

Evaluation of Farinographic Properties and Bread-Making Performance of Wheat across Three Harvest Years

Mihaela Muțescu^{1*}, Iulia-Elena Susman¹, Gabriela Șerban², Cristina-Mihaela Marinciu²

¹National Institute of Research and Development for Food Bioresources - IBA Bucharest, 6 Dinu Vintila Street, Bucharest, Romania

²National Agricultural Research and Development Institute Fundulea, 915200 Fundulea, Călărași County, Romania

*Corresponding author. E-mail: mihaela.muțescu@gmail.com

ABSTRACT

Common wheat (*Triticum aestivum* L.) is a major cereal crop of global significance and plays a key role in bread production. In the present study, 27 wheat samples harvested across three production years (2023-2025) were evaluated for their farinographic characteristics bread-making quality. Dough development time ranged from 2.04 to 4.12 minutes in 2023, from 2.15 to 10.09 minutes in 2024, and from 3.37 to 6.27 minutes in 2025. Dough stability values varied between 9.59 and 15.15 minutes in 2023, 8.12 and 23.11 minutes in 2024, and 4.39 and 11.50 minutes in 2025. Additionally, the wheat samples were used to produce bread, which was subsequently assessed for moisture, loaf volume, crumb porosity, and elasticity. Overall, all tested cultivars demonstrated suitable physical characteristics, with good bread volumes and porosities. Samples harvested in 2024 harvest showed the highest bread volumes and porosities, reflecting the stronger dough properties measured in that year. The bread evaluation confirmed that Pitar, FDL Fagur, and FDL Abund produced the most desirable baking outcomes, characterized by high loaf volume, strong crumb structure, and good moisture retention.

Keywords: wheat, flour, bread, farinographic parameters, moisture, volume, porosity, elasticity.

INTRODUCTION

Common wheat (*Triticum aestivum* L.) is one of the most widely cultivated cereal crops worldwide (Mitura et al., 2023). In 2024/2025 period, the global harvested wheat area was approximately 220.40 million hectares, while worldwide wheat production reached around 800.86 million tonnes. The leading wheat-producing countries were China (140.10 million tonnes), European Union (122.12 million tonnes), India (113.29 million tonnes), Russia (81.60 million tonnes), the USA (53.65 million tonnes), Canada (35.94 million tonnes) Australia (34.11 million tonnes), Pakistan (31.44 million tonnes), Ukraine (23.40 million tonnes), and Turkey (19.00 million tonnes) (USDA, 2025). Due to its valuable chemical

composition and exceptional technological properties, wheat is considered a fundamental cereal in food processing and is commonly classified as a "bread cereal" in many countries (Mitura et al., 2023).

Wheat is also the most important cereal crop in the European Union, including Romania. Romania ranked fourth in wheat cultivation within the European Union, following France, Germany, and Poland (INSSE, 2024). The harvested wheat area in Romania in 2023 was approximately 2.3 million hectares, with a total production of 9.6 million tonnes (FAO, 2023).

In 2023, the top 10 wheat-producing counties in Romania were Teleorman, Dolj, Timiș, Constanța, Olt, Călărași, Ialomița, Arad, Giurgiu, and Brăila (Table 1) (INSSE, 2024).

Table 1. Top 10 wheat-producing counties in Romania

County	Total production (tones)
Teleorman	802323
Dolj	790791
Timiș	703240
Dolj	698448
Constanța	653556
Olt	503261
Călărași	476485
Ialomița	426533
Arad	400268
Giurgiu	374168
Brăila	356209

Given its significant role in global agriculture and food production, wheat serves as a primary raw material for various staple foods. Wheat flour, bread, and bakery products are considered essential for human nutrition worldwide, as they provide important macronutrients (mainly carbohydrates and protein), micronutrients (vitamins and minerals), dietary fiber, and antioxidants (Cappelli and Cini, 2021). Bread is a vital food in the diet of many people worldwide (da Costa et al., 2021) with average consumption ranging from 59 to 70 kg per capita annually (Benayad et al., 2021). This is attributed to its versatility in preparation, relatively low cost, and high energy content (Gerardo-Rodríguez et al., 2021). Various types of breads have been developed, influenced by regional or cultural differences in baking techniques and ingredients (Kuligowski et al., 2019). However, the fundamental ingredients remain flour, water, yeast, and salt (Calvo Carrillo et al., 2020). In this context, breeding for quality traits has become an important objective in breeding programs in Romania and worldwide, aiming to improve technological and baking properties of wheat cultivars (Marinciu and Săulescu, 2008; Mustățea et al., 2009; Ittu et al., 2011; Mustățea et al., 2013).

