lusk, 2020). These
57 variations meet diverse dietary needs and preferences, leading to a broad range in nutritional content, taste,
58 texture, and prices (Dello Russo et al., 2021; Gorgitano and Sodano, 2019).

59 In the diverse landscape of gluten-free products, accurate labeling becomes crucial, especially for
60 individuals with diagnosed pathologies requiring strict dietary adherence. It is important to differentiate
61 between those who must avoid gluten-containing products due to adverse physiological reactions and those
62 who choose not to consume these products for various reasons. Very small amounts of gluten can cause
63 severe reactions in susceptible individuals, making clear labeling and adherence to standards critical. The
64 transparency of labels is not just a matter of preference but a necessity for those managing their health
65 through dietary choices. Global guidelines, set forth by Codex Standard CXS 118-1979, outline strict
66 requirements for gluten-free products, underlining the importance of precision and clarity in labeling. In
67 this context, our study presents an opportunity to explore the accuracy and transparency of gluten-free pasta
68 labels. The present study analyzed the gluten-free pasta market launched in the last five years (2019-2023).
69 Utilizing the information available on product labels, the pasta products were categorized followed by a
70 thorough assessment of their ingredient lists, nutritional quality, nutritional claims, the implementation of
71 quantitative ingredient declarations (QUID) and pricing. This investigation aimed to address the query of
72 whether pasta varieties have a significant impact on nutritional aspects. The outcomes could provide
73 valuable insights into the diverse landscape of gluten-free pasta offerings and their potential implications
74 for nutritional choices.

75 **2. Materials and methods**

76 **2.1. Data collection and extraction**

77 The search for gluten-free pasta was conducted on January 23rd, 2024, utilizing the Mintel Global New
78 Product Database (Mintel GNPD-Mintel Group Ltd., London, UK). The search parameters were precisely
79 configured to focus globally, encompassing five different regions: Europe, Middle East and Africa, Asia-
80 Pacific, Latin America, and North America. Nutrition-related criteria were integral to the search, covering
81 saturated fat, fat, carbohydrates, salt, sugars, fiber, protein, and energy (kcal), with each attribute being
82 listed on the packaging. The search timeframe covered from January 1st, 2019, to December 31st, 2023,
83 ensuring a comprehensive coverage of the last five years. The additional criterion of "Gluten-free" claims
84 further refined the search to align with the specific dietary preferences of interest. In total, 1,366 gluten-
85 free pasta products were retrieved. The outcomes of these searches were systematically exported to
86 Microsoft Excel (Microsoft Office, Redmond, Washington (WA), United States), forming the initial set of
87 data for the subsequent creation and analysis of the database.

88 **2.2. Database preparation**

89 Out of total, this study focused on products available in the European market, accounting for 1188. The
90 products retrieved for this study were classified based on several criteria, ensuring a comprehensive analysis
91 of the gluten-free pasta market. The classifications included type, label, grain type, organic certification,
92 main ingredient, and dietary preferences.

93 Type of pasta: The products were divided into two categories based on storage requirements. Fresh pasta
94 included those that required refrigeration or freezing, while dry pasta referred to shelf-stable products. This
95 classification helped in understanding the market distribution of different pasta forms.

96 Product labeling: Products were categorized by their branding into two types: branded and private. Branded
97 products are those owned and marketed by specific food companies and are widely available across various
98 supermarket chains (Pulker et al., 2018). In contrast, private label products, often referred to as "own-brand"
99 or "home-brand," are exclusively sold in the supermarkets that own them (Coyle et al., 2020).

100 Ingredient type: The classification of grain type distinguished between refined grain and whole grain
101 products. Refined grain products are made from refined flours, whereas whole grain products contain whole
102 grains. It is crucial to note that some whole grain products may include a combination of refined flour and
103 a certain amount of unrefined grains. Due to differing national standards on what qualifies as whole grain,
104 this classification considered the variations in regional labeling requirements to ensure fairness in the
105 analysis.

106 Ingredient category: Based on organic certification, products were classified based on their organic
107 certification status. Conventional products are those not certified as organic, while organic products hold
108 certification proving their organic status. This classification helped in assessing the market share and
109 consumer preferences for organic versus conventional products, taking into account regional variations in
110 organic standards.

111 First ingredient listed: The primary ingredient in each product determined its classification into pulses,
112 grains, or potatoes. Products were categorized based on the first ingredient listed, indicating whether the
113 main ingredient belonged to pulses (such as lentils or chickpeas), grains (such as rice or corn), or potatoes.
114 This helped in analyzing the nutritional composition and diversity of ingredients used in gluten-free pasta
115 products.

116 Product status: The dietary preferences were classified based on the presence of animal-derived ingredients.
117 Vegan products were those declared to contain no animal-derived ingredients, making them suitable for
118 vegan consumers. Vegetarian products, on the other hand, contained animal-derived ingredients such as
119 eggs but did not include meat, catering to vegetarian dietary preferences.

120 **2.3. Nutritional data collection and standardization**

121 Different nutritional components were systematically collected from the nutritional labels of products sold
122 in the European market (1188). These included energy content (kcal/100 g), total fat (g/100 g), saturated
123 fatty acids (SFA) (g/100 g), carbohydrates (g/100 g), sugars (g/100 g), fibers (g/100 g), proteins (g/100 g),
124 and salt (g/100 g), as well as any nutrition claims. Moreover, the list of ingredients and pricing details
125 (Euro/100g) were retrieved. This comprehensive data set forms the basis for an in-depth evaluation of the
126 nutritional quality, ingredient composition, and economic aspects of the gluten-free pasta products under
127 scrutiny. Due to the difference in terms of moisture content between dry and fresh pasta, the nutritional
128 facts of all the retrieved products were standardized by expressing them on a dry basis. For dry pasta, a
129 moisture content of 12.5 g/100 g was applied, while for fresh pasta, categorized as an intermediate moisture
130 food, a moisture content of 30 g/100 g was considered (Del Nobile et al., 2009; Gasparre et al., 2019).

131 **2.4. Identification and extraction of quantitative ingredient declarations (QUID)**

132 As part of the comprehensive analysis, we also examined the presence of QUID on the labels of 1,188
133 gluten-free pasta products available in the European market. QUID primarily governed by the Regulation
134 (EU) No 1169/2011 refers to the explicit declaration of the percentage of key ingredients. Each product
135 label was reviewed to determine whether QUID was applied. Products were categorized as having QUID
136 if the label explicitly stated the percentage of key ingredients such as whole grains, pulses, or other primary
137 components. Initially, 758 products were found to include QUID. However, products with water as the first
138 ingredient (32 products) and those where no ingredient reached at least 10% of the total formulation (63
139 products) were excluded, resulting in a final total of 663 products with valid QUID data. For each product
140 identified with QUID, data on the declared percentage of emphasized ingredients (e.g., 70% whole grain,
141 50% pulses) were extracted.

142 **2.5. Statistical data analysis**

143 The statistical analysis of marketed products was performed using Statgraphics Centurion XVII software
144 (Version 19.2, Virginia, USA), while data plotting was conducted using OriginPro 2022 (OriginLab,
145 Northampton, Massachusetts, USA). An alluvial plot was used to show the relationship and frequencies

146 between the main ingredients. To evaluate the relationship between the declared QUID and the nutritional
147 profile of the products, a correlation matrix was generated, and subsequently visualized using a heat map.
148 Multivariate analysis of variance (MANOVA) was employed to identify significant differences among the
149 different variables with a 95% confidence level. When significant effects were observed, honestly
150 significant differences (HSD) were determined using Tukey's test.

