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Classification of different types of flours available in the Romanian market based on the nutrition content

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Abstract. Flour is one of the most widely used products typically derived from wheat, corn, and rye and is classified based on its nutrition content. The present study aimed to identify and classify the different types of flour (wheat, rye, maize) commercially available in Romania. The market research covered eight types of flour available on the Romanian market: 1. Wheat Flour 000 (N-19), 2. Wheat Flour 550 (N-11), 3. Wheat Flour 650 (N-13), 4. Whole-Wheat Flour (N-15), 5. Durum Wheat Flour (N-8), 6. Spelt Wheat Flour (N-8), 7. Rye Flour (N-15), and 8. Maize Flour (N-23). The classification was carried out by analysing the most important parameters: energy, protein, fat, saturated fatty acid, carbohydrate, sugar, and dietary fibre content, using different statistical methods: descriptive statistics, box plot, hierarchical cluster, and surface radar analysis. The results revealed that white wheat flour represented more than 50% of the analysed samples, and significant differences were found between the tested types of flour. In addition, white wheat flour is characterized with lower dietary fibre, fat and protein content, but it has higher energy content and carbohydrate content. In contrast, whole meal, durum, spelt, and rye flours are characterized by lower carbohydrate

and higher fibre and fat content. The hierarchical cluster analysis showed that, on the basis of nutritional similarities and differences, the flours studied in Romania can be grouped into three distinct clusters.

Keywords and phrases: wheat, flour, carbohydrate, dietary fibre, nutrition value

1. Introduction

The different types of flour are produced primarily by using grain milling technologies, which have undergone major changes and developments from the beginning to the present. The milling of cereals is as old as mankind, with the earliest archaeological findings dating back to 6000 BC, and the flours produced played a fundamental role in human nutrition, which are still widely used in the world and are excellent sources of protein, complex carbohydrates, fibre, or even vitamins. According to different statistical reports, the total wheat consumption worldwide has increased from 742.82 to 759.54 million tonnes over the last four years (*Statista 1*, 2022). The top seven cereals grown in the world are maize, wheat, rice, barley, sorghum, oat, and rye, in the proportions of 1.125, 775.8, 505, 159.74, 62.05, 25.53, 14.3 million tonnes respectively (*Statista 2*, 2021).

The market offer of the different types of flour is much diversified, depending on the part of the grain that remains after milling. Within the European Union, thanks to the EU's single market, flour produced in any EU country can be bought and compared on the market of a given country. The grain kernel is structurally made up of three major components: the husk, the kernel core, and the germ (*Olugbire et al.*, 2021; *Zafar et al.*, 2020).

White flour generally contains only the endosperm part of the grain, which is high in carbohydrates, protein and has a small amount of oil. If all the husk content is milled into the flour during the milling process, wholemeal flour is obtained, which is darker in colour and has a higher fibre content (*Goesaert et al.*, 2005; *Zhang*, 2020).

Furthermore, the types of flour that contain the germ (reproductive epicentre) are rich in vitamins, minerals, oil, and fibre as well. While gluten is a unique protein found in wheat flour and products, it provides elasticity to the raw dough and helps to retain the gases produced during dough maturation (*Gómez et al.*, 2020).

According to the literature, there are different types of flour: all-purpose flour, unbleached flour, bread flour, cake flour, pastry flour, self-rising flour, and whole-wheat flour. The protein content, especially the gluten quality and quantity, is responsible for the rheological properties of raw pasta (*Araujo et al.*, 2008; *Ciudad-Mulero et al.*, 2021).

Therefore, flours with higher protein content provide a higher gluten ratio and a stronger dough for products such as bread, while low-protein flours are suitable for cakes and biscuits (*Hughes & Vaiciurgis*, 2020).

In addition to wheat flour, the baking industry also uses rye flour as supplementary flour, and corn flour has a wide range of uses, such as cornflakes and polenta, which is the national dish of the Romanian population.

The fat content of flour is used as a technological indicator, hence increased fat content can increase the volume of the bread as well by helping in the incorporation and retention of air during dough mixing (*Pareyt et al.*, 2011). It also imparts fat sensitivity, moisture, spread ability, flavour, colour, and anti-caking properties to bakery products (*Dewettinck et al.*, 2008).