Although higher protein levels improve breadmaking quality within a cultivar, differences among cultivars with similar protein content are mainly determined by the quality of their gluten proteins, which governs dough rheology (Khatkar et al., 1995). Rheological properties of dough during mixing are very important in wheat

flour processing (Vizitiu and Danciu, 2011). The farinograph is a primary instrument for characterizing the viscoelastic behavior of wheat flour dough. It provides quantitative data on the structural transformations occurring during the kneading process, enabling a comprehensive assessment of critical quality determinants, including flour strength and protein quality (Codină, 2010). The farinograph properties of flour, including the absorption required to reach a fixed consistency and subsequent stability during mixing, correlate strongly with baking quality. According to Preston and Kilborn (1984), these mixing profiles serve as critical indicators of the flour's ability to withstand mechanical stress and maintain gas retention. Water absorption represents the precise volume of water required to reach a standard consistency of 500 FU (Farinograph Units). This metric indicates the hydration capacity of the protein fractions and serves as a critical predictor of overall baking quality (Van Lill et al., 1995). Dough development time is the time interval from the initial water addition to the point of maximum dough consistency. This reflects the rate of hydration and the formation of a continuous gluten matrix, representing the stage where the dough achieves the optimal balance of elasticity and viscosity necessary for gas retention. Stability defined as the duration during which the dough maintains its peak consistency, stability is a primary indicator of mixing tolerance. Stronger flours, characterized by a robust protein network, typically exhibit higher stability values, whereas weaker flours

break down more rapidly under mechanical stress (Vizitiu and Danciu, 2011).

The purpose of this study was to perform the baking test on 27 samples of white wheat flour (5 wheat samples harvested in 2023, 11 wheat samples harvested in 2024, and 11 wheat samples harvested in 2025) and determine the moisture, volume, porosity and elasticity of the obtained bread samples. Before conducting the baking test, the water absorption capacity of the flour sample was evaluated using a farinograph to ensure appropriate dough consistency during processing.

MATERIAL AND METHODS

Chemicals

Distilled water (Elix Millipore, USA) was used for the farinographic analysis.

Materials

The wheat flour samples used in this study were sourced from the National Agricultural Research and Development Institute (NARDI) - Fundulea, Romania. The tested cultivars included:

- Cultivar Glosa, released in 2005, which has been for many years and still is the most widely grown cultivar in Romania;

- Cultivars Pitar (released in 2015), Voinic (released in 2019), Ursita (released in 2021), FDL Abund (released in 2022), FDL Consecvent (released in 2024) and FDL Columna, released in 2025);

- Advanced lines under official testing, in order of their submitting to National trials: FDL Darnic, FDL Evident, FDL Fagur, FDL Granprim, FDL Gospodar, FDL Glorios, FDL Hora and FDL Hotar;

- One breeding line F20099GP1.

In 2023, the following varieties were analyzed: FDL Consecvent, FDL Columna, FDL Abund, FDL Fagur, and Pitar. In 2024, the samples analyzed included F20099GP1, FDL Darnic, FDL Evident, Voinic, FDL Abund, Ursita, FDL Consecvent, Glosa, FDL Columna, Pitar, and FDL Fagur. In 2025, FDL Granprim, FDL Consecvent, FDL Gospodar, Pitar, FDL Glorios, FDL Hora,

FDL Hotar, FDL Abund, Glosa, FDL Columna, and FDL Fagur samples were analysed.

Baking Performance Evaluation

A 1.0 kg sample of flour was used for each baking test. Water was added according to the flour's water absorption capacity, preheated to achieve a final dough temperature of 29-31°C. Yeast (3%) and salt (1.5%) were incorporated, and the dough was mixed for 8-10 minutes until homogeneous. After fermentation (90-100 minutes), the dough was divided, shaped, and proofed for 60 minutes (M.C.E. Meccanica, Italy). Baking was performed at 230°C in an oven (Mondial Forni, Italy) for 35 minutes.

Methods

Determination of absorption capacity

The water absorption capacity of the flour was determined using a Brabender Farinograph according to SR EN ISO 5530-1:2025. Approximately 300 g of flour (corrected to 14% moisture basis) was weighed and placed into the farinograph mixing bowl. Distilled water was gradually added through a burette until the dough consistency is between 480-520 Brabender Units (BU), which represents the point of optimal dough development. The amount of water required to reach this consistency was recorded and expressed as a percentage of the flour weight. This percentage indicates the water absorption capacity of the flour, which reflects its ability to retain water during mixing and is influenced by the protein content, starch damage, and the presence of fiber or other constituents.

Each measurement was performed in duplicate, and the average value was reported.

Determination of bread humidity

Moisture content (H) of bread was determined by the gravimetric loss-on-drying method (SR EN ISO 712:2024).

Determination of the specific volume

The specific volume of the baked product was determined by rapeseed displacement, following standard procedure. The volume (V)

displaced by the sample was measured and expressed per 100 g of product (cm³/100 g) (SR 90:2007, p. 5).

Determination of porosity

Porosity (P) was assessed by determining the total volume of voids in a known volume of the sample core, calculated using its measured mass and density. The result was expressed as g/100 g (%) (SR 90:2007, p. 6).

Elasticity determination

A crumb sample of defined geometry was compressed under a constant force for a specified time. Upon removal of the force, the extent to which the sample returned to its original height was measured and used as an indicator of crumb elasticity. The result was expressed as g/100 g (%) (SR 90:2007, p. 7).