151 **3. Results**

152 **3.1. Overview of the global market of gluten-free pasta**

153 Table 1 indicates the distribution of gluten-free pasta products across different regions globally. Europe has
154 a significant representativeness, with 88.9% of the total products. Although the Middle East & Africa
155 represents 6.5% of the market, further investigation revealed a pattern consistent with the overall
156 distribution. Therefore, our study primarily analyzes countries with more than 5% of the global market
157 share to provide a comprehensive understanding of the gluten-free pasta market. Europe stands out with the
158 highest number of products, suggesting that gluten-free pasta is more prevalent and diverse in the European
159 market compared to other regions. This dominance is likely influenced by the cultural and dietary
160 preferences of European consumers, contributing to the abundance of gluten-free pasta options available in
161 Europe. The following sections will focus exclusively on European products.

162 **Table 1.**

163

164 **3.2. In-depth analysis of the European market of gluten-free pasta**

165 **3.2.1. Number and types of products**

166 Table 2 provides an overview of the diverse array of gluten-free pasta offerings in Europe. A comprehensive
167 search yielded a total of 1215 products, which were categorized into seven distinct groups. When classified
168 by type, most marketed pasta products were found to be dry (96%). Notably, a significant proportion of
169 these products were branded, while 21% had a private label, reflecting the diverse branding strategies
170 employed within the market. In terms of ingredients, refined grains, including flour and grains, were
171 predominant in pasta production, overshadowing the use of whole grains. Additionally, organic certification
172 was apparent in 44% of the products, indicating a growing consumer preference for organic gluten-free
173 options. Further analysis based on grain type revealed that cereals were the primary source of ingredients
174 for gluten-free pasta production, followed by pulses and potatoes, highlighting the versatility and
175 adaptability of gluten-free formulations. Dietary preferences also played a pivotal role in product

176 development, with 43% of products boosting vegan claims and 57% catering to vegetarian diets. This
177 highlights a growing consumer demand for products that align with these ethical and dietary lifestyles. It
178 also suggests that manufacturers are responding to a broader market trend towards plant-based diets.

179 **Table 2:**

180 **3.2.2. Main ingredients analysis**

181 Fig. 1 illustrates the first ingredient declared on the label of gluten-free fresh and dry pasta, including
182 various cereal flours, seeds, pulses, pseudocereals, and potatoes. To ensure a more robust comparison
183 considering the different nutritional compositions, stuffed pasta products were excluded from the final list.
184 Therefore, the initial number of products retrieved for our study was 1215, and after excluding stuffed pasta
185 products, the final number of products included in our analysis was 1188. Most products are made with a
186 simple combination of two ingredients, i.e., flour and water. Corn and rice (brown or white) flours were the
187 primary cereal flours used, while other cereals such as oat, sorghum, and millet were employed to a lesser
188 extent. Pulses such as beans, red lentils, chickpeas, and peas are the predominant ingredients utilized in
189 gluten-free pasta formulations. Additionally, fresh pasta commonly includes primary ingredients such as
190 potato puree and potato flakes. Among the surveyed products, soybean flour was utilized in 13 items, while
191 pea proteins were present in 58 products. Various seeds, such as linseeds, sesame, flaxseed, and pumpkin,
192 were also in pasta formulations. Emulsifiers, thickeners (konjac, guar gum, locust bean gum, xanthan gum),
193 and vegetable fibers (potato fiber, corn fiber, pea fiber, and psyllium fiber), are also utilized. Fresh pasta
194 formulations often incorporate vegetables such as spinach, tomato, and onion to improve flavor and
195 nutritional value. Other animal-derived ingredients like egg, egg white, and mascarpone were also used.
196 Salmon was found in one fresh ready-to-eat pasta (Salmon Tagliatelle, Pescanova, Spain), while spirulina
197 was utilized in one product as a main ingredient. Another exotic ingredient, palm hearts (*Bactris gasipaes*)
198 flour, was utilized as the sole ingredient in a single dry pasta product (Hearts of Palm Veggie Spaghetti
199 Pasta, Mipama, Poland).

200 **Fig. 1:**

201 **3.2.3. Nutritional comparisons of gluten-free pasta**

202 The nutritional quality of fresh and dry gluten-free pasta is illustrated in Fig. 2. Significant ($P \leq 0.05$)
203 variations were observed among all the nutritional parameters. These differences provide valuable insights
204 into the factors that contribute to the nutritional qualities of each type of pasta. It is important to note that
205 all composition values were adjusted to a dry weight basis, as previously described (Del Nobile et al., 2009;

206 Gasparre et al., 2019). Dry pasta provides more energy than fresh pasta. Nevertheless, fresh pasta showed
207 significantly ($P \leq 0.001$) higher total fat and saturated fat (SF) contents, maybe due to the presence of eggs
208 in their formulations. In fact, in fresh pasta samples, the average of the total fat and saturated fat contents
209 were 5.05 and 2.15 g/100 g, respectively, while their dry counterparts contained 2.85 and 0.64 g/100 g.
210 Conversely, dry pasta showed higher carbohydrates, total fiber, and sugar content than those of fresh pasta.
211 The average protein content of dry pasta (14.18 g/100 g) was found significantly ($P \leq 0.001$) higher than that
212 of fresh pasta (6.72 g/100 g), Additionally, the salt content of dry pasta was negligible, while fresh pasta
213 contained a median of 1.2 g/100 g.

214 **Fig. 2:**

215 With a focus on dry pasta, branded gluten-free products provide more calories, and have higher fat, SF,
216 fiber, sugar, and protein than private brands (Table 3). Furthermore, pulse-based pasta provides more energy
217 than grains and potatoes due to higher fat, SF, carbohydrates, and sugar. It also significantly ($P \leq 0.001$)
218 showed the highest content of fibers (10.91 g/100 g), sugars (2.99 g/100 g), and proteins (25.89 g/100 g).
219 The certification organic did not translate into differences in nutritional composition, except for higher
220 protein and lower salt compared to products without this certification. Specifically, organic products had a
221 protein content of 13.03 g/100 g compared to 10.97 g/100 g for conventional products. Additionally, the
222 salt content in organic products was 0.37 g/100 g, while conventional products had a salt content of 0.43
223 g/100 g. Wholegrain products showed higher energy, SF, and carbohydrates, but lower fiber, sugar, and salt
224 compared to pasta made with refined flours. Vegan pasta showed lower energy, SF, and carbohydrates but
225 higher fiber and sugar. Specifically, vegan pasta had an energy content of 297.77 kcal/100 g compared to
226 342.14 kcal/100 g for vegetarian pasta. SF was 0.43 g/100 g in vegan pasta, whereas vegetarian pasta had
227 0.53 g/100 g. Carbohydrates in vegan pasta were 55.26 g/100 g, compared to 66.83 g/100 g in vegetarian
228 pasta. In contrast, vegan pasta had higher fiber content at 5.63 g/100 g compared to 4.78 g/100 g in
229 vegetarian pasta, and sugar content was 1.56 g/100 g in vegan pasta versus 1.31 g/100 g in vegetarian pasta.

230 As for fresh pasta, no significant ($P > 0.05$) differences were observed among branded and private brands
231 (Table 4) except for salt content, which was nearly double in branded products compared to private label
232 ones. Based on the first ingredient, energy, fat, SF and protein content showed significant ($P \leq 0.05$)
233 differences. The energy content ranged from 196.07 kcal/100 g for products with pulses as the first
234 ingredient, to 229.71 kcal/100 g for those with grains, and 149.25 kcal/100 g for those with potatoes. The
235 fat content ranged from 4.24 g/100 g in products with pulses, to 5.42 g/100 g in those with grains, and 0.02
236 g/100 g in products with potatoes. For saturated fat, the content was 1.36 g/100 g in products with pulses,
237 2.83 g/100 g in those with grains, and 0.41 g/100 g in products with potatoes. Protein content also varied
238 significantly, with products containing pulses showing 13.81 g/100 g, those with grains containing 6.34

239 g/100 g, and products with potatoes containing 2.70 g/100 g. These ranges highlight the significant
240 nutritional differences based on the first ingredient listed. Grain-based products resulted in the most energy
241 dense because of their highest content in fat and SF, while pulses-based pasta contained the highest content
242 of protein. Organic products resulted like those conventional apart from SF, where organic products had
243 significantly ($P \leq 0.05$) the highest amount of SF. Refined samples showed higher energy and fat than
244 wholegrain. Vegan and vegetarian were nutritionally similar except for salt content, which was higher in
245 vegetarian products (1.31 g/100g compared to 0.75 g/100g in vegan products).

