NUTRITIONAL VALUE OF GLUTEN-FREE PRODUCTS USING THE FRONT-OF-PACK LABELING NUTRI-SCORE

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ABSTRACT

Background. Nutri-score is a useful and comprehensible system of extended nutrition labeling of food, which is intended to provide the consumer with simple guidance in choosing food products, taking into account the consumer's healthy diet. In several countries, in addition to the mandatory nutritional value of food indicated on the product packaging, the use of the so-called food traffic lights, which, based on a simple graphic display, make it easier for consumers to concentrate on choosing healthier food options.

Objective. The aim of the work was to evaluate the nutritional composition of gluten-free food products based on the nutritional data indicated on the packaging of these products in order to find out how useful the use of Front-of-Pack labeling (FOPL) Nutri-score will be in distinguishing the nutritional value of products.

Material and Methods. We analyzed 206 randomly selected gluten-free food products obtained from commercial retail chains (semi-finished products, other bakery products, biscuits, flour mixtures, porridges, pasta, muesli, snacks, confectionery, etc.) intended for celiacs. Based on the obtained data, we evaluated the composition of the products using a modified algorithm for calculating the Nutri-score.

Results. We found that gluten-free products are a very rich source of energy, especially fats, carbohydrates and sugars, while the proportion of fiber and protein is very low. More than one third of the products had a nutritional score of category A or B, which are healthier variants, but over 40% of the analyzed products already fell into categories D or E. We found the lowest average energy value in the case of products classified in category B, the lowest average fat content and saturated fatty acids were found in products labeled A, the highest sugar content was found in products labeled D and E, the highest average protein content in products labeled A. The highest average salt content was found in products labeled C, fiber in products labeled B and A.

Conclusions. Nutritional profiling can significantly contribute to several health-beneficial decisions, especially when choosing and buying healthier food options, including gluten-free foods.

Key words: *nutrients, gluten-free foods, nutrition, healthy eating, Nutri-score*

INTRODUCTION

Gluten-free foods are intended for special dietary use. They are formulated, processed or manufactured for special nutritional purposes in people with gluten intolerance. A medical prescription is not required to purchase gluten-free food for special dietary use. They are commercially available, not only for gluten-intolerant subjects, but for anyone who voluntarily chooses to follow a gluten-free diet or consume these products [30]. Foods for special medical/nutritional purposes should contain nutrients at the level of nutrients found in the foods to be replaced. Nowadays, in developed countries, thanks to marketing strategies and trends related to healthy foods, as well as self-

diagnosis of disorders related to the consumption of gluten or wheat, the representation of the population eating gluten-free is increasing. This diet is currently one of the three most popular diets in the world, along with low-carbohydrate and fat-free diets [3]. These trends have boosted the global market for gluten-free and reduced-gluten products. Several factors affect the quality of gluten-free products. The quality of the input raw materials is important, as well as the production technology [13]. After overcoming earlier technological obstacles, the attention of producers and developers focused on the texture, taste and above all the nutritional quality of gluten-free products. Their quality is getting closer and closer to products containing gluten. One of the possibilities of increasing

their nutritional value is fortification (with vitamins, minerals) or adding nutritionally rich raw materials to recipes [20, 27]. The nutritional quality of gluten-free food has been a persistent problem for consumers. Studies have shown that the total fat content of gluten-free bread is almost double the amount found in their gluten-containing counterparts. Conversely, many gluten-free pastas are significantly higher in carbohydrates and sodium. Gluten-free products are generally poorer sources of protein and fiber. The glycemic index of these products varies depending on the type and quality of the ingredients used, as well as on the processing of food and the technological process of production [28]. Since gluten-free products are not usually fortified, they are usually deficient in folate, iron, niacin, thiamin and riboflavin. According to *Barone* et al. [1] patients with celiac disease consume significantly higher amounts of fat, sugar and lower amounts of fiber compared to healthy individuals.