Statistical analysis

All methods were applied for samples characterisation in at least two repetitions. Results are expressed as mean values \pm standard deviation (SD). Statistical analysis was conducted using one-way analysis of variance (ANOVA), followed by Tukey's test to evaluate differences between means (Minitab software, Minitab Inc., Coventry, UK). A significance level of $p < 0.05$ was considered statistically significant.

RESULTS AND DISCUSSION

Assessment of Farinograph Parameters

The farinograph characteristics of the flour samples collected in 2023 are summarized in Table 2.

Table 2. Farinograph characteristics of flour samples collected in 2023

Parameter	WA	DT	S	DS
Pitar	59.7	2.37 \pm 0.23 ^d	15.16 \pm 0.31 ^a	32 \pm 1.52 ^b
FDL Abund	60.1	2.04 \pm 0.29 ^e	11.15 \pm 0.28 ^b	37 \pm 2.15 ^b
FDL Consecvent	60.8	3.45 \pm 0.21 ^b	9.59 \pm 0.15 ^d	50 \pm 3.53 ^a
FDL Columna	59.5	4.12 \pm 0.32 ^a	10.12 \pm 0.32 ^c	16 \pm 1.22 ^c
FDL Fagur	55.7	3.32 \pm 0.19 ^c	11.15 \pm 0.41 ^b	18 \pm 1.89 ^c

DT: development time, minutes; WA: water absorption, %; S: stability, minutes; DS: degree of softening, minutes. The values are expressed as means \pm standard deviations (n = 2). Values followed by different letters in the same column are significantly different ($p < 0.05$).

Water absorption represents the amount of water required by a specific quantity of flour to produce dough with a defined standard consistency. This target consistency is typically represented by a farinograph curve centered around the 500 BU line. The water absorption capacity of flour is primarily determined by the characteristics of its major components, gluten proteins and starch. In addition, farinograph absorption is known to be associated with dough stability.

A high water absorption value is generally considered advantageous, as it indicates strong hydration capacity and often reflects better breadmaking potential. When elevated water absorption is accompanied by a low degree of softening, the flour is typically regarded as high quality, showing good dough strength and resistance to mechanical stress. Conversely, high water absorption

combined with a high degree of softening suggests weaker dough behavior, signaling a flour of lower technological value (Aydoğan et al., 2015).

Water absorption capacity ranged from 55.7% to 60.8%, whereas dough development time (DT) varied between 2.04 and 4.12 minutes. Dough stability was recorded in the range of 9.59 to 15.16 minutes, while the degree of softening ranged from 16 to 50 minutes. All cultivars had acceptable farinographic parameters.

Moreover, Table 3 summarizes the farinographic parameters of the 11 flour samples collected in 2024, which were analyzed to assess their dough rheological properties, including water absorption, development time, stability, and softening degree.

Table 3. Farinograph characteristics of flour samples collected in 2024

Parameter	WA	DT	S	DS
Glosa	63.5	5.10±0.29 ^c	10.14±0.88 ^h	44±0.48 ^{a,b}
Pitar	64.3	5.04±0.41 ^c	14.28±0.71 ^e	39±1.09 ^{a,b,c}
Ursita	67.8	2.30±0.22 ^h	8.12±0.36 ^j	37±1.16 ^{b,c}
Voinic	64.6	4.33±0.31 ^d	14.37±0.41 ^e	34±1.82 ^{b,c}
FDL Abund	60.5	4.08±0.45 ^e	22.40±0.29 ^b	11±1.48 ^d
FDL Consecvent	65.1	4.25±0.31 ^d	16.22±0.29 ^d	29±1.33 ^c
FDL Columna	62.8	2.55±0.19 ^g	23.11±0.39 ^a	15±1.32 ^d
FDL Darnic	63.6	3.10±0.25 ^f	9.48±0.29 ⁱ	49±1.39 ^a
FDL Evident	61.7	5.39±0.23 ^b	13.13±0.39 ^g	34±1.21 ^{b,c}
FDL Fagur	60.3	2.15±0.35 ⁱ	13.34±0.58 ^f	30±1.41 ^c
F20099GP1	59.0	10.09±0.27 ^a	21.23±0.39 ^c	10±1.26 ^d

DT: development time, minutes; WA: water absorption, %; S: stability, minutes; DS: degree of softening, minutes.

The values are expressed as means ± standard deviations (n = 2). Values followed by different letters in the same column are significantly different (p < 0.05).

The water absorption capacity of the analyzed flour samples ranged from 59.0% to 67.8%, indicating notable variability among samples. The farinograph development time represents the duration required for the dough to reach its point of optimum gluten development during mixing.

This parameter, often referred to as the peak time, provides insight into the quality and strength of the flour's protein network. Flours with stronger gluten structures typically exhibit longer development times, whereas weaker flours reach their peak much more quickly. In this study, the dough development time (DT) varied between 2.15 and 10.09 minutes, reflecting differences in gluten strength.