246 **Table 3**

247 **Table 4**

248 **3.3. Analysis of QUID in gluten-free pasta products**

249 In our dataset of 1,188 gluten-free pasta products, we identified that a subset of 663 products included
250 QUID on their labels. Specifically, 55.8% of the products declared the percentage of key ingredients. This
251 subset includes 629 dry pasta products (52.9%) and 34 fresh pasta products (2.9%). Within this subset, 314
252 products listed cereals as the main ingredient, while 8 products featured eggs. Potatoes were highlighted in
253 46 products, and pseudocereals in 32 products. Pulses were a key ingredient in 182 products, and roots were
254 specified in 1 product. Seeds were emphasized in 4 products, and 76 products declared wholegrain cereals
255 as a primary component. Focusing on this subset ($n=663$), Fig. 3 presents a heat map derived from the
256 correlation matrix, which examines the relationship between QUID categories—such as whole grains,
257 cereals, and pulses—and various nutritional factors. The correlation matrix revealed predominantly weak
258 correlations (correlation coefficients did not exceed 0.25) among these variables, indicating that the
259 percentage of the first/most abundant ingredients does not strongly predict the nutritional profile of the
260 products.

261 **Fig. 3**

262 **3.4. Nutrition claims**

263 Table 5 summarizes the accuracy of nutritional claims on gluten-free pasta products by comparing label
264 claims with actual nutrient content. Of the 251 products (21.12%) labeled as high in fiber, 247 (20.79%)
265 met the regulatory standard of at least 3 g of fiber per 100 g, demonstrating high accuracy. For protein, 318
266 products (26.76%) claimed to be high in protein, with 313 (26.35%) meeting the products (4.80%) labeled
267 as low or reduced fat and all 16 products (1.35%) claiming low or reduced saturated fat were consistent
268 with the criteria of no more than 3 g of fat per 100 g and 1.5 g of saturated and trans-fatty acids per 100 g,

269 respectively. Among 49 products (4.13%) making low or reduced energy claims, 45 (3.79%) met the
270 requirement of no more than 40 kcal per 100 g, though a few showed minor discrepancies. Additionally, 19
271 products (1.60%) claimed to be low in sodium or salt, all of which met the criterion of no more than 0.12 g
272 of sodium per 100 g. Lastly, 13 products (1.09%) labeled as low in sugar were found to have no more than
273 5 g of sugars per 100 g, aligning perfectly with the claims. Overall, the analysis showed that most nutritional
274 claims on gluten-free pasta products are accurate and reflect the actual nutrient content.

275 **Table 5**

276 **3.5. Price comparison**

277 Table 6 shows the median price comparison among gluten-free pasta products across the different
278 categories. Fresh pasta products tend to be more expensive than dry products (1.14 Euro/100 g vs 0.83
279 Euro/100 g, respectively). Branded products are significantly ($P \leq 0.001$) more expensive than private-label
280 products. Products with pulses listed as the first ingredient are pricier (1.22 Euro/100 g), followed by grains
281 (0.95 Euro/100 g) and potatoes (0.79 Euro/100 g). Certified organic products are more expensive than
282 conventional products (1.09 Euro/100 g). The price of pasta made with refined flours and wholegrains was
283 statistically similar, like vegan and vegetarian.

284 **Table 6:**

285 **4. Discussion**

286 Food transparency and literacy play crucial roles in the modern food market, influencing consumer choices
287 and fostering trust in product quality and safety (Rai et al., 2023). Consumers are increasingly seeking clear
288 and informative labeling to understand the origins, production methods, and potential health implications
289 of the foods they consume. In this context, our study aims to contribute to the understanding of nutritional
290 quality in the gluten-free pasta market, considering various factors such as ingredients, processing methods,
291 branding, and associated prices. To the best of our knowledge, this study is the first to examine the
292 nutritional quality of gluten-free pasta products available in the global market, considering a variety of
293 factors including the versatility of ingredients, process, and branding among other factors, along with the
294 associated prices. Notably, among the top 10 countries for pasta consumption per capita, European countries
295 represent 40% of the total (Statista, 2023). This abundance confirms that Europe is the biggest market for
296 gluten-free pasta. Its vast variety underlines the remarkable advancements in gluten-free formulation in
297 Europe in response to a wide range of dietary needs and preferences.

298 A remarkable evolution in the formulation of gluten-free pasta was translated by the versatility of
299 ingredients beyond classical ones deriving from corn and rice. In the case of dry samples obtained via
300 extrusion, the choice of corn and rice flours is due to their distinctive properties. Specifically, the elevated
301 shear stress and extrusion temperature appear to promote the development of a reinforced starchy network
302 with a beneficial impact on the texture of cooked pasta (Marti and Pagani, 2013). Pseudocereals like
303 amaranth, buckwheat, and quinoa are increasingly being incorporated into gluten-free pasta formulations
304 due to their health benefits (Linares-García et al., 2019). Additionally, whole grains from rice, oats, and
305 corn are utilized in some gluten-free pasta varieties, contributing to their nutritional value with rich fiber
306 and essential nutrients (Boukid and Rosell, 2022). Pulses are gaining recognition as healthier alternatives
307 because of their higher protein content and lower digestibility compared to traditional gluten-free pasta
308 made with flour and starches (Laleg et al., 2016). This reduced digestibility can be attributed to the
309 distinctive starch composition found in pulses, offering potential advantages for individuals seeking
310 alternatives with enhanced nutritional profiles (Boukid et al., 2019; Duijsens et al., 2023). Potato ingredients
311 including starch puree, and flour are characterized by their functional properties, thus contributing to the
312 texture and structure of gluten-free pasta (Gao et al., 2018). The incorporation of protein-rich ingredients
313 from animal or plant sources serves nutritional and functional purposes in gluten-free pasta production
314 (Bolarinwa and Oyesiji, 2021). Whey protein, derived from milk, may be utilized to enhance the protein
315 content and impart a creamy texture to the pasta (Bouziane et al., 2024). Egg also contributes to the richness
316 and texture of the pasta. Plant proteins such as are increasingly used in the improvement of texture and
317 structure (Boukid et al., 2021). Microalgae were also used to provide a peculiar color and potential health
318 benefits (Fanari et al., 2023). The inclusion of various seeds serves to enrich the nutritional profile by
319 providing additional fiber, healthy fats, and micronutrients (Aydin et al., 2023). Vegetables also contribute
320 to the enhancement of flavor and nutritional value. To maintain a firm structure like that of semolina pasta,
321 emulsifiers, and thickeners play a crucial role in improving texture, consistency, and shelf stability by
322 facilitating the uniform dispersion of ingredients and preventing their separation. Vegetable fibers are also
323 utilized to modify the viscosity and mouthfeel of the pasta, ensuring a desirable eating experience for
324 consumers. These ingredients contribute not only to the sensory attributes but also to the overall quality and
325 consumer acceptability of gluten-free pasta given that they mimic the elasticity and mouthfeel that gluten
326 provides in traditional wheat-based pasta (Gasparre and Rosell, 2023, 2019).