The main objective of this research was to collect and compare the nutritional values of different types of flour commercially available in Romania in order to provide a comprehensive picture for consumers and users regarding the nutrient content.

2. Materials and methods

In this study, a market control was conducted in all existing supermarkets in Miercurea Ciuc (Romania) in August 2021 – a city of approx. 34,500 inhabitants (based on the 2021 census), and online shops available in Romania were also included. A total of 113 different flour nutritional values were collected from product labels, including: energy, fat, saturated fatty acids, carbohydrate, sugar, fibre, and protein content, per 100 g of flour. The origin of the examined flour products covers not only the Romanian production but also the products of several EU Member States (Supplementary Tables 1–8). Eight flour categories were analysed separately: 1. Wheat flour 000 (N-19), 2. Wheat flour 550 (N-11), 3. Wheat flour 650 (N-13), 4. Whole-grain wheat flour (N-15), 5. Durum wheat flour (N-8), 6. Spelt wheat flour (N-8), 7. Rye flour (N-15), 8. Corn flour (N-23). The collected data were analysed by using different statistical methods. For the 95% confidence interval calculation, the following equation was used (Equation 1):

$$\bar{x} - t * \frac{s}{\sqrt{n}} \leq \mu \leq \bar{x} + t * \frac{s}{\sqrt{n}}, \tag{1}$$

where $\bar{x}$ = the average, t = Student t, s = standard deviation, and n = sample size.

In addition, descriptive statistics (Minimum, 25th percentile, Median, Average, 75th percentile, Maximum) were used to find patterns among the data and characterize the different flours. The data distribution was determined by using the widely adopted box plot method, and surface radar charts were created using Microsoft Excel 2016 in order to compare the characteristics of the samples.

Before performing the cluster analysis, the data were verified, and the average values of the energetic value as well as of the fat, fatty acid, carbohydrate, sugar, and protein content were used. The applied parameters were centroid linkage

and Euclidian distance using IBM SPSS Statistics 22 software. The hierarchical relationships of the flour samples were visualized as a dendrogram. Centroid linking is a commonly used method that attempts to find a user-specified number (K) of clusters represented by their centroids. The hierarchical cluster analysis examines the point at which pairs that are related earlier are more similar than those that are related later in order to clarify common sources. To perform the hypothesis tests, the f-test and the two-sample t-test of the Microsoft Excel Data Analysis program package were carried out.

According to the GD 106/2002, the below wheat flour category specifications were established (*Table 1*). Based on the WHO recommendations, the maximum permitted moisture content is 15.5% (*Food and Agriculture Organization of the United Nations and World Health Organization*, 2021).

Table 1. The wheat flour classifications based on the standards (Ministry of Health, 2009)

Characteristics	White flour				Semi-white	Black flour	Black dietary
	Type 480	Superior type 000	Type 550	Type 650			
Humidity (max. %)	14.5						
Acidity degree (max.)	2.2			2.8	3.2	5	5
Ash content reported to the dry substance (max. %)	0.48		0.55	0.65	0.66–0.90	0.91–1.4	1.41–2.2
Insoluble ash content in HCl 10 (max. %)	0.2						

3. Results

3.1 Statistical analysis of the studied flours

The nutritional data of 113 flour products were collected and classified during the experiment. The nutritional values of the studied flour types are presented in *Table 2*, where the means and 95% confidence intervals (Mean ± 95% CI) are given. The results revealed that in terms of energy content the rye flour has the lowest value with 1,376 kJ/100 g, while the highest one was in the case of the

durum wheat flour: 1,487 kJ/100 g. In terms of fat and saturated fatty acid content, the lowest values were identified for spelt wheat, with 2.35 g/100 g and 0.52 g/100 g, respectively, and this category of flour has been characterized by the lowest carbohydrate percentage, 63.42 g/100 g, and the highest sugar and protein content, 2.72 g/100 g and 13.79 g/100 g respectively. From a dietetic point of view, this type of flour has the most favourable composition (*Wieser & Kieffer*, 2001). Regarding the dietary fibre content, the highest value (higher than 7 g/100 g) was found in the case of rye, whole-grain flour, and spelt flour.