Dough development time (DDT) and stability value are indicators of the flour strength, with higher values suggesting stronger doughs (Wang et al., 2002).

Dough stability ranged from 8.12 to 23.11 minutes, whereas the degree of softening varied between 10 and 49 minutes, suggesting a wide diversity in dough tolerance. All newer cultivars, except Ursita and Darnic had better stability than the widely grown Glosa, and only FDL Darnic showed more degree of softening than Glosa.

Table 4 summarizes the farinographic parameters of the flour samples collected in 2025, providing an overview of their rheological behavior and comparative performance with previous years.

Table 4. Farinograph characteristics of flour samples collected in 2025

Parameter	WA	DT	S	DS
Glosa	64.6	4.33±0.29 ^e	6.57±0.39 ^h	74±1.32 ^b
Pitar	66.2	4.46±0.19 ^d	9.11±0.41 ^g	71±1.26 ^{b,c,d}
FDL Abund	62.8	5.14±0.42 ^c	11.16±0.62 ^f	56±0.98 ^e
FDL Consecvent	63.2	4.21±0.32 ^f	9.38±0.32 ^a	62±1.82 ^{c,d,e}
FDL Columna	63.8	6.27±0.41 ^a	11.35±0.71 ^d	52±1.29 ^e
FDL Fagur	61.6	6.25±0.29 ^a	11.50±0.66 ^d	61±1.32 ^{d,e}
FDL Granprim	65.9	4.20±0.30 ^f	7.13±0.22 ^c	73±1.96 ^{b,c}
FDL Gospodar	61.0	5.09±0.23 ^c	7.52±0.39 ^b	74±2.15 ^b
FDL Glorios	59.7	5.48±0.40 ^b	11.40±0.29 ^e	55±1.48 ^e
FDL Hora	59.5	3.37±0.19	4.39±0.23 ⁱ	86±1.26 ^a
FDL Hotar	61.6	4.31±0.22 ^{e,f}	7.52±0.31 ^h	81±2.05 ^{a,b}

DT: development time, minutes; WA: water absorption, %; S: stability, minutes; DS: degree of softening, minutes.

The values are expressed as means ± standard deviations (n = 2). Values followed by different letters in the same column are significantly different (p < 0.05).

The water absorption capacity of the analyzed flour samples ranged from 59.5% to 66.2%, indicating substantial variability in their hydration properties. Dough development time (DT) varied between 3.37 and 6.27 minutes, suggesting differences in gluten strength and dough formation kinetics. Dough stability ranged from 6.57 to 11.50 minutes, whereas the degree of softening varied between 52 and 86 minutes, reflecting diverse levels of dough tolerance and resistance to mechanical stress. All newer cultivars, except FDL Hora, had better stability than Glosa, and only FDL Hora and Hotar had higher degree of softening than Glosa.

A comparative analysis of the farinograph parameters of flour samples collected from the same variety over three consecutive years (2023-2025) revealed notable variations in dough rheological properties (Table 5). Water absorption capacity increased slightly from 55.7-60.8% in 2023 to 59.5-66.2% in 2025, indicating enhanced hydration potential in the more recent samples. Dough development time (DT) exhibited a broadening range over the years, from 2.04-4.12 minutes in 2023 to 3.37-6.27 minutes in 2025, suggesting progressive differences in gluten strength and dough formation kinetics. Similarly, dough stability values varied from 9.59-15.16 minutes in 2023 to 6.57-11.50 minutes in 2025, while the degree of softening showed

increased variability from 16-50 minutes in 2023 to 52-86 minutes in 2025, reflecting growing diversity in dough tolerance and resistance to mechanical stress. Overall, these trends indicate that the flour samples from 2025 generally exhibited higher water absorption and more heterogeneous dough properties compared to earlier years, which may be attributed to differences in flour composition, protein content, or environmental factors affecting wheat quality.

A total of five flour samples (FDL Consecvent, FDL Columna, FDL Abund, FDL Fagur, and Pitar) were analyzed across the three-year period (Table 5).

The farinograph results obtained for the five flour samples across the three-year period reveal distinct differences in hydration capacity, gluten development, and dough strength, all of which influence their suitability for white bread production. Water absorption varied between approximately 58-66%, with FDL Consecvent, FDL Columna, and Pitar consistently exhibiting the highest values across the years. These elevated water absorption levels indicate a stronger hydration potential and suggest that these flours contain protein and starch fractions capable of binding more water - an advantageous characteristic for white bread, as it contributes to improved dough yield, loaf volume, and crumb softness.