327 The nutritional data revealed significant variations in terms of energy and nutrients between fresh and dry
328 pasta products. These differences can be attributed to the ingredients used and the production methods
329 (Andrés et al., 2023). Our analysis showed that fresh pasta costs more than dry pasta. Indeed, consumers
330 are willing to pay more for fresh pasta due to its superior taste, texture, and perceived quality (Maesen et
331 al., 2022). Notably, dry pasta is more convenient due to its long and stable shelf life. Despite the differences

332 in nutritional content and price, both fresh and dry pasta options are staples offering variety and flexibility
333 in the pasta market.

334 Brands often invest in building trust and loyalty with consumers by creating recognizable products, while
335 retailers use private labels to provide affordable options for budget-minded clients (Gorgitano and Sodano,
336 2019). Consumers often perceived private labels, which are products branded and sold by retailers under
337 their own store names or exclusive brands, as less healthy compared to their national brand counterparts
338 (Maesen et al., 2022). The presence of a private label brand on a product has been shown to negatively
339 impact the perceived health benefits of the product (Burke et al., 2020). Our analysis did not reveal a
340 consistent pattern in brand effect on dry and fresh gluten-free pasta. While some branded products exhibited
341 a positive nutritional profile, others showed favorable characteristics among private label items (Burke et
342 al., 2020). Therefore, it is not accurate to categorize branded products as uniformly indicative of superior
343 nutritional quality compared to private-label items (Angelino et al., 2021). Noteworthy, fresh branded
344 products showed almost double the amount of salt in private brands. In Australian supermarkets, active
345 interventions aimed to reduce salt in response to public health initiatives (Coyle et al., 2020). Private brands
346 were able to achieve great reductions in salt content through the formulation of new products and the
347 discontinuation of old product lines. However, the lower price of private labels compared to branded
348 products does not necessarily correlate with nutritional quality (Košíčiarová et al., 2022). The price
349 difference between private labels and branded products can often be attributed to several factors beyond
350 labeling. Private label products are typically manufactured by third-party producers and sold under a
351 retailer's brand, which can lead to cost savings. Additionally, private labels often incur lower marketing and
352 advertising costs compared to national brands, which spend significantly on brand promotion and consumer
353 awareness. Consumers should be mindful and make informed choices based on the nutritional information
354 provided rather than solely relying on brand or price (Maesen et al., 2022).

355 Global increased awareness about the benefits of pulses for human health and sustainability increased their
356 integration into food products including pasta (Pinel et al., 2023). The use of pulses in making gluten-free
357 pasta significantly contributed to improving the nutritional quality, especially fibers and proteins. Initially,
358 manufacturers faced various challenges in creating 100% pulses-based pasta. However, these challenges
359 have been overcome with the use of advanced wet-extrusion technologies (Blandino et al., 2023). Unlike
360 conventional extrusion, lentil pasta produced via extrusion-cooking exhibited enhanced stability during
361 cooking and resistance to overcooking, resulting in firmer pasta textures (Blandino et al., 2023). The
362 extrusion-cooking process involves subjecting flour to thermal and mechanical treatments to alter starch
363 functionality (Bresciani et al., 2022). On the other hand, gluten-free pasta made from cereals and potatoes
364 may not exhibit the same cooking characteristics and stability as pulse-based pasta. Cereals, while

365 commonly used in traditional pasta production, may not provide the same level of protein and fiber as pulses
366 due to the use of refined flour and starches. Similarly, potatoes may not offer the same nutritional benefits
367 as pulses. This difference in nutritional content was reflected in the price of the pasta options. Pulses-based
368 pasta was more expensive than pasta made from cereals and potatoes. This higher cost may be attributed to
369 processing methods required for pulses, besides the availability and sourcing of pulses, as pulses might be
370 more expensive than ingredients deriving from cereals and potatoes.

371 The market for organic products is experiencing rapid growth, likely due to the general perception among
372 customers that they are healthier options with superior nutritional profiles compared to conventional
373 products. Organic foods are recognized for their higher micronutrient content and lower pesticide residues
374 compared to non-organic foods, though differences in macronutrient content are not consistent. Our study
375 focused on the accuracy and transparency of macronutrient information on product labels rather than
376 regulatory status. The analysis did not consistently find a link between organic certification or whole grain
377 labeling and improved nutritional quality in gluten-free pasta. Food labeling regulations, such as organic
378 certification, can influence consumer perceptions and the attributes of food products . The analysis did not
379 consistently reveal a clear association between organic certification or whole grain labeling and enhanced
380 nutritional quality in gluten-free pasta. This trend reflects a growing interest in health-conscious choices
381 and a desire for foods perceived as more natural and beneficial for overall well-being. However, there is no
382 direct association between organic certification and nutritional quality. This misconception could
383 potentially influence dietary habits and purchase decisions. To explore the presence of organic declarations,
384 the nutritional quality of organic versus conventional products was compared. Organic dry gluten-free pasta
385 had higher protein content and lower salt content. On the other hand, organic fresh pasta products were
386 similar to those conventional except for SF. Different trends were observed in previous studies focused on
387 semolina pasta sold in the Italian market (Dall'Asta et al., 2020; Dello Russo et al., 2021). The comparison
388 indicated that organic pasta products had lower energy and protein content, but higher SF compared to
389 conventional products (Dall'Asta et al., 2020). However, another study found that organic pasta had a
390 significantly lower protein content, but a higher fiber amount compared to the conventional counterpart
391 (Dello Russo et al., 2021). While organic products are often perceived as healthier options due to their
392 cultivation methods, our analysis reveals that this perception may not always align with nutritional content.
393 Noteworthy, organic products are more expensive than conventional counterparts. This higher cost can be
394 attributed to the farming practices, certification requirements, and potentially lower yields associated with
395 organic farming (Michalke et al., 2023).

396 Consumption of whole grain products is known to have a beneficial effect on reducing the risk of non-
397 communicable diseases such as cardiovascular diseases, cancers, gastrointestinal disorders, and type 2

398 diabetes (Dai et al., 2020; Nusairat and Wang, 2020). These benefits are largely attributed to the high dietary
399 fiber content of whole grain products. Currently, there is no global legislation specifically addressing the
400 labeling of whole grains. Dietary guidelines from various organizations worldwide emphasize increased
401 fiber intake through the consumption of whole grains. Based on our results, in the case of dry pasta, refined
402 pasta exhibited higher fiber content, while no differences were observed in fiber content between refined
403 and wholegrain-based fresh pasta. Similarly, for gluten-free breads, no significant ($P>0.05$) differences
404 were found in fiber between white and wholegrain gluten-free breads (Boukid and Rosell, 2022). In our
405 analysis, we found that there was no difference in the price of refined and whole grain options. However,
406 historically, whole grain pasta costs more than refined pasta may be influenced by production costs, market
407 demand, consumer perceptions of health benefits, and branding strategies employed by manufacturers
408 (Harriman, 2013).

409 Comparing vegetarian and vegan dry and fresh gluten-free pasta options reveals distinct nutritional profiles.
410 It is important to note that all nutritional values presented have been adjusted to a dry weight basis, as
411 previously described (Del Nobile et al., 2009; Gasparre et al., 2019) to facilitate accurate comparisons.
412 Particularly a higher heterogeneity was observed in the dry products due to the high number of products
413 while fresh pasta seems more nutritionally homogeneous probably due to the limited number of items. The
414 increased demand for vegan products is attributed to ethical, environmental, and/or health concerns over
415 animal-derived ingredients (Boukid, 2021). Egg and milk proteins are conventionally used for nutritional
416 and functional reasons in gluten-free pasta (Linares-García et al., 2019). Currently, they are being
417 increasingly substituted by plant proteins and fiber to maintain a firm structure. In addition, emulsifiers and
418 hydrocolloids are commonly used due to their gel formation capacity, providing the pasta with high
419 consistency, and improved firmness, and enhancing its overall body and mouthfeel (Padalino et al., 2016).
420 Notably, the price of vegan and vegetarian products was found to be similar, thus providing consumers with
421 flexibility in choosing plant-based options without significant cost differences (Košíčiarová et al., 2022).