Recently, the issue of mandatory labeling of the nutritional value of foods on the front of the packaging, the so-called Front-of-Pack nutrition labeling (FOPL). Front-of-pack nutrition labeling is one measure that has recently been introduced in combination with educational campaigns to promote healthy eating and prevent diet-related chronic diseases [5, 44]. FOPL nutrition labels use nutritional profiling models to assess the nutritional quality of food products, which is then transformed into a simple visual form. The purpose of FOPL is to simply and succinctly clarify mostly back-of-package nutritional information to help consumers make healthier food choices and to encourage the food industry to improve the nutritional composition of their products [26]. Discussions are currently underway in the EU and in several countries, including Slovakia, about the introduction of the FOPL label as a measure in the field of public health, which will direct consumers to healthier food choices. Nutri-score represents an alternative supported by several actors. The FOPL Nutri-score labeling scheme is a scientifically validated five-colour system developed by independent French researchers [24]. It was inspired by the British Food Standards Agency's nutritional profiling system, which was originally developed to regulate television advertising for children [34,35]. The algorithm assigns a given food/beverage a total score according to its nutritional composition. Based on this total score, Nutri-score categorizes food products into five color categories that reflect their nutritional quality [24]. Each color is also associated with a letter from A (dark green) to E (dark orange) to make labeling more accessible and understandable for consumers. With the exception of some specific commodities, FOPL also applies to gluten-free products.

The objective of our work was to evaluate the nutritional composition of selected gluten-free products based on the nutritional information provided on the packaging of these products in order to find out how useful the FOPL Nutri-score will be in distinguishing the nutritional value of products.

MATERIAL AND METHODS

Study design

Our study was methodically based on the evaluation of the nutritional values of randomly selected gluten-free products based on the nutritional information provided on the product packaging. We assessed the representation of basic nutrients such as proteins, fats, as well as the total energy value of the products and specific components such as saturated fatty acids, sugars, fiber and salt. We focused on gluten-free products of various types and from various manufacturers. In total, we analyzed 206 randomly selected gluten-free products obtained from commercial retail chains. These were mainly semi-finished products, other bakery products such as bars, soles, crackers, flour mixes, porridge, pasta, muesli, snacks, confectionery, etc. intended for celiacs. Based on the obtained data we evaluated the composition of the products using a modified Nutri-score algorithm [37]. The score calculation algorithm is based on the assessment of the presence and amount of unfavorable components of the food, such as energy (kJ per 100 g or 100 ml), sugars (g per 100 g or 100 ml), saturated fatty acids (g per 100 g or 100 ml) and salt (g per 100 g or 100 ml); and the favorable ones such as proteins (g per 100 g or 100 ml), fiber (g per 100 g or 100 ml) and the proportion of fruits, vegetables and legumes (%). The resulting score decides what class and color distinction the given product will receive. Final Nutri-score thresholds include five scaling classes A to E and five colors from dark green to dark orange, with the former being the healthiest variants and the latter the least healthy.

Statistical analysis

We used Microsoft Office Excel 2016 (Los Angeles, CA, USA) in combination with XLSTAT (version 2019.3.1) for statistical data processing. We performed descriptive analysis using mean ± standard deviation. For monitored parameters, we present additional statistical characteristics: max (maximum), min (minimum), med (median). We performed statistical analysis using the computer software STATISTICA 13 (TIBCO Software, Inc., Palo Alto, CA, USA, version 13.5.0.17) and MedCalc® Statistical Software version 22.009 (MedCalc Software Ltd, Ostend, Belgium; 2023). The level of statistical significance was set as P <0.05. Using one-way analysis of variance (ANOVA),

we tested differences between variables and compared using *Tukey's post hoc* test.

RESULTS AND DISCUSSION

We evaluated more than two hundred gluten-free products from the point of view of the nutritional information mandatory listed on the back of the product packaging. The values of the selected nutritional data of the examined gluten-free products are shown in Table 1.