Table 5. A comparative study among 5 flour samples across 3 year period

Sample	2023				2024				2025			
	WA	DT	S	DS	WA	DT	S	DS	WA	DT	S	DS
FDL Consecvent	60.8	3.45±0.21 ^b	9.59±0.15 ^d	50±3.53 ^a	65.1	4.25±0.31 ^b	16.22±0.29 ^c	29±1.33 ^a	63.2	4.21±0.32 ^d	9.38±0.32 ^d	62±1.82 ^{a,b}
FDL Columna	59.5	4.12±0.32 ^a	10.12±0.32 ^c	16±1.22 ^c	62.8	2.55±0.19 ^d	23.11±0.39 ^a	15±1.32 ^b	63.8	6.27±0.41 ^a	11.35±0.71 ^b	52±1.29 ^b
FDL Abund	60.1	2.04±0.29 ^c	11.15±0.28 ^b	37±2.15 ^b	60.5	4.08±0.45 ^c	22.40±0.29 ^b	11±1.48 ^b	62.8	5.14±0.42 ^b	11.16±0.62 ^c	56±0.98 ^b
FDL Fagur	55.7	3.32±0.19 ^c	11.15±0.41 ^b	18±1.89 ^c	60.3	2.15±0.35 ^c	13.34±0.58 ^c	30±1.41 ^a	61.6	6.25±0.29 ^a	11.50±0.66 ^a	61±1.32 ^{a,b}
Pitar	59.7	2.37±0.23 ^d	15.16±0.31 ^a	32±1.52 ^b	64.3	5.04±0.41 ^a	14.28±0.71 ^d	39±1.09 ^a	66.2	4.46±0.19 ^c	9.11±0.41 ^e	71±1.26 ^a

For a more comprehensive comparison among samples, the average values of the farinographic parameters over the 2023-2025

period were calculated and are summarized in Table 6.

Table 6. Mean values of farinographic parameters of the analyzed samples over the 2023-2025 period

Sample	Mean values			
	WA	DT	S	DS
FDL Consecvent	63.03±2.15	3.97±0.45	11.73±3.89	47.00±16.70
FDL Columna	62.03±2.25	4.31±1.87	14.86±7.17	27.67±21.08
FDL Abund	61.13±1.46	3.75±1.58	14.90±6.49	34.66±22.59
FDL Fagur	59.20±3.10	3.91±2.11	12.00±1.18	36.33±22.19
Pitar	63.40±3.34	3.96±1.40	12.85±3.27	47.33±20.79

Dough development time (DT) showed an overall increasing trend from 2023 to 2025, indicating that the gluten networks in several samples required more time to reach optimal development in the later years. Samples such as FDL Fagur and Pitar displayed longer development times, characteristic of stronger gluten structures with enhanced mixing tolerance. In contrast, FDL Columna demonstrated shorter development times, reflecting rapid gluten hydration but lower dough strength. Dough stability (S) further distinguished the flours: FDL Abund, FDL Fagur, and Pitar presented markedly higher stability, excellent resistance to mechanical stress, which is especially beneficial under industrial mixing conditions.

The degree of softening (DS) increased in several samples over time, reflecting the dough's susceptibility to weakening during extended mixing. While higher softening values may negatively affect dough handling and final structure, the samples with high stability were capable of withstanding this weakening effect. Considering all farinograph

parameters together, FDL Abund, FDL Fagur, and Pitar exhibited the most balanced and favorable technological properties for white bread production, combining strong gluten networks with good stability and acceptable softening. Meanwhile, FDL Consecvent, despite its high water absorption, displayed weaker stability profiles and may require process adjustments such as shorter mixing times or blending with stronger flours to achieve optimal bread quality.

Determination of physical properties of bread samples

To evaluate how the technological properties of the flour samples influenced final product quality, bread was prepared using each type of flour from the three study years. This allowed us to directly observe how differences in water absorption, dough development, stability, and softening were reflected in the baked bread.

The physical properties of the bread samples were determined, and the corresponding results for 2023 are shown in Table 7.

Table 7. Physical properties of bread samples from 2023

Bread	H, %	V, cm ³ /100 g	P, %	E, %
Pitar	43.23 ^a	362 ^a	85 ^a	98 ^a
FDL Abund	42.26 ^d	341 ^b	84 ^a	98 ^a
FDL Consecvent	42.72 ^b	328 ^c	81 ^a	98 ^a
FDL Columna	42.48 ^c	284 ^d	76 ^a	98 ^a
FDL Fagur	41.05 ^e	338 ^{b,c}	84 ^a	96 ^a

H: moisture, %; V: volume, cm³/100 g; P: porosity, %; E: elasticity, %.

Among the analyzed samples, the Pitar sample demonstrated the highest values for all evaluated physical parameters, including moisture content, loaf volume, crumb porosity, and elasticity (Table 6). Overall, these parameters ranged from 41.05 to 43.23%, 284 to 362 cm³, 76 to 85%, and

96 to 98%, respectively. In contrast, the FDL Columna sample exhibited the lowest loaf volume and crumb porosity, while the FDL Fagur sample showed the lowest elasticity.

In addition, the bread results obtained for the 2024 samples are presented in Table 8.