Table 2. The nutrient composition of the main flour categories per 100 g

	(mean ± conf. int., α = 0.05)	Energetic value, kJ	Energetic value, kcal	Fat, g	Fat of which saturated fatty acids, g	Carbohydrates, g	Carbohydrates of which sugars, g	Dietary fibre, g	Protein, g
Wheat flour 000	***Avrg.***	***1,467***	***346***	***0.96***	***0.18***	***72.8***	***1.02***	***1.69***	***10.7***
	CI	*±25.61*	*±6.12*	*±0.07*	*±0.03*	*±1.55*	*±0.35*	*±0.55*	*±0.3*
Wheat flour 550	***Avrg.***	***1,448***	***345***	***1.07***	***0.3***	***70.7***	***1.73***	***2.68***	***10.7***
	CI	*±13.22*	*±6.5*	*±0.16*	*±0.09*	*±0.84*	*±0.96*	*±1.25*	*±10.5*
Wheat flour 650	***Avrg.***	***1,469***	***347***	***1.2***	***0.27***	***72.4***	***1.15***	***2.04***	***10.7***
	CI	*±20.12*	*±2.59*	*±0.14*	*±0.11*	*±0.82*	*±1.06*	*±1.01*	*±0.30*
Whole-grain wheat flour	***Avrg.***	***1,462***	***346***	***1.93***	***0.32***	***66***	***1.93***	***7.44***	***12.7***
	CI	*±41.88*	*±10.14*	*±0.28*	*±0.12*	*±3.04*	*±3.20*	*±0.82*	*±0.02*
Durum wheat flour	***Avrg.***	***1,487***	***350***	***1.65***	***0.37***	***69.4***	***2.05***	***5.57***	***13***
	CI	*±40.38*	*±10.58*	*±0.70*	*±0.11*	*±5.18*	*±1.76*	*	*±1.63*
Spelt wheat flour	***Avrg.***	***1,431***	***340***	***2.35***	***0.52***	***63.4***	***2.72***	***7.12***	***13.8***
	CI	*±50.23*	*±12.94*	*±0.50*	*±0.26*	*±5.44*	*±2.24*	*±2.21*	*±0.65*
Rye flour	***Avrg.***	***1,376***	***326***	***1.7***	***0.31***	***67.7***	***2.72***	***8.09***	***9.52***
	CI	*±50.58*	*±10.02*	*±0.29*	*±0.25*	*±2.59*	*±2.02*	*±3.50*	*±1.10*
Corn flour	***Avrg.***	***1,469***	***348***	***1.44***	***0.23***	***75.6***	***1.13***	***3***	***7.14***
	CI	*±11.28*	*±2.84*	*±0.31*	*±0.09*	*±1.09*	*±0.90*	*±1.14*	*±0.69*