422 A significant aspect of our analysis was the accuracy of nutritional claims and the implementation of QUID
423 on product labels. Despite recommendations from the Codex Alimentarius Committees for QUID to specify
424 the percentage of key ingredients such as whole grains, our analysis revealed that not all gluten-free pasta
425 products adhered to this practice. Even among those that included QUID, there were weak correlations
426 between the declared percentages of main ingredients and their actual nutritional contents. We observed
427 that several products with whole grain ingredients did not list the percentage of whole grain on their labels.
428 This inconsistency contributes to uncertainty regarding the true composition of products marketed as whole
429 grain. Furthermore, it has been reported that benefit-related claims, such as "high in fiber" and "whole
430 grain," can create a positive health halo effect (Mediano Stoltze et al., 2021). This effect leads consumers

431 to generalize from the one positive attribute to the entire product, resulting in beliefs that the product is
432 healthy overall, regardless of its total nutritional content (Sandvik et al., 2018). This suggests that QUID
433 was not consistently applied or effective in enhancing the transparency of ingredient content. For more
434 rigorous labeling practices, manufacturers are encouraged to report the percentages of all the ingredients to
435 ensure that consumers receive accurate information about the content and quality of the products they
436 purchase. In contrast, our results indicated high accuracy in nutritional claims, with products labeled as
437 high in fiber, protein, and low in fat, saturated fat, energy, and sugar generally meeting their respective
438 criteria. This reflects a general adherence to regulatory standards, which is crucial for maintaining consumer
439 trust.

440 Overall, the present study presents several advantages. Retrieving data from commercial product labeling
441 provides a real-world perspective, giving consumers insight into the actual available pasta. The recent
442 (2019-2023) large sample size of gluten-free pasta reflects current trends in product formulation and
443 nutritional goals. Despite these strengths, there are some limitations to consider, like the accuracy of
444 labeling information or the pasta-making processes. Additionally, the nutrient contents are calculated
445 according to the presumed moisture content of the pasta and not obtained through experimental analysis.
446 Furthermore, while the large sample size strengthens the study's conclusions, these findings are specific to
447 the products available during the study period. Changes in product formulations or new market entries that
448 occurred after this period are not reflected in the results. Therefore, the reliability of the study is contingent
449 on the accuracy and completeness of the product labels, which could affect the overall validity of the
450 conclusions drawn.

451 **5. Conclusion**

452 In conclusion, this study not only contributes to understanding the nutritional landscape of gluten-free pasta
453 but also provides actionable insights for policymakers and industry stakeholders aiming to improve label
454 transparency and promote healthier dietary habits among consumers. Our results provide a holistic
455 perspective on the nutritional quality of gluten-free marketed pasta. The evolution in gluten-free pasta
456 formulation is marked by a shift towards using a variety of ingredients including pseudocereals, whole
457 grains, and pulses beyond traditional ones like corn and rice. Consumers often perceive private labels as
458 less healthy, but this study did not reveal a consistent pattern regarding brand effect on nutritional quality.
459 Pulses-based pasta showed better nutritional quality and higher prices compared to cereals and potato-based
460 products. Organic certification and wholegrain mentioned did not reflect superior nutritional quality. Vegan
461 and vegetarian options showed slight nutritional differences and similar prices. While nutritional claims on
462 gluten-free pasta generally met standards, the incomplete application of QUID for all listed ingredients led

463 to a lack of strong correlations with the nutritional facts. This underscores the importance of applying QUID
464 for each listed ingredient to ensure transparency and empower consumers to make informed choices. Food
465 market trends emphasize sustainability, health, and transparency, fueling the debate on “more for less”
466 versus “less for more”. Therefore, consumers are encouraged to make informed choices based on individual
467 dietary needs, preferences, and nutritional information provided on packaging instead of depending entirely
468 on branding or price.

469 These findings hold significant implications for policymakers and industry stakeholders. They underline
470 the need for harmonized and transparent labeling regulations that accurately reflect product contents and
471 nutritional claims. By implementing clearer labeling standards, policymakers can empower consumers to
472 make informed choices aligned with their dietary needs and preferences, while fostering trust in product
473 information. Moreover, the study’s insights into the nutritional profiles of organic, whole grain, vegan, and
474 vegetarian pasta options provide a basis for enhancing food literacy and promoting healthier dietary
475 practices. Educating consumers on interpreting nutritional labels can enhance public health outcomes by
476 enabling better-informed food choices and reducing the risks associated with allergens and dietary
477 restrictions.

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481 Fatma Boukid: Writing – review & editing, Writing – original draft, Formal analysis, Methodology,
482 Investigation, Conceptualization. Nicola Gasparre: Writing – review & editing, Investigation, Data
483 curation, Conceptualization. Cristina M. Rosell: Writing – review & editing, Conceptualization.

484 Declaration of Competing Interest

485 The authors declare that they have no known competing financial interests or personal relationships that
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TABLES and FIGURES

645

646 **Table 1:** Global market of gluten-free pasta.

Region	Number of products	Percentage out of total (%)
Europe	1215	88.9
Middle East and Africa	89	6.5
Asia-Pacific	39	2.9
Latin America	16	1.2
North America	7	0.5

647 Duration: January 1st, 2019, to December 31st, 2023.

648 **Table 2:** Classification of commercial gluten-free pasta products sold in the European market.

Categories	Types	Number of products	Percentage out of total (%)
Type	Fresh	45	4
	Dry	1170	96
Product labelling	Branded	962	79
	Private	253	21
First ingredients listed	Pulses	385	32
	Grains	792	65
	Potato	38	3
Ingredient category	Conventional	675	56
	Organic	540	44
Ingredient type	Refined grain	1041	86
	Wholegrain	174	14
Product status	Vegan	528	43
	Vegetarian	687	57

649 Duration: January 1st, 2019, to December 31st, 2023; Geographical scope: Europe.

650 **Table 3:** Least squares mean and standard error of the means from the MANOVA test comparing the nutritional facts of dry gluten-free pasta¹.