Table 8. Physical properties of bread samples from 2024

Bread	H, %	V, cm ³ /100 g	P, %	E, %
Glosa	45.23 ^d	402 ^c	84 ^a	98 ^a
Pitar	44.99 ^e	441 ^a	85 ^a	98 ^a
Ursita	46.11 ^b	356 ^g	81 ^a	98 ^a
Voinic	45.41 ^c	396 ^{c,d}	82 ^a	98 ^a
FDL Abund	43.97 ^h	355 ^g	82 ^a	98 ^a
FDL Consecvent	46.47 ^a	370 ^f	83 ^a	98 ^a
FDL Columna	44.74 ^f	374 ^{e,f}	82 ^a	98 ^a
FDL Darnic	46.04 ^b	356 ^g	82 ^a	98 ^a
FDL Evident	44.39 ^g	386 ^d	84 ^a	98 ^a
FDL Fagur	43.34 ^h	414 ^b	82 ^a	98 ^a
F20099GP1	45.01 ^e	385 ^{d,e}	83 ^a	98 ^a

H: moisture, %; V: volume, cm³/100 g; P: porosity, %; E: elasticity, %.

Among the analyzed samples, the Pitar sample had the highest values for volume and porosity parameters. All analysed sampled presented the same value of elasticity, 98%.

Only two of the new cultivars had higher bread volume than Glosa.

The physical parameters of the samples analyzed in 2025 are listed in Table 9.

Table 9. Physical properties of bread samples from 2025

Bread	H, %	V, cm ³ /100 g	P, %	E, %
Glosa	43.83 ^c	375 ^b	82 ^a	98 ^a
Pitar	43.82 ^c	374 ^{b,c}	83 ^a	98 ^a
FDL Abund	43.85 ^c	373 ^{b,c}	80 ^a	97 ^a
FDL Consecvent	42.72 ^f	363 ^{c,d}	81 ^a	98 ^a
FDL Columna	44.28 ^b	361 ^d	81 ^a	98 ^a
FDL Fagur	43.36 ^c	367 ^{a,b}	84 ^a	98 ^a
FDL Granprim	44.81 ^a	346 ^e	80 ^a	97 ^a
FDL Gospodar	42.93 ^e	372 ^{b,c,d}	82 ^a	98 ^a
FDL Glorios	42.58 ^g	333 ^f	80 ^a	98 ^a
FDL Hora	43.14 ^d	404 ^a	83 ^a	98 ^a
FDL Hotar	43.02 ^e	382 ^b	84 ^a	96 ^a

H: moisture, %; V: volume, cm³/100 g; P: porosity, %; E: elasticity, %.

The FDL Hora sample showed the highest bread volume (404 cm³), whereas FDL Glorios recorded the lowest value (333 cm³). The porosity ranged from 80% to 84%, while the elasticity parameter was identical for most samples at 98%, except for FDL Granprim and FDL Abund, which both showed slightly lower elasticity values of 97%.

A comparison of the bread samples over the 2023–2025 period shows noticeable year-to-year variation in several physical parameters (Table 10).

The bread quality parameters presented in Table 10 reveal consistent differences among the five flour samples, particularly in terms of loaf volume, porosity, elasticity, and moisture content. These characteristics reflect the functional behavior of each flour during baking and complement the farinograph findings. Samples such as Pitar showed slightly higher moisture value in most years, which is often associated with improved crumb softness and longer freshness retention.

Table 10. A comparative study among 5 bread samples across 3 year period

Sample	2023				2024				2025			
	H	V	P	E	H	V	P	E	H	V	P	E
FDL Consecvent	42.72 ^b	328 ^c	81 ^a	98 ^a	46.47 ^a	370 ^c	83 ^a	98 ^a	42.72 ^d	363 ^{a,b}	81 ^a	98 ^a
FDL Columna	42.48 ^c	284 ^d	76 ^a	98 ^a	44.74 ^c	374 ^c	82 ^a	98 ^a	44.28 ^a	361 ^b	81 ^a	98 ^a
FDL Abund	42.26 ^d	341 ^b	84 ^a	98 ^a	43.97 ^d	355 ^d	82 ^a	98 ^a	43.85 ^b	373 ^a	80 ^a	97 ^a
FDL Fagur	41.05 ^e	338 ^{b,c}	84 ^a	96 ^a	43.34 ^e	414 ^b	82 ^a	98 ^a	43.36 ^c	367 ^{a,b}	84 ^a	98 ^a
Pitar	43.23 ^a	362 ^a	85 ^a	98 ^a	44.99 ^b	441 ^a	85 ^a	98 ^a	43.82 ^b	374 ^a	83 ^a	98 ^a

H: moisture, %; V: volume, cm³/100 g; P: porosity, %; E: elasticity, %.

Loaf volume exhibited the most notable variation among samples and across years. In 2023, the highest volumes were observed for Pitar (362 cm³), FDL Abund (341 cm³) and FDL Fagur (338 cm³), while FDL Columna presented the lowest volume (284 cm³). In 2024, a significant change occurred for all samples, with Pitar (441 cm³) and FDL Fagur (414 cm³) showing higher values, reflecting strong gas retention and optimal gluten performance. Although loaf volume slightly decreased in 2025 compared to 2024, Pitar, FDL Fagur, and FDL Abund continued to have the highest loaves. These results align with the farinograph data, where these flours demonstrated stronger gluten development and stability.