The average energy value of the products was 1533 ± 390 kJ.100 g^{-1} or 100 mL^{-1}. Furthermore, we found an average fat content of 10.19 ± 9.29 g.100 g^{-1} or 100 mL^{-1}, of which saturated fatty acids 4.14 ± 5.58 g.100 g^{-1} or 100 mL^{-1}, content sugars 13.82 ± 16.45 g.100 g^{-1} or 100 mL^{-1}, protein content 5.43 ± 2.94 g.100 g^{-1} or 100 mL^{-1}, salt content 0.73 ± 0.73 g.100 g^{-1} or 100 mL^{-1} and fiber content 3.05 ± 2.81 g.100 g^{-1} or 100 mL^{-1}.

Based on the obtained values of nutritional data and calculations of the nutritional score, we found that 33 (16%) products were included in category A, i.e. the category with the best nutritional profile, category B 41 (19.9%), category C 47 (22.8%), category D 50 (24.3%) and category E 35 (17%) of gluten-free products. The average values of nutritional data of gluten-free products of individual categories A to E according to Nutri-score are shown in Table 2. Figure 1 shows the distribution of the energy value of gluten-free products adjusted according to the classification of products in individual Nutri-score categories. We found the lowest average energy value in the case of products classified in category B. As expected, the highest average energy value was found in category E. The energy value of gluten-free products in categories A, B and C differed significantly from the values in categories D and E (P<0.001). The energy value of the products is also significantly influenced by the fat content (Figure

Table 1. Basic descriptive characteristics of the evaluated sample of gluten-free products

N=206	Mean	SD	Min	Max	Med
Energy (kJ.100 g^{-1} or 100 mL^{-1})	1533	390	142	2260	1515
Total fat (g.100 g^{-1} or 100 mL^{-1})	10.19	9.29	0.1	32.19	6.60
Saturated fatty acids (g.100 g^{-1} or 100 mL^{-1})	4.14	5.58	0	22.90	1.50
Sugars (g.100 g^{-1} or 100 mL^{-1})	13.82	16.45	0	65.70	3.85
Proteins (g.100 g^{-1} or 100 mL^{-1})	5.43	2.94	0.31	14.30	4.60
Salt (g.100 g^{-1} or 100 mL^{-1})	0.73	0.73	0	4.00	0.68
Fibres AOAC (g.100 g^{-1} or 100 mL^{-1})	3.05	2.81	0	13.20	2.85

Table 2. Statistical evaluation of the nutritional value of gluten-free products profiled using Nutri-score

	Nutri-score A	Nutri-score B	Nutri-score C	Nutri-score D	Nutri-score E
	n=33	n=41	n=47	n=50	n=35
Energy (kJ.100 g^{-1} or 100 mL^{-1})	1391[a]	1264[a]	1362[a]	1660[b]	2032[c]
Total fat (g.100 g^{-1} or 100 mL^{-1})	2.76[a]	3.45[a]	7.89[b]	12.24[c]	25.25[d]
Saturated fatty acids (g.100 g^{-1} or 100 mL^{-1})	0.67[a]	0.68[a]	1.66[a]	4.43[b]	14.40[c]
Sugars (g.100 g^{-1} or 100 mL^{-1})	0.85[a]	2.53[ab]	6.89[b]	25.46[c]	31.94[d]
Proteins (g.100 g^{-1} or 100 mL^{-1})	7.09[a]	5.14[b]	4.58[b]	5.12[b]	5.75[ab]
Salt (g.100 g^{-1} or 100 mL^{-1})	0.28[a]	0.67[b]	0.98[c]	0.90[bc]	0.66[b]
Fibres AOAC (g.100 g^{-1} or 100 mL^{-1})	3.58[a]	3.98[a]	3.24[a]	2.95[a]	1.34[b]