Factor		P-value	Energy (kcal/100 g)	P-value	Fat (g/100 g)	P-value	Saturated Fat (g/100 g)	P-value	Carbohydrates (g/100 g)	
Product labelling	Branded	***	332.89 ± 6.89 ^b	**	2.47 ± 0.24 ^b	***	0.54 ± 0.04 ^b	-	62.17 ± 1.61	
	Private		307.03 ± 8.95 ^a		1.70 ± 0.32 ^a		0.42 ± 0.05 ^a		59.92 ± 2.09	
First ingredient listed	Pulses		390.61 ± 6.23 ^c		3.71 ± 0.22 ^c		0.72 ± 0.04 ^c		57.92 ± 1.46 ^b	
	Grains	***	362.08 ± 4.90 ^b	***	2.22 ± 0.17 ^b	***	0.57 ± 0.03 ^b	***	76.53 ± 1.15 ^c	
	Potatoes		207.18 ± 17.58 ^a		0.33 ± 0.62 ^a		0.16 ± 0.10 ^a		48.69 ± 4.11 ^a	
Ingredient category	Conventional		317.84 ± 7.62 ^a		2.04 ± 0.27 ^a		0.46 ± 0.04		61.97 ± 1.78	
	Organic	-	322.08 ± 7.89 ^a	-	2.13 ± 0.28 ^a	-	0.51 ± 0.05	-	60.12 ± 1.84	
Ingredient type	Refined	***	304.19 ± 6.32 ^a	-	1.97 ± 0.22 ^a	***	0.42 ± 0.04 ^a	***	56.98 ± 1.48 ^a	
	Wholegrain		335.73 ± 9.83 ^b		2.20 ± 0.35 ^a		0.54 ± 0.06 ^b		65.11 ± 2.30 ^b	
Product status	Vegan	***	297.77 ± 7.82 ^a	-	2.14 ± 0.28 ^a	***	0.43 ± 0.04 ^a	***	55.26 ± 1.83 ^a	
	Vegetarian		342.14 ± 7.68 ^b		2.03 ± 0.27 ^a		0.53 ± 0.04 ^b		66.83 ± 1.80 ^b	
			Fiber (g/100 g)				Sugars (g/100 g)			
Product labelling	Branded	***	6.16 ± 0.32 ^b	***	1.74 ± 0.13 ^b	***	13.02 ± 0.47 ^b	-	0.42 ± 0.03	
	Private		4.25 ± 0.42 ^a		1.12 ± 0.17 ^a		10.98 ± 0.61 ^a		0.38 ± 0.03	
First ingredient listed	Pulses		10.91 ± 0.29 ^c		2.99 ± 0.12 ^b		25.89 ± 0.43 ^c		0.00 ± 0.02 ^a	
	Grains	***	2.92 ± 0.23 ^b	***	0.74 ± 0.10 ^a	***	7.67 ± 0.34 ^b	***	0.05 ± 0.02 ^b	
	Potatoes		1.79 ± 0.82 ^a		0.56 ± 0.34 ^a		2.44 ± 1.21 ^a		1.16 ± 0.06 ^c	
Ingredient category	Conventional	***	4.66 ± 0.36 ^a	-	1.36 ± 0.15	***	10.97 ± 0.52 ^a	**	0.43 ± 0.03 ^b	
	Organic		5.76 ± 0.37 ^b		1.50 ± 0.15		13.03 ± 0.54 ^b		0.37 ± 0.03 ^a	
Ingredient type	Refined	***	5.69 ± 0.29 ^b	*	1.60 ± 0.12 ^b	-	12.44 ± 0.43	**	0.45 ± 0.02 ^b	
	Wholegrain		4.72 ± 0.46 ^a		1.26 ± 0.19 ^a		11.55 ± 0.67		0.36 ± 0.04 ^a	
Product status	Vegan	**	5.63 ± 0.36 ^b	*	1.56 ± 0.15 ^b	-	12.19 ± 0.54	-	0.39 ± 0.03	
	Vegetarian		4.78 ± 0.36 ^a		1.31 ± 0.15 ^a		11.81 ± 0.53		0.42 ± 0.03	

651 ¹ Nutritional values adjusted to dry weight basis

652 Different letters indicate that significant differences exist among them as determined by the Tukey HSD test. Values are expressed on a dry basis.

653 -: not significant; *: P ≤ 0.05; **: P ≤ 0.01; ***: P ≤ 0.001.

654

655 **Table 4:** Least squares mean and standard error of the means from the MANOVA test comparing the nutritional facts of fresh gluten-free pasta¹.

Factor		P-value	Energy (kcal/100 g)	P-value	Fat (g /100 g)	P-value	Saturated Fat (g/100 g)	P-value	Carbohydrates (g/100 g)	
Product labelling	Branded	-	204.71 ± 44.06 ^a	-	3.89 ± 2.96 ^a	-	1.66 ± 1.45 ^a	-	32.96 ± 9.13 ^a	
	Private	-	178.64 ± 53.32 ^a	-	2.57 ± 3.58 ^a	-	1.41 ± 1.75 ^a	-	29.29 ± 11.05 ^a	
First ingredient listed	Pulses	-	196.07 ± 80.30 ^{ab}	-	4.24 ± 5.39 ^{ab}	-	1.36 ± 2.63 ^{ab}	-	22.59 ± 16.65 ^a	
	Grains	*	229.71 ± 37.40 ^b	*	5.42 ± 2.51 ^b	*	2.83 ± 1.23 ^b	-	37.17 ± 7.75 ^a	
	Potatoes	-	149.25 ± 45.32 ^a	-	0.02 ± 3.04 ^a	-	0.41 ± 1.49 ^a	-	33.62 ± 9.40 ^a	
Ingredient category	Conventional	-	183.82 ± 41.51 ^a	-	1.21 ± 2.78 ^a	*	0.07 ± 1.36 ^a	-	31.88 ± 8.61 ^a	
	Organic	-	199.54 ± 55.95 ^a	-	5.25 ± 3.75 ^a	-	3.00 ± 1.84 ^b	-	30.37 ± 11.60 ^a	
Ingredient type	Refined	*	242.78 ± 28.35 ^b	*	5.39 ± 1.90 ^b	-	2.41 ± 0.93 ^a	-	38.70 ± 5.88 ^a	
	Wholegrain	-	140.57 ± 76.12 ^a	-	1.07 ± 5.11 ^a	-	0.66 ± 2.50 ^a	-	23.55 ± 15.78 ^a	
Product status	Vegan	-	179.32 ± 45.69 ^a	-	2.62 ± 3.06 ^a	-	1.06 ± 1.50 ^a	-	30.38 ± 9.47 ^a	
	Vegetarian	-	204.03 ± 51.44 ^a	-	3.84 ± 3.45 ^a	-	2.00 ± 1.69 ^a	-	31.87 ± 10.66 ^a	
			Fiber (g/100 g)				Sugars (g/100 g)			
Product labelling	Branded	-	3.98 ± 1.82 ^a	-	0.95 ± 0.66 ^a	-	7.60 ± 2.71 ^a	**	1.39 ± 0.34 ^b	
	Private	-	3.78 ± 2.20 ^a	-	0.78 ± 0.80 ^a	-	7.63 ± 3.28 ^a	-	0.67 ± 0.42 ^a	
First ingredient listed	Pulses	-	6.02 ± 3.32 ^a	-	1.49 ± 1.21 ^a	-	13.81 ± 4.94 ^b	-	0.54 ± 0.63 ^a	
	Grains	-	3.55 ± 1.55 ^a	-	0.75 ± 0.56 ^a	*	6.34 ± 2.30 ^{ab}	-	1.18 ± 0.29 ^a	
	Potatoes	-	2.07 ± 1.87 ^a	-	0.36 ± 0.68 ^a	-	2.70 ± 2.79 ^a	-	1.37 ± 0.35 ^a	
Ingredient category	Conventional	-	4.82 ± 1.72 ^a	-	0.95 ± 0.62 ^a	-	8.89 ± 2.55 ^a	-	0.88 ± 0.32 ^a	
	Organic	-	2.94 ± 2.31 ^a	-	0.78 ± 0.84 ^a	-	6.34 ± 3.44 ^a	-	1.18 ± 0.44 ^a	
Ingredient type	Refined	-	4.29 ± 1.17 ^a	-	1.14 ± 0.43 ^a	-	7.88 ± 1.74 ^a	-	0.91 ± 0.22 ^a	
	Wholegrain	-	3.47 ± 3.15 ^a	-	0.59 ± 1.14 ^a	-	7.35 ± 4.68 ^a	-	1.14 ± 0.59 ^a	
Product status	Vegan	-	4.56 ± 1.89 ^a	-	0.79 ± 0.69 ^a	-	6.28 ± 2.81 ^a	*	0.75 ± 0.36 ^a	
	Vegetarian	-	3.20 ± 2.13 ^a	-	0.94 ± 0.77 ^a	-	8.95 ± 3.16 ^a	-	1.31 ± 0.40 ^b	

656 ¹ Nutritional values adjusted to dry weight basis

657 Different letters indicate that significant differences exist among them as determined by the Tukey HSD test. Values are expressed on a dry basis.

658 -: not significant; *: $P \leq 0.05$; **: $P \leq 0.01$; ***: $P \leq 0.001$.