Porosity (P%) and elasticity (E%) remained consistently high across all three years, with values typically between 76-85% for porosity and 96-98% for elasticity. This uniformity suggests that the structural properties of the bread crumb were largely stable and minimally influenced by year-to-year variations. Notably, Pitar consistently achieved high porosity and elasticity values, supporting its

classification as a high-performance flour for white bread. FDL Fagur and FDL Abund also maintained robust crumb structure characteristics, consistent with their superior farinograph stability. In contrast, FDL Consecvent and FDL Columna exhibited slightly lower porosity values, reflecting their weaker dough strength and reduced loaf expansion potential. Overall, the bread evaluation confirms that Pitar, FDL Fagur, and FDL Abund produced the most desirable baking outcomes, characterized by high loaf volume, strong crumb structure, and good moisture retention. These findings correlate directly with their favorable farinograph properties and indicate that these flours are best suited for white bread production. FDL Consecvent and FDL Columna, which were on average the highest yielding in yield trials all over Romania, were still capable of producing suitable bread (Marinciu et al., 2025).

We determined the correlation between farinographic parameter and humidity, volume, porosity and elasticity of bread samples (Table 11).

Table 11. Correlation between farinograph parameters and flour characteristics

Parameter	H	V	P	E
WA	-0.5242	0.4134	0.0891	0.4288
DT	-0.1542	0.0982	0.0969	0.0344
S	-0.1161	0.2504	0.1191	0.1610
DS	-0.2735	0.2054	0.0280	0.1344

A positive and significant correlation was observed between water absorption (WA) and both bread volume and elasticity (Table 10). Additionally, positive but non-significant correlations were noted between water absorption and dough stability ($r = 0.2504$) as well as the degree of softening ($r = 0.2054$).

These results are consistent with those reported by Aydoğan et al. (2015), who found that bread volume is influenced by water absorption ($r = 0.374$). The results highlight the key role of water absorption in determining both dough rheology and final bread quality.

CONCLUSIONS

Based on the evaluation of 27 wheat samples collected over the 2023-2025 period, which included both farinographic characterization and assessment of bread quality attributes (moisture, loaf volume, crumb porosity, and elasticity), several key observations can be drawn regarding the technological performance of the studied materials. All bread samples analyzed during the 2023-2025 period exhibited physicochemical properties that complied with the quality requirements established by the standard for baking test evaluation. Moisture content remained below the maximum allowable limit of 45% for most samples, with the exception of FDL Darnic, Voinic, Ursita, FDL Consecvent, and Glosa in 2024. Regarding porosity, elasticity, and loaf volume, all samples fell within the accepted limits, showing porosity values of at least 66%, elasticity values of at least 92%, and minimum loaf volumes of 280 cm³.

These consistent results across three harvest years highlight the stability and baking potential of the studied wheat varieties.

Overall, this research provides valuable insights into the year-to-year performance of wheat used in breadmaking and offers a solid foundation for selecting raw materials with reliable dough properties and baking quality.

ACKNOWLEDGEMENTS

This study was funded by the ADER program (ADER 1.1.1/20.07.2023 project) and supported by Ministry of Agriculture and Rural Development.