[abcd] Different symbols in a line mean significant differences between samples
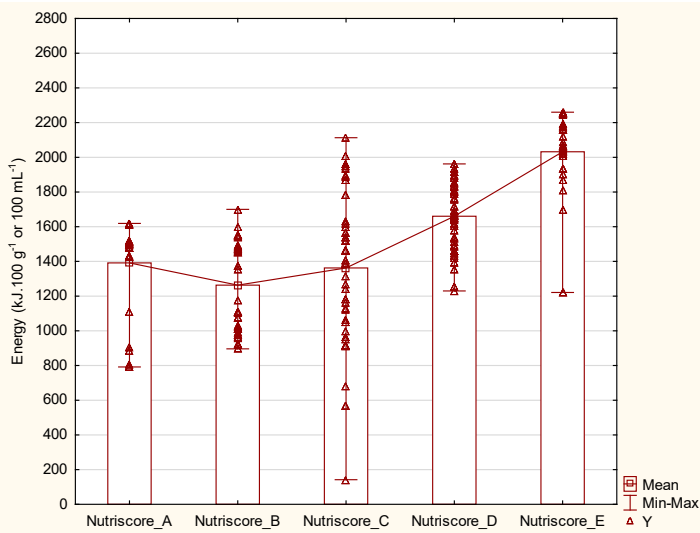
Figure 1. Variability of the energy value of gluten-free products adjusted according to Nutri-score
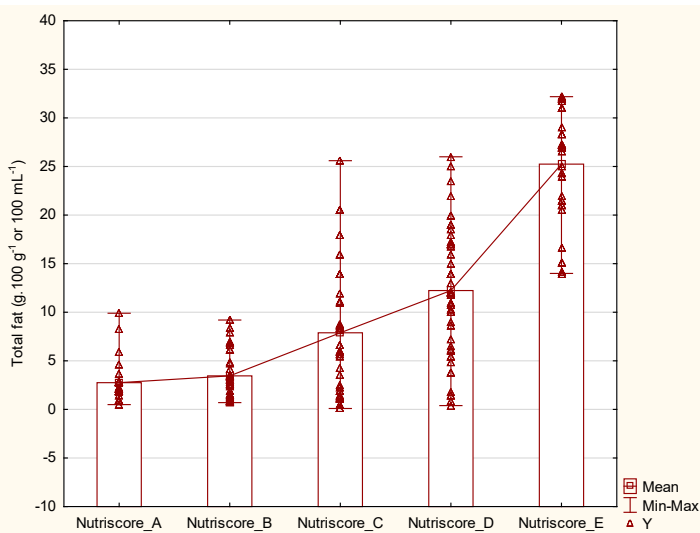

Figure 2. Variability of the total fat value of gluten-free products adjusted according to Nutri-score
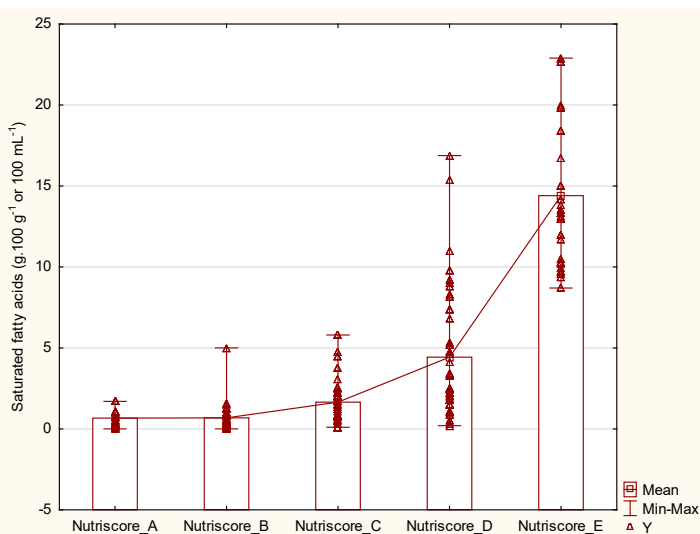

Figure 3. Variability of the saturated fatty acids value of gluten-free products adjusted according to Nutri-score