659 **Table 5:** Nutrients claims of gluten-free pasta sold on European market according to the Regulation (EC)
 660 No 1924/2006, lastly amended by Regulation (EU) No 1047/2012.

Claims	Description	Based on nutrient claims	Based on the nutrition facts	Comparison (claims vs. facts)
High/source of fiber	Contains at least 3 g of fiber per 100 g or at least 1.5 g of fiber per 100 kcal	251 (21.12%)	247 (20.79%)	Almost all claimed high fiber products meet the facts.
High/source of protein	At least 12% of the energy value of the food is provided by protein	318 (26.76%)	313 (26.35%)	Almost all claimed high protein products meet the facts.
Low/no/reduced fat	No more than 3 g of fat per 100 g for solids	57 (4.80%)	57 (4.80%)	All low/reduced fat claims meet the nutritional criteria.
Low/no/reduced saturated fat	The sum of saturated fatty acids and trans-fatty acids does not exceed 1.5 g per 100 g for solids	16 (1.35%)	16 (1.35%)	All claimed low/reduced saturated fat products meet the facts.
Low/no/reduced energy	No more than 40 kcal (170 kJ) per 100 g for solids	49 (4.13%)	45 (3.79%)	Most low/reduced energy claims meet the nutritional criteria.
Low sodium/salt	No more than 0.12 g of sodium, or the equivalent value for salt	19 (1.60%)	19 (1.60%)	All low/reduced salt claims meet the nutritional criteria.
Low/reduced sugar	No more than 5 g of sugars per 100 g	13 (1.09%)	13 (1.09%)	All low/reduced sugar claims meet the nutritional criteria.

661 Percentages are calculated based on the total number of gluten-free pasta products (1188).

662 A single product may have multiple claims.

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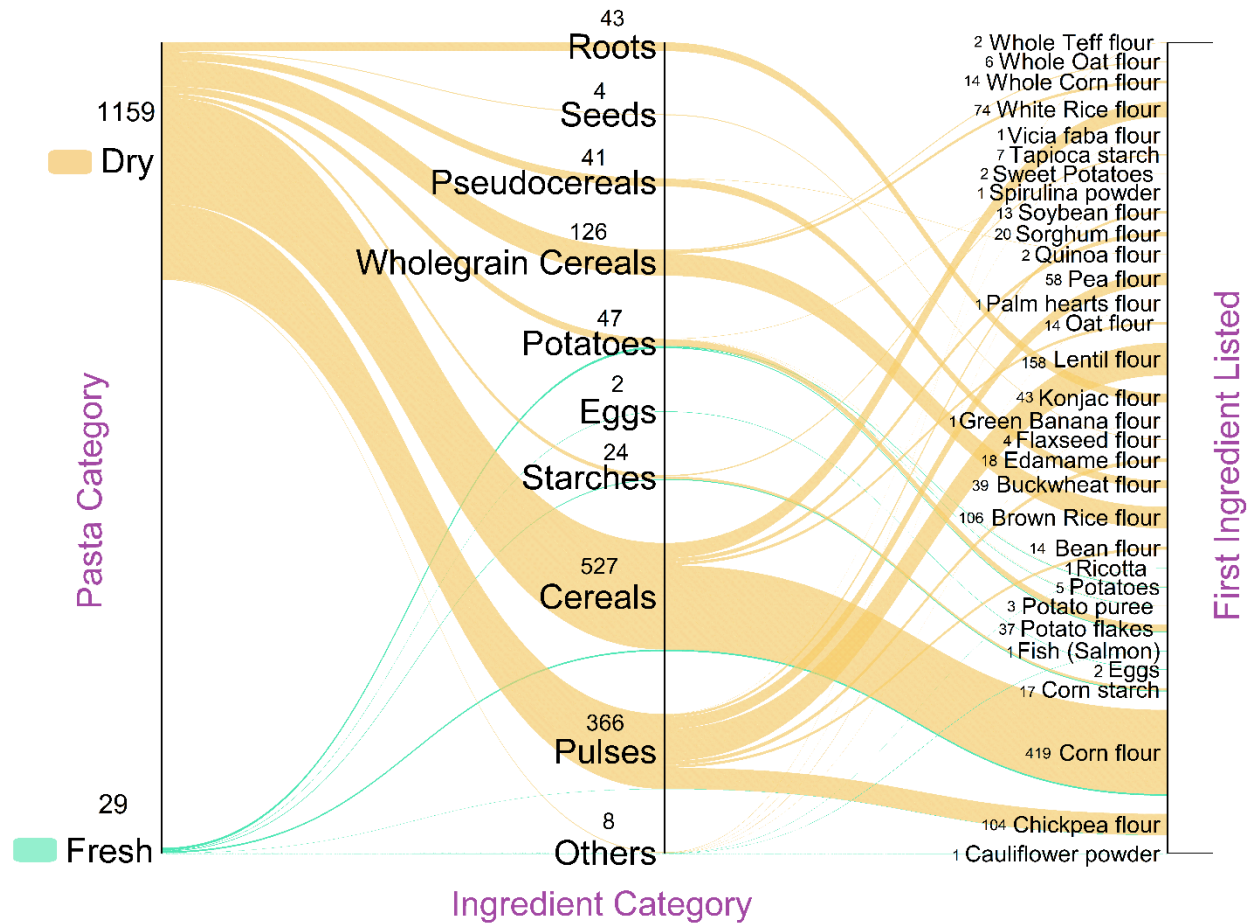
665 **Table 6:** Least squares mean and standard error of the means from the MANOVA test comparing prices of
 666 the dry and fresh gluten-free pasta as they are marketed.

Factor		P-value	Price (Euro/100 g)
Type	Dry	***	0.83 ± 0.04 ^a
	Fresh		1.14 ± 0.09 ^b
Product labelling	Branded	***	1.22 ± 0.05 ^b
	Private		0.76 ± 0.06 ^a
First ingredient listed	Pulses	***	1.22 ± 0.06 ^b
	Grains		0.95 ± 0.05 ^a
	Potatoes		0.79 ± 0.09 ^a
Ingredient category	Conventional	***	0.88 ± 0.05 ^a
	Organic		1.09 ± 0.05 ^b
Ingredient type	Refined	-	1.03 ± 0.05 ^a
	Wholegrain		0.94 ± 0.06 ^a
Product status	Vegan	-	0.99 ± 0.05 ^a
	Vegetarian		0.99 ± 0.05 ^a

667 Different letters indicate that significant differences exist among them as determined by the Tukey HSD
 668 test.

669 -: not significant; *: P ≤ 0.05; **: P ≤ 0.01; ***: P ≤ 0.001.

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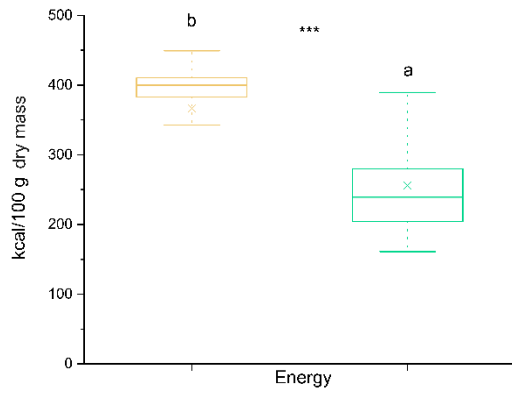


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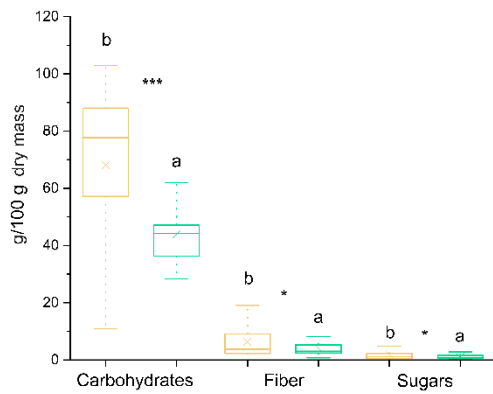
672 **Fig. 1:** First ingredient listed on the label of gluten-free pasta products (dry and fresh). Alluvial plot
 673 illustrating the distribution of the first ingredient listed on the labels of gluten-free pasta products,
 674 categorized by both their form (dry or fresh) and their ingredient category (roots, seeds, pseudocereals,
 675 wholegrain cereals, potatoes, eggs, starches, cereals, pulses and others). The numbers represent the counts
 676 of gluten-free pasta products that fall into each category (left column), ingredient category (middle column)
 677 and the exact count of products where each specific ingredient is the first listed (right column).