3.2 Box plot analysis of the nutritional content of different flour categories

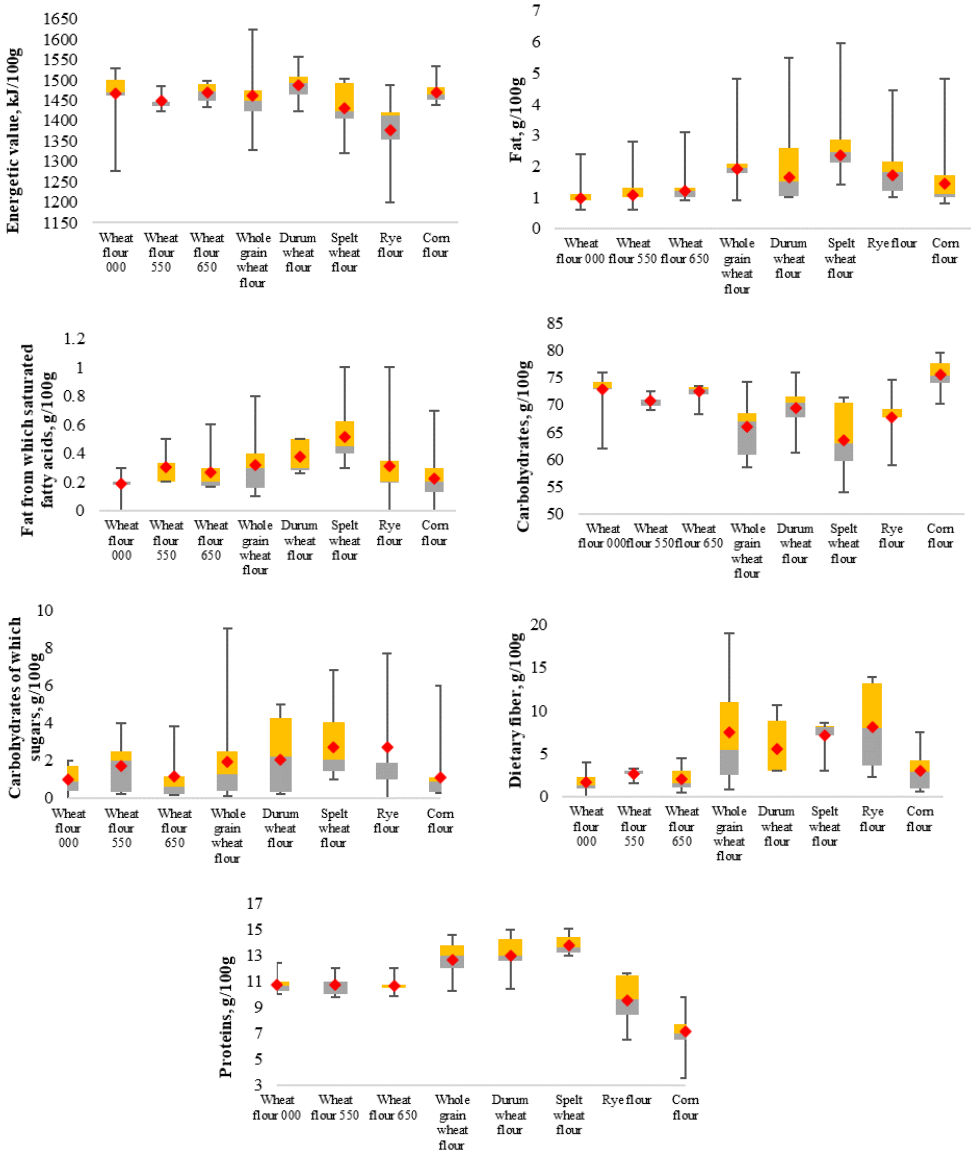
The box plot is an important tool to visualize and analyse the distribution of the values in the dataset. Thus, in order to provide a better insight into the characteristics of the flours analysed during this study, box plot analysis was used for the different types of flours, taking into consideration the most important parameters. As stated earlier, the median is statistically more representative than the mean values (*Williamson et al.*, 1989).

From the median energy values, it can be concluded that the studied flour types decrease in the following order: Durum wheat flour> Wheat flour 650> Wheat flour 000> Maize flour> Wholemeal wheat flour> Wheat flour 550> Spelt wheat flour> Rye flour (*Figure 1*). In terms of fat and saturated fatty acid content, it can be seen that the highest levels were found in whole-wheat flour, durum wheat flour, and spelt wheat flour. On the other hand, the lowest fat content was found in white wheat flour (000, 550, 650).

Furthermore, it is evident from the analysis that there are large differences between the highest and lowest values within the various product categories. The largest variation between the maximum and minimum energy content of the category was found for wholemeal flour (297 kJ/100 g), rye flour (288 kJ/100 g), and wheat flour 000 (251 kJ/100 g). The difference for spelt flour and durum flour was 183 kJ/100 g and 133 kJ/100 g respectively. The smallest differences were observed for maize (94 kJ/100 g), wheat flour 650 (63 kJ/100 g), and wheat flour 550 (60 kJ/100 g).

In all studied flour categories, the highest energy content was found in the case of *K classic* wholemeal wheat flour (1,625 kJ/100 g), while the lowest was identified for *Góbé* rye flour, with an energy content of 1,199 kJ/100 g. The individual values of the flours tested may be found in the supplementary materials, whereas the tables (S1–S8) summarize those values based on product categories, taking into account the following parameters: fat content, carbohydrate, protein, dietary fibre.