2). We found the lowest average fat content in the case of products labeled A and similar values in products labeled B. We did not find a significant difference between these categories (P >0.05). In the case of the other categories (C, D, E), a significant difference in fat content was observed (P <0.001). This indicator also confirmed the expected highest average fat content in products marked E. Similar results were also found in the case of saturated fatty acids, but we did not detect significant differences between products marked A, B and C in connection with this parameter (P>0.05; Figure 3). Sugar content also contributes to the energy value of food (Figure 4). As expected, we found a higher content in products labeled D and E, whose values differed significantly from other products classified in categories A to C (P<0.001). At the same time, in their case, we also found a relatively large variability of values. Proteins are a nutrient that is perceived very positively by consumers, especially in athletes and in baby food. The protein content of gluten-free products fluctuated considerably in all Nutri-score categories (Figure 5). We found the highest average protein content in the case of products marked A, which was significantly higher than in the case of the other categories (P<0.001). Unexpectedly, we found the second highest average protein content in the case of products labeled E. Based on the above, we can conclude that products with a worse score and label can also be a good source of protein. Figure 6 expresses the salt content of the products. We found the highest average salt content in products labeled C, the lowest in products in category A (P<0.001). Paradoxically, we again found the second lowest average salt content in the case of products marked E. The fiber content is shown in Figure 7. We found the highest average content of this health-protective component in products marked B and A. The fiber content differed significantly only in the case of products of category E, which was also the lowest (P<0.001).

As we can see in Table 3 in the correlogram of mutual correlations between individual parameters, a high score (negative status) is clearly related to a higher content of total and saturated fats, as well as energy and sugars. In their case, we found significant positive correlations. A negative correlation was confirmed for protein and fiber in relation to the score.

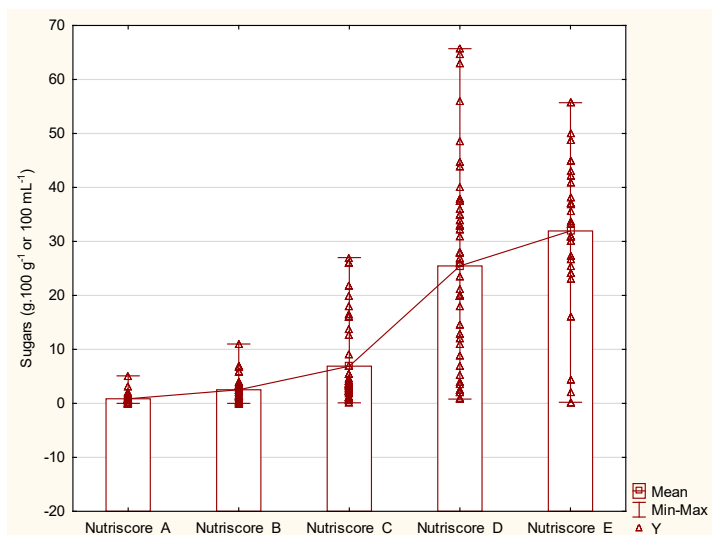Health in connection with food consumption is perceived and defined by

Figure 4. Variability of the sugars value of gluten-free products adjusted according to Nutri-score
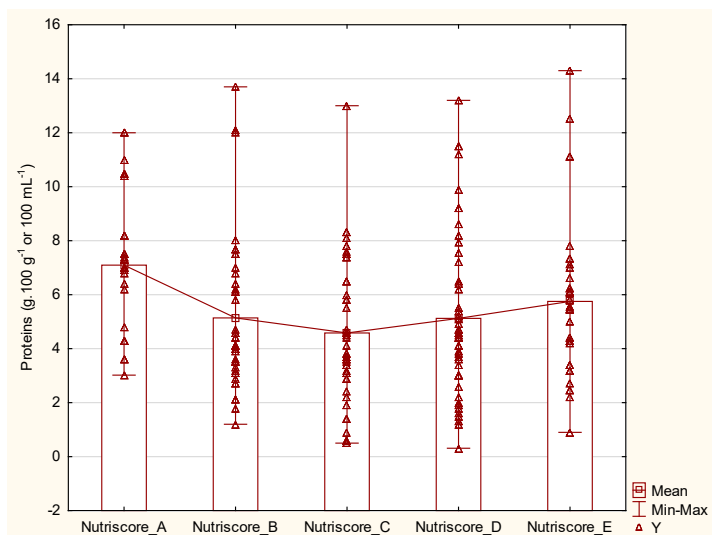