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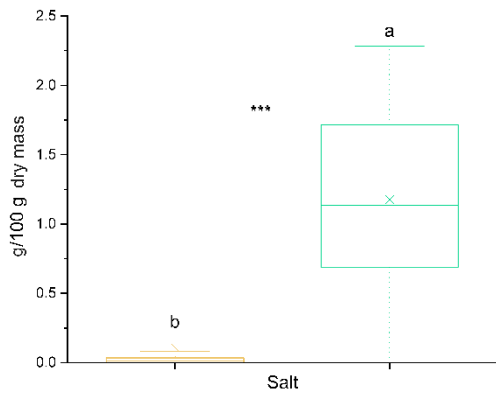
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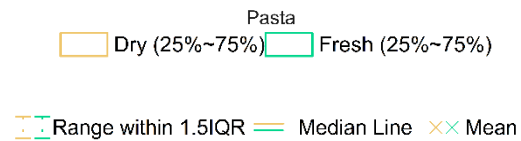
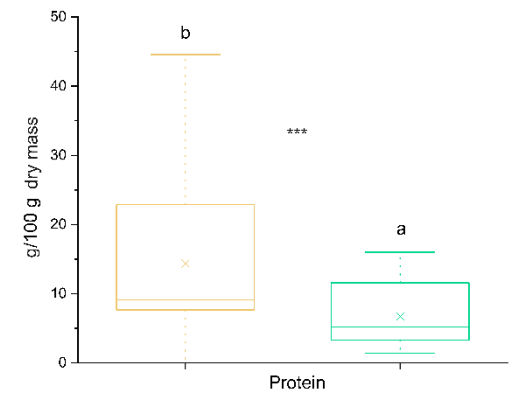
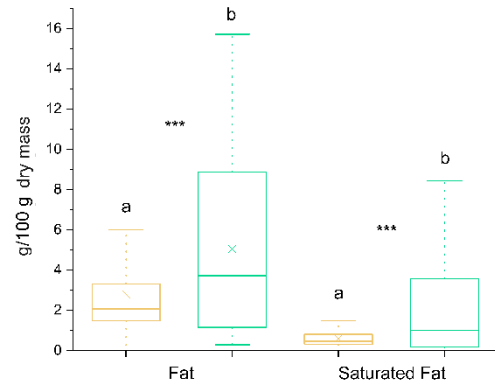


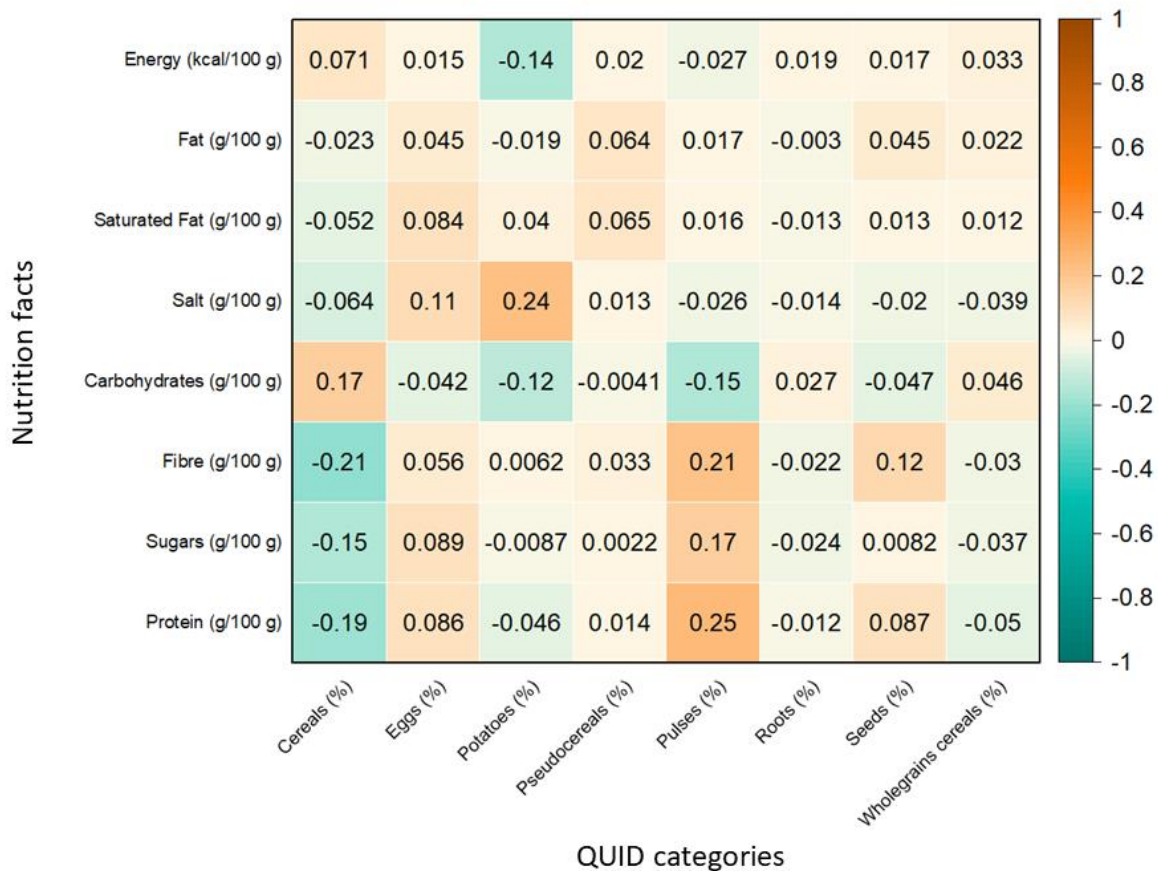
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682 **Fig. 2:** Nutritional facts of gluten-free pasta sold in the European market. For comparison purposes,
 683 nutritional facts were standardized by expressing them on dry basis. Different letters indicate significant
 684 differences exist among them as determined by the Tukey HSD test. *: $P \leq 0.05$; **: $P \leq 0.01$; ***: $P \leq 0.001$.
 685 Yellow and green boxes represent dry and fresh gluten-free pasta, respectively. The box is defined by the
 686 lower and upper quartiles with the median marked by a line in the center, and the mean indicated by a cross.
 687 The whiskers at the end of each box indicate the extreme values (minimum and maximum).

688





689

690 **Fig. 3:** Correlation between QUID categories and nutrition facts reported on the label of gluten-free pasta
 691 sold in Europe. The figure presents a correlation matrix that illustrates the relationships between various
 692 QUID (Quantitative Ingredient Declarations) categories and the corresponding nutritional facts as reported
 693 on the labels of gluten-free pasta products available in the European market. The color gradient in the matrix
 694 indicates the strength and direction of these correlations, with values representing correlation coefficients.
 695 Strong positive and negative correlations are indicated by deeper colors, while weaker correlations are
 696 represented by lighter shades.

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698