Regarding the fat content of flours, the lowest and the highest values were identified for *Auchan 000* wheat flour (0.6 g/100 g) and *Kenyérvarázs* corn flour (3.1 g/100 g) respectively. Since carbohydrates are present in the highest proportion in the flour, the samples were categorized based on this parameter, and the lowest carbohydrate content was found in the case of products under the *Economia* brand (54 g/100 g), while the highest carbohydrate content was found for the *Monidiferro* brand maize flour (79.55 g/100 g). On the other hand, the lowest protein concentration was observed for *Pronat* corn flour (3.6 g/100 g) and the highest for *Biopont* and *Dr. Avraham* (15 g/100 g). Furthermore, in terms of dietary fibre, the minimum value was observed for wheat flour 650 (0.4 g/100 g) and the maximum for rye flour (13.9 g/100 g) (see supplementary material tables S1–8).



Notes: The box plots were prepared using Microsoft Excel software. The lower and upper limits represent the second (50P) and third (75P) quartiles, the rhombus represents the average, and the ends of the whiskers represent the minimum and the maximum values.

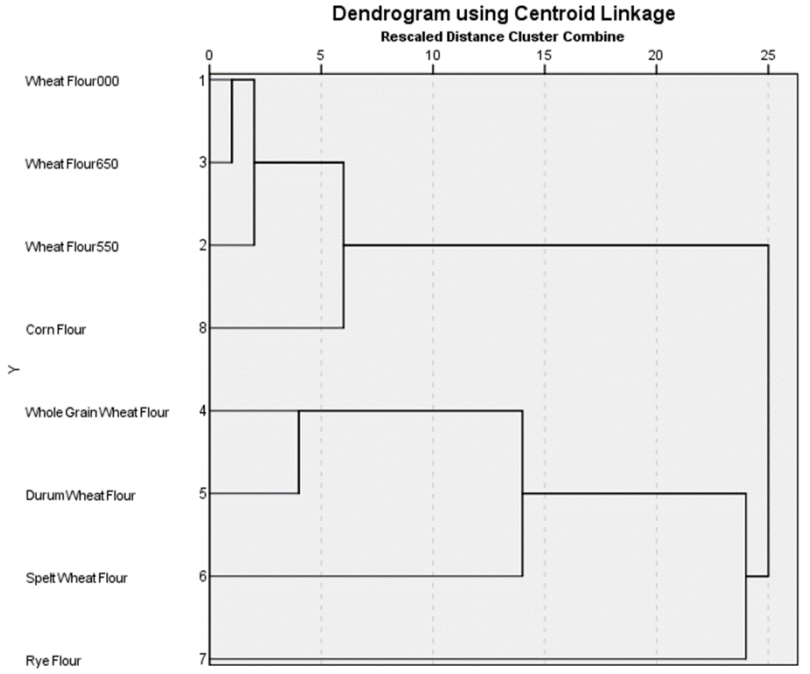
Figure 1. Box plot analysis of different flour categories

It has been shown that saturated fat intake increases heart disease risk factors, and hence the AHA (American Heart Association) recommends 5% to 6% of calories from saturated fat per day. The analysed saturated-fat-to-fat ratio in our case was on average 0.21, ranging from 0.16 (corn flour) to 0.28 (wheat flour 550). In terms of carbohydrate,

maize flour and white wheat flour have the highest carbohydrate content, with more than 70 g/100 g. Similar carbohydrate levels were observed for durum wheat (69.4 g/100 g), while spelt flour was characterized by low carbohydrate content (63.43 g/100 g) and high sugar content (2.72 g/100 g). The percentage of sugars in relation to total carbohydrates varied within the categories, the highest sugar content being found in flours with lower carbohydrate, particularly spelt (4.28%) and rye flour (4.02%). This type of negative correlation between carbohydrate, dietary fibre, and protein content has also been detected. Among the flours evaluated, wholemeal flour, durum, spelt, and rye flours have the highest protein and fibre content.

3.3 Hierarchical cluster analysis (HCA)

The aim of hierarchical cluster analysis is to create a dendrogram where the studied flours are grouped into branches that are close to each other based on their similarities. *Figure 2* depicts the hierarchical cluster analysis results as a dendrogram.



Note: The dendrogram was prepared using SPSS statistical software (centroid linkage, Euclidian distance).