Figure 5. Variability of the proteins value of gluten-free products adjusted according to Nutri-score
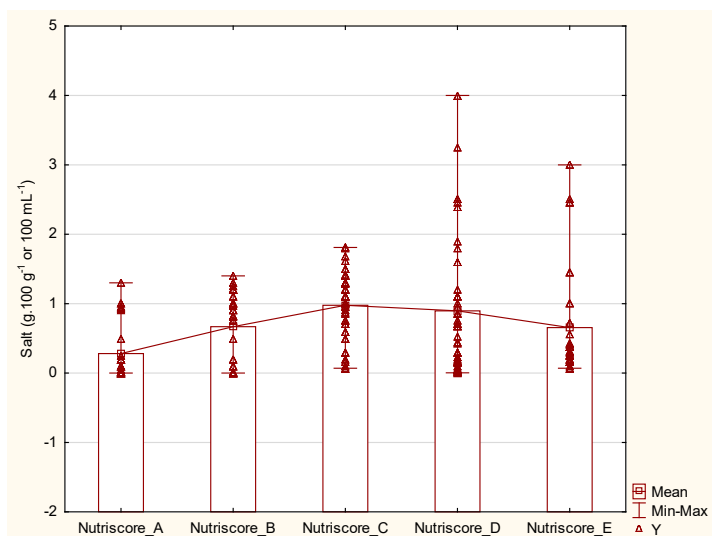

Figure 6. Variability of the salt value of gluten- products adjusted according to Nutri-score

consumers precisely by the quality of food [18]. The perceived quality of food is derived from the likelihood that the product supports health and a healthy lifestyle. However, the perception of products from a nutritional point of view depends on nutritional labeling [31]. Consumers rely on available nutritional information to form opinions about food commodities because nutrients in a product are invisible and intangible [4]. Since 2011, all food manufacturers are obliged to provide information on the nutritional value of food by stating mandatory data on the product packaging [36]. The original intention was to make it easier for the consumer to navigate between products and choose healthier options. However, the consumer effect was not achieved, because it is not easy to find your way around the numbers and evaluate them correctly from the point of view of the degree of suitability and nutritional balance. This is also why the European Union plans to introduce a unified system of nutritional labeling of food with the aim of building better lifestyle habits and reducing the obesity epidemic. The objective of Nutri-score is not to divide food into healthy and unhealthy, but to make the consumer choose a healthier version of the product based on the label. In the case of a worse score, the consumer can evaluate which parameter of the nutritional value reduced the score of the product and also evaluate the risks that would be related to the eventual consumption of the product. It has been found that consumers generally perceive food to be of high quality if the calorie, sugar and fat content remains low [19]. Consumers evaluate the quality of products both at the point of purchase through nutritional labels and at the point of consumption, where the initial perception is either confirmed or refuted, which affects future food choices [43].

Several studies have shown that the basic Nutri-score algorithm is able to differentiate the nutritional quality of foods in a way that is mostly consistent with current nutritional recommendations [23, 40]. In addition, the Nutri-score format (i.e., an interpretive, color-coded summary nutritional rating system) was found to be well perceived and better understood by consumers than other FOPL nutrition labels [11, 15]. Nutri-score has also been shown to be relatively useful as a shopping aid tool, which is ultimately reflected in the nutritional quality of purchases [7, 9, 22]. In addition, in the long term, FOPL labels, and thus the Nutri-score, are thought to have the potential to help reduce
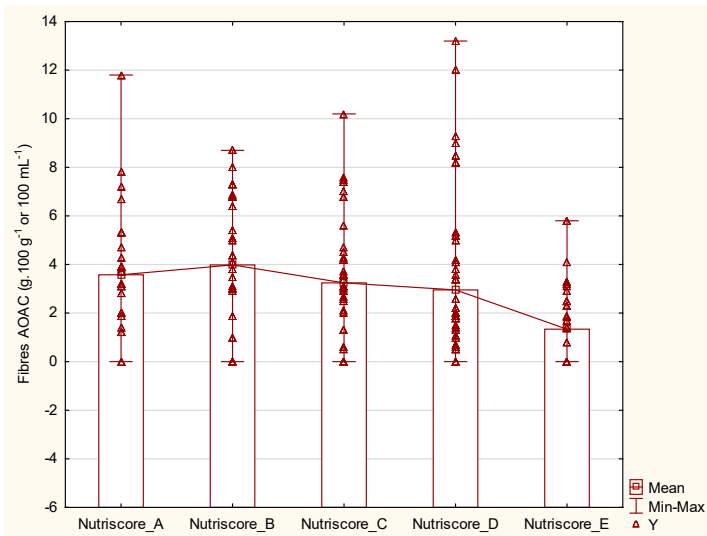
Figure 7. Variability of the fibres value of gluten-free products adjusted according to Nutri-score