REFERENCES

- Aydoğan, S., Şahin, M., Göçmen Akçacık, S., Hamzaoğlu, S., Taner, S., 2015. *Relationships between Farinograph Parameters and Bread Volume, Physicochemical Traits in Bread Wheat Flours*. Bahri Dağdaş Bitkisel Araştırma Dergisi Journal of Bahri Dagdas Crop Research, 3(1): 14-18.
- Benayad, A., Taghouti, M., Benali, A., Aboussaleh, Y., Benbrahim, N., 2021. *Nutritional and technological assessment of durum wheat-faba bean enriched flours, and sensory quality of developed composite bread*. Saudi Journal of Biological Sciences, 28: 635-642.
- Calvo Carrillo, Md.I.C., López Méndez, O.X., Carranco Jáuregui, M.E., Marines, J., 2020. *Evaluación fisicoquímica y sensorial de un pantipo baguette utilizando harinas de trigo (*Triticum spp*) y chícharo (*Pisum sativum L.*)*. Biotecnica, 22: 116-124.
- Cappelli, A., and Cini, E., 2021. *Challenges and Opportunities in Wheat Flour, Pasta, Bread, and Bakery Product Production Chains: A Systematic Review of Innovations and Improvement Strategies to Increase Sustainability, Productivity, and Product Quality*. Sustainability, 13: 2608. <https://doi.org/10.3390/su13052608>
- Codină, G.G., Mironeasa, S., Bordei, D., Leahu, A., 2010. *Mixolab versus Alveograph and Falling Number*. Czech Journal of Food Science, 28: 185-192.
- da Costa Borges, V., Fernandes, S.S., da Rosa Zavareze, E., Haros, C.M., Hernandez, C.P., Dias AR, G., de las Mercedes Salas-Mellado, M., 2021. *Production of gluten free bread with flour and chia seeds (*Salvia hispânica L.*)*. Food Bioscience, 43: 101294.
- FAO, 2023. <https://www.fao.org/faostat/en/#data/QCL/visualize>
- Gerardo-Rodríguez, J.E., Ramírez-Wong, B., Torres-Chávez, P.I., Ledesma-Osuna, A.I., Carvajal-Millán, E., López-Cervantes, J., Silvas-García, M.I., 2021. *Effect of part-baking time, freezing rate and storage time on part-baked bread quality*. Food Science Technology, 41: 352-359.
- INSSE, 2024. https://insse.ro/cms/sites/default/files/field/publicatii/revista_romana_statistica_supliment_03_2024.pdf
- Ittu, G., Săulescu, N.N., Mustăţea, P., Păunescu, G., 2011. *Wheat breeding for improved baking quality in Romania*. Romanian Agricultural Research, 28: 23-30.
- Khatkar, B.S., Bell, A.E., Schofield, J.D., 1995. *The dynamic rheological properties of glutens and gluten sub-fractions from wheats of good and poor bread making quality*. Journal of Cereal Science, 22: 29-44.
- Kuligowski, M., López Otero, R., Polanowska, K., Montet, D., Jasinska-Kuligowska, I., Nowak, J., 2019. *Influence of fermentation by different microflora consortia on pulque and pulque bread properties*. Journal of Science and Food Agriculture, 99: 6307-6314.
- Marinciu, C., and Săulescu, N.N., 2008. *Cultivar effects on the relationship between grain protein concentration and yield in winter wheat*. Romanian Agricultural Research, 25: 20-27.
- Marinciu, C.M., Şerban, G., Manda, V., Galit, I., Ciucă, M., Cristina, D., Săulescu, N.N., 2025. *Direct Multi-trials Estimation of Genetic Progress in Wheat Breeding at NARDI Fundulea, Romania*. Romanian Agricultural Research, 42: 165-173. <https://doi.org/10.59665/rar4214>
- Mitura, K., Cacak-Pietrzak, G., Feledyn-Szewczyk, B., Szablewski, T., Studnicki, M., 2023. *Yield and Grain Quality of Common Wheat (*Triticum aestivum L.*) Depending on the Different Farming*

- Systems (Organic vs. Integrated vs. Conventional)*. *Plants*, 12: 1022.
<https://doi.org/10.3390/plants12051022>
- Mustăța, P., Săulescu, N.N., Ittu, G., Păunescu, G., Voinea, L., Stere, I., Mîrlogeanu, S., Constantinescu, E., Năstase, D., 2009. *Grain yield and yield stability of winter wheat cultivars in contrasting weather conditions*. *Romanian Agricultural Research*, 26: 1-8.
- Mustăța, P., Ittu, G., Săulescu, N.N., Păunescu, G., 2013. *Grain yield and quality performance of winter wheat cultivars under Romanian conditions*. *Romanian Agricultural Research*, 30: 75-82.
- Preston, K.R., and Kilborn, R.H., 1984. *Dough Rheology on the Farinograph*. In: D'Appolonia, B.I., Kunerth, W.E. (eds.), *The Farinograph handbook*, third edition. AACC, Inc., St. Paul: 38-40.
- SR 90:2007, p. 5. *Pâine și produse proaspete de patiserie. Metode de analiză. Determinarea volumului*.
- SR 90:2007, p. 6. *Pâine și produse proaspete de patiserie. Metode de analiză. Determinarea porozității*.
- SR 90:2007, p. 7. *Pâine și produse proaspete de patiserie. Metode de analiză. Determinarea elasticității*.
- SR EN ISO 5530-1:2025. *Făină de grâu. Caracteristici fizice ale aluaturilor. Partea 1: Determinarea absorbției apei și a proprietăților reologice utilizând un farinograf*.
- SR EN ISO 712:2024. *Cereale și produse din cereale. Determinarea umidității Partea 1: Metoda de referință*.
- USDA, 2025. <https://www.fas.usda.gov/data/production/commodity/0410000>
- Van Lill, D., Purchase, J.L., Smith, M.F., Agenbag, G.A., De Viliers, O.T., 1995. *Multivariate assessment of environmental effects on hard red winter wheat. I. Principle components analysis on yield and bread making characteristics*. *South African Journal of Plant and Soil*, 12: 158-163.
- Vizitiu, D., and Danciu, I., 2011. *Evaluation of farinograph and mixolab for prediction of mixing properties of industrial wheat flour*. *Acta Universitatis Cibiniensis Series E: Food Technology*, XV(2): 31-38.
- Wang, J., Rosell, C.M., Benedito, B.C., 2002. *Effect of the addition of different fibres on wheat dough performance and bread quality*. *Food Chemistry*, 79: 221-226.