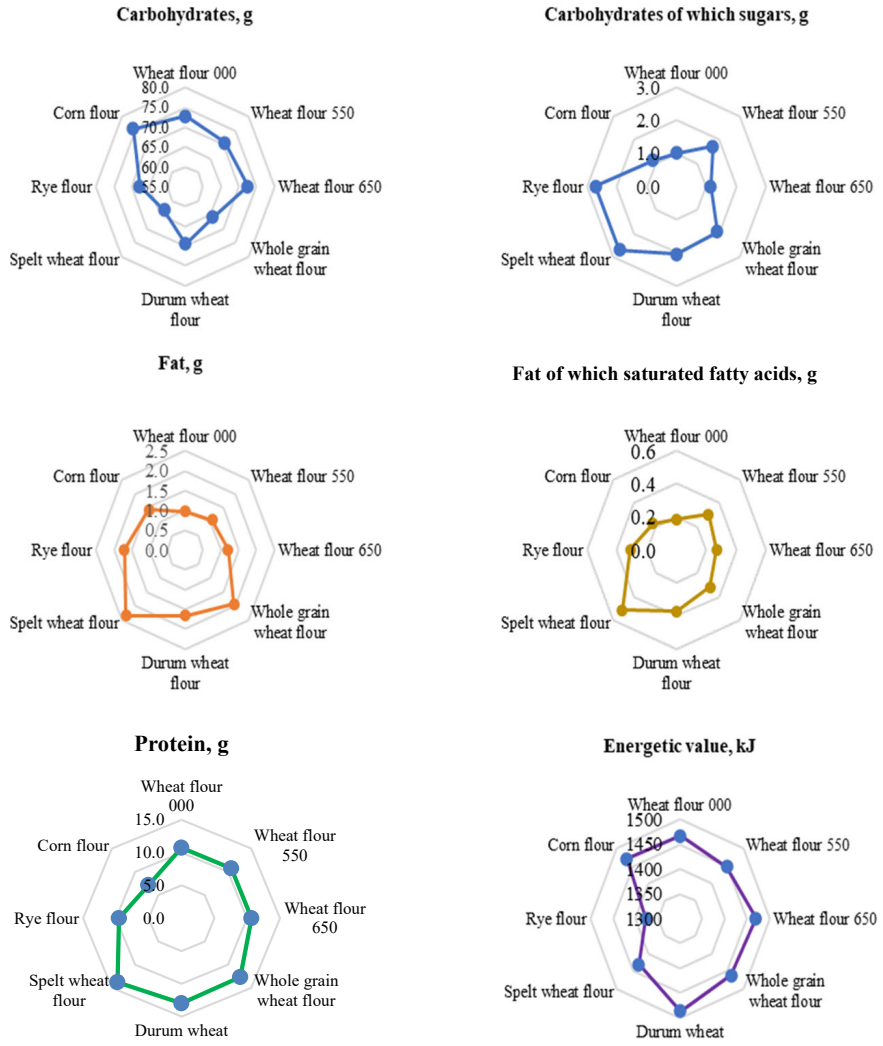
Figure 2. Cluster analysis of different types of flour

Based on the declared nutrition values, three distinct clusters can be identified. Wheat flour 000, 650, and 550 together with corn flour represent the first main cluster. In cluster two, whole-grain wheat flour and durum wheat flour are located most closely

in sub-cluster 2.1. Sub-cluster 2.2 contains only spelt wheat flour. Meanwhile, rye flour has different properties than the other flours and thus forms the third cluster.

3.4 Surface radar plot analysis

Similarly to the box plot analysis, an alternative visualization method was used to further illustrate the conspicuous properties. The purpose of surface radar plot graphs was to convey meaning to the various flour types through their difference by using surface radar plots.



Note: Plots were prepared using Microsoft Excel 2016.

Figure 3. Surface radar plots of the studied flours based on the composition

Data of the nutrition components (fat, saturated fatty acid, carbohydrate, sugar, dietary fibre, protein, energetic value) of the studied flours are presented separately (*Figure 3*). By analysing the composition of the groups, it is possible to clearly determine the order of the groups. Based on the carbohydrate content, the following increasing order was obtained (g/100 g): Spelt wheat flour (63) < Whole-grain wheat flour (66) < Rye flour (68) < Durum wheat flour (69) < Wheat flour 550 (71) < Wheat flour 650 (72) < Wheat flour 000 (72.8) < Corn flour (76). Similarly, the protein content shows the following order (g/100 g): Corn flour (7) < Rye flour (10) < Wheat flour 000 (10.7) < Wheat flour 550-650 (11) < Whole-grain and durum wheat flour (13) < Durum wheat flour (14).