mortality from civilization diseases by improving dietary habits [10].

The analysis of the gluten-free products showed that with the worsening of the score, all the parameters of the nutritional value did not have to deteriorate legally and proportionally. Exceeding the amount of even one component of the product is enough to worsen and reduce the score. The taste of gluten-free products is mostly associated with a higher caloric value of the products. Research has shown that the nutritional value of gluten-free products varies not only depending on the producer, but also on the country of origin, and they also found a higher content of fats, especially saturated, and carbohydrates, especially

simple sugars [29]. The raw materials from which gluten-free products are made usually have a higher energy value, thus increasing the energy value of the final product [30]. Studies analyzing gluten-free products have found that bread, pasta, various snacks and cakes have a significantly lower protein content than those that contain gluten. The gluten-free ones contained an average of 4.4 g per 100 g of protein compared to 10 g per 100 g in gluten-containing products [14]. It follows from many studies that gluten-free products are generally deficient in protein content. We reached a similar result in our analysis. Fats have an important sensory function and also affect the taste of gluten-free products. They are a very good source of energy for our body and its activity. In general, according to the principles of healthy nutrition, they should represent a maximum of 30% of the total energy intake [39]. The basic components of fats are fatty acids and glycerol. It is the representation of fatty acids that determines the properties of fats. However, a high intake of saturated and trans fatty acids is not recommended. Their intake should be a maximum of 10% and 1% of the total daily energy intake, respectively [33]. The intake of simple sugars should not exceed 60 grams during the day. Their long-term and excessive consumption may lead to weight gain and other undesirable consequences of this consumption. The fiber content of gluten-free products is generally very low. Studies confirm that fiber intake in patients on a gluten-free diet is significantly lower compared to a normal diet. This

Table 3. Correlogram of mutual correlations between individual parameters

Parameters	Score	Total fat	Saturated fatty acids	Energy	Sugars	Salt	Proteins	Fibres
Score	1	0.822	0.802	0.663	0.745	0.137	-0.059	-0.276
		P<0.0001	P<0.0001	P<0.0001	P<0.0001	P=0.0492	P=0.3990	P=0.0001
Total fat	0.822	1	0.814	0.697	0.555	0.033	0.134	-0.179
	P<0.0001		P<0.0001	P<0.0001	P<0.0001	P=0.6334	P=0.0549	P=0.0101
Saturated fatty acids	0.802	0.814	1	0.621	0.625	-0.141	-0.008	-0.135
	P<0.0001	P<0.0001		P<0.0001	P<0.0001	P=0.0436	P=0.9136	P=0.0530
Energy	0.663	0.697	0.621	1	0.535	-0.2	0.171	-0.222
	P<0.0001	P<0.0001	P<0.0001		P<0.0001	P=0.0039	P=0.0139	P=0.0014
Sugars	0.745	0.555	0.625	0.535	1	-0.246	-0.016	0.041
	P<0.0001	P<0.0001	P<0.0001	P<0.0001		P=0.0004	P=0.8245	P=0.5592
Salt	0.137	0.033	-0.141	-0.2	-0.246	1	-0.155	0.083
	P=0.0492	P=0.6334	P=0.0436	P=0.0039	P=0.0004		P=0.0265	P=0.2343
Proteins	-0.059	0.134	-0.008	0.171	-0.016	-0.155	1	-0.044
	P=0.3990	P=0.0549	P=0.9136	P=0.0139	P=0.8245	P=0.0265		P=0.5291
Fibres	-0.276	-0.179	-0.135	-0.222	0.041	0.083	-0.044	1
	P=0.0001	P=0.0101	P=0.0530	P=0.0014	P=0.5592	P=0.2343	P=0.5291	

fact, in combination with other facts, increases the probability of developing diseases such as obesity, diabetes and various cardiovascular diseases [41]. It is important to pay attention to the increased fiber intake, because the average consumption is only about 15 g per day, while the recommended intake is around 30 g [17, 25]. Our body needs to receive even a small amount of salt for optimal functioning. However, most people consume significantly higher amounts than recommended. The main source of salt is processed food (including bakery products). We should not take more than 5-6 grams per day. However, today's salt consumption exceeds 10-12 g per day. High salt consumption with the participation of other nutritional deficiencies (e.g. potassium deficiency) increases blood pressure and thus promotes the development of not only hypertension, but also diseases of the heart and blood vessels and the development of a heart attack or stroke. Most people consume too much salt, due to excessive consumption of processed and ultra-processed foods and dishes that are either naturally rich in salt and sodium or have salt added to them for technological and sensory reasons (bread, pastries, meat products, instant semi-finished products and snacks, seasoning mixes, etc.). Food containing an excessive amount of salt is considered to have a salt content higher than 1.5 g per 100 g. Low salt foods have less than 0.3 g per 100 g. And it is precisely the amount of salt in the product that can affect the final Nutri-score score. The World Health Organization and its members (including Slovakia) have agreed to reduce salt intake by 30% by 2025. Manufacturers are gradually reducing the amount of salt in their products so that consumers get used to the new taste. With this trend, the manufacturer can also achieve an improvement in the score of its products within the Nutri-score. At the same time, the benefits of eating foods with a reduced salt content are being promoted through activities aimed at increasing consumer awareness. It is generally believed that the main source of salt in the diet is precisely the salt added to dishes during cooking. The fact is that most of our salt comes from processed foods [12, 21, 42, 45, 47]. Nutri-score can alert us to the presence of a higher amount of salt in the product, because the value of the score will be affected by the high salt content, of course negatively. In that case, the consumer has a choice whether to choose the green and healthier option, or the dark orange one, which is therefore the least healthy.

Consumers usually do not read the information about the product on the back of the package during the purchase, whether it is nutritional information or the composition of the product. This is mainly due to lack of time or due to nutritional illiteracy and the inability to understand the meaning of nutritional information [2, 16, 38]. In this regard, FOPL graphic labels on the front of the package provide simpler and more visible information about the important nutritional elements of food products, thereby facilitating and speeding up consumer decision-making [46]. As reported by *Poquet* et al. [32], Nutri-score appears to be more effective in stimulating healthy food choices and improving the nutritional quality of shopping baskets than other FOPL labels. Moreover, the Nutri-score was the only one that led consumers to add products with significantly lower amounts of (saturated) fat and salt to their shopping carts [7]. The results of the studies indicate the potential of Nutri-score to stimulate the purchase of healthy products (A and B) and to inhibit the purchase of less healthy foods (D and E). The presence of Nutri-score helped the respondents in the study by de *Temmerman* et al. [6] to more easily assess the nutritional value of products. Respondents rated products as healthier when the Nutri-score logo was present on their packaging. These findings resonate with previous research showing that respondents tend to choose more products with a green Nutri-score and less products with a dark orange Nutri-score [8].

CONCLUSIONS

Healthy and nutritionally balanced foods are an integral part of the diet not only of healthy consumers, but also of people with specific nutritional needs or restrictions, including celiacs. The introduction of FOPL labels is becoming common practice and also applies to gluten-free products. Their quality has increased considerably in recent years, both in terms of sensory and nutritional aspects. Nutritional profiling can significantly contribute to several health-beneficial decisions, especially when choosing and buying healthier food options, including gluten-free ones, if the consumer is dependent on their consumption, which will also favorably affect the consumer basket and ensure healthier eating practices.

Conflict of interest
The Authors declare no conflict of interest.

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