3.5 Hypothesis tests

According to the hypothesis test results, differences were plotted out between the studied flour types. The summary of the t-test results are presented in *Table 3*. The detailed results are presented in the supplementary material tables (S9–15). The most significant differences were found in the case of spelt and rye flour (6 out of the 7 parameters) compared to the white flours.

Table 3. Summarized t-test results; the number of parameters that present the differences

	Wheat flour 550	Wheat flour 650	Whole-grain wheat flour	Durum wheat flour	Spelt wheat flour	Rye flour	Corn flour
Wheat flour 000	2	2	5	5	6	6	3
Wheat flour 550		1	4	2	4	3	2
Wheat flour 650			4	2	4	3	2
Whole-grain wheat flour				1	1	2	4
Durum wheat flour					1	2	3
Spelt wheat flour						2	5
Rye flour							4

4. Discussion

According to the results, it can be stated that there is a wide variety of flours on the Romanian market, and they show a very high variability regarding the nutrient content. The majority of the flour types examined (51.75%) were white

flours derived from wheat, while durum wheat flour (7%) and spelt wheat (7%) were present in smaller amounts. Only 13.27% of the products examined in this study were considered whole wheat, indicating that Romania's reform bakery is still in its early stages. Therefore, most of the bread and baked goods on the market are made from white wheat flour.

Whole-wheat flour has a high mineral content derived from the grain husk and a high fat content derived from the germ (*Wieser et al.*, 2020). Furthermore, low-ash white flours (types 000, 550, 650) are obtained from the endosperm (*Zafar et al.*, 2020).

According to similar research, wholemeal wheat flour, with its higher micronutrient content, plays an important role in human nutrition, with Mg^{2+} being an essential ion, containing at least 56.25 mg of magnesium per 100 g of food (*Ciudad-Mulero et al.*, 2021).

In order to have a healthy lifestyle, a key step is to eat a healthy diet, and therefore it is essential to promote these values. Regarding Romania, there is a major gap in the promotion of healthy eating, which favours a different lifestyle with lower carbohydrate and higher fibre flour (*Liu et al.*, 2020).

Furthermore, in terms of maize flour variability, it can be seen that it is present on the Romanian market with a diverse range of products, accounting for more than 20% of the studied products, which is not surprising given that corn flour is frequently used in the preparation of polenta in Romanian cuisine (*Laurentiu*, 2018).

The nutritional content of various grain flours is determined fundamentally by the varieties. Moreover, the variation in the quality of cereals depends on a wide range of factors influencing genotype and growing conditions (*Wieser & Kieffer*, 2001). There is an important trend in the baking industry worldwide to harmonize the benefits of different flour varieties in order to develop healthier products (*Dabija & Paius*, 2015; *Pontonio et al.*, 2021; *Valli et al.*, 2016).

5. Conclusions

In this study, we analysed the most commonly used cereal flours and their nutritional content available in the Romanian market, which is dominated by wheat flour because wheat is the most important cereal. Regarding the origin of the studied flour products, besides Romanian production, products from several EU Member States are also present on the Romanian market. Significant differences were found between the categories of the studied flours, with white wheat flour having a lower dietary fibre, fat, and protein content but a high energy and carbohydrate content. On the other hand, wholemeal, durum, spelt, and rye flours are lower in carbohydrate and higher in fibre and fat. Product labelling checks revealed inconsistencies, with many local producers failing to indicate

the fibre and salt content. Further studies are needed to determine the mineral composition of the flours in order to reveal the possible health effects and benefits.

Abbreviations

Avrg – average, 50P – median, 50P – 50 percentile, 75P – 75 percentile, CI – confidence interval, EU – European Union, GD – government decision, HCA – hierarchical cluster analysis, HCl – hydrochloric acid, n – sample size, N – number of samples, s – standard deviation, t – student t